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Technological Innovation and Basic Income: An Agent-Based Simulation Facing Structural Changes in Labor Market

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"From each according to his ability,
to each according to his needs".
(Étienne-Gabriel Morelly)

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INTRODUCTION

The basic aim of this work is to analyze the relationship existing between technological innovation and the dynamics driving labor market in order to develop some considerations about welfare systems and to propose a basic income hypothesis updating them.

In order to do so, we introduce some theoretical references recalling the debates about the issues we focus on in the first section.

In particular, this analysis develops basically four issues: technological unemployment as a condition coming from structural changes affecting labor market, the historical outlines of the debate around machinery questions, the emerging need of updating welfare systems by introducing a basic proposal as a welfare tool, and the role of innovation within this process by investigating why and how to promote innovation.

First step of our investigation is to track out an overview about the Great Recession introducing the concept of jobless recovery as a relevant one in order to understand structural changes affecting labor market through the analysis of these episodes in recent history and the explanation of causes yielding them. Introducing such a concept seems to be relevant in order to introduce the idea of technological anxiety as a debate recurring over time.

In fact, second step of our investigation goes through the recurring debate around machinery question(s), starting from a brief discussion of how it developed over the past centuries and focusing on the analysis of how technological innovation affects employment in order to introduce the incumbent revolution of Artificial Intelligence as the crucial element in tracking out an overlook about future explaining why this time the increase in unemployment rates may be permanent.

By following this line of reasoning, it seems to be proper introducing the debate over the need of updating welfare systems as the third building block of our theoretical analysis, and we do so by introducing a basic income proposal as a policy tool facing this issue. In such a perspective, we recall the academic definition of basic income and the philosophical debate around the idea of social justice. After doing so, we go over again the historical development of welfare systems introducing basic income as the natural step to be made in order to update them and we recall - and partially reply to - some of the critiques moved against such a model.

The fourth building block of our theoretical analysis moves its first steps by recalling the definition of innovation in order to develop some

considerations around how to promote innovation by creating networks as to make it to spread.

Second section of our work introduces the Agent Based Model (ABM) that we build by using NetLogo consistently with the ideas exposed in the first section.

Our ABM is based on two steps: the first one sets up the starting conditions of the model, whereas the second one displays how the model develops over time.

The first step, the setting up one, is based on two different procedures: during the first one we create our ecology by defining variables in them, whereas during the second one we establish the first interaction within our agents (i.e. we define how firms employ individuals).

The second step instead is composed by many procedures, which are activated while running the experiments. The main procedure is the one defining firms' production and individuals' consumption and the interaction between those giving our market as an outcome. Then we define how firms fire or rehire over time according to the results performed on the market. As a last but not least procedure, we define an exogenous technological shock hitting the model, within we plug our basic income proposal, which is financed by taxing firms' profits according to different methods of contribution.

Third section of our work sums up the results performed by the model, after recalling a methodological remark clarifying our choice of having recourse to ABM. As first, we expose the starting point of our model, and then we expose the impact of a technological shock by performing two different hypotheses of firms' reaction to the shock (they may react by implementing production or by firing workers).

Within the second hypothesis, we perform our basic income proposal under different taxation hypotheses.

1. THE THEORETICAL FRAMEWORK

1.1. Technological unemployment, the *new normal*

1.1.1. An overview about the Great Recession

Many commentators and economists define the last crisis as the deepest one ever hitting the whole global economy after the Great Depression: the credit crunch, the job-places disruption and the drops in incomes, consumptions and investments levels are just some of the main consequences affecting the real economy of many countries of the world - especially the western ones - since 2007.

The Great Recession started in the US in 2007 with the burst of the housing bubble: until August 2007 house prices had been increasing since the 1990s and the ease of access to credit for US citizens led to rising for subprime mortgages in order to buy a house. Subprime mortgages are basically loans supplied to high-risk customers: at that time, banks were well-disposed to lend subprime mortgages, since they could benefit from customers' insolvency seizing the house at an increased price - and this was the main reason of the ease of credit concession. It was in 2007 that house prices suddenly dropped, and many customers preferred not to reimburse their loans because of the drastic reduction in the value of the houses for which mortgages were subscribed: in fact, many estates lost up to 30% of their values. The second issue connected with the subprime mortgages was that banks charged the risk of these "toxic" mortgages on third parties by collateralizing them with a huge variety of financial instruments (in particular the credit default swaps).

Although being first considered as a financial crisis, the Great Recession turned out very soon to be an economic crisis. It took very little time for this phenomenon to grow, infect real economy and spread all over the planet. While GDP stays below its pre-crisis peak in many of the rich countries, especially in Europe, where the financial crisis has evolved into the Euro crisis (as highlighted by the article "The origins of financial crisis: crash course", *The Economist*, 2013), it is to be noted how real economy has been mainly affected through two channels: the credit and the fiscal systems.

In such a scenario, the bankruptcy of Lehman Brothers (September15th, 2008) and the spread of these collateralized loans freaked everybody out in the market: institutional investors, banks and small savers could find

themselves to be infected by those toxic assets and, even if they actually were not, the lack of confidence among these agents operating in the credit sector stuck the liquidity in all the markets, as *The Economist* notes. This phenomenon, which takes the name of "credit crunch", as a first consequence, made sticky the monetary movements among banks, but soon hit also firms and consumers. The credit crunch, in fact, caused a drop in the credit supply to the firms and the households, which reduced their consumption levels. Furthermore, by hitting the middle-termed and long-termed loans, it provoked a fall in the investments levels of the firms: in fact, the startups could not begin new activities without a financing and the firms existing could not build long-term plans. Clearly, all these elements made the labor market stuck and raised the unemployment rates, which took a lot of time to get over the crisis.

The second channel through which the crisis affected the real economy was the fiscal system: national debts of many countries grew up hugely because of the increase in the unemployment rate (due to the firings of the firms trying to adjust their balance sheets) and because of the reduction in the aggregate demand. Furthermore, governments of those countries tried to repair their debt problems with austerity policies choking the demand and worsening the situation.

As just highlighted, one of the most dramatic consequences of the Great Recession, has been the relapse on the labor market: in fact, by observing the Bureau of Labor Statistics data- related to the unemployment in US -rates were at 4.6% in 2006, i.e. before the recession began, whereas it increased up to 5.8% in 2008, at the heart of the crisis, and then peaked by overcoming 9.5% in 2010, when the recession was declared closed in July 2009. To this day, the unemployment rate has not reached the pre-crisis level (the most recent data - recorded at June 2016 - marks a 4.9% rate).

When the wakes of these events drag for such a long time, we should ask ourselves whether to consider it meaningful to still talk about the crisis or if it would be more proper to assume the deep changes involving the global economic structure as a *new normal,* in order to find more effective solutions.

Unemployment levels observed by the Bureau of Labor Statistics, in fact, seem to underline a phenomenon emerging in several occasions in the last twenty-five years: the jobless recoveries. Coined by the US economist Nick Perna in the early 1990s, the term *jobless recovery* is referred to an economic recovery, following a recession, where the economy as a whole improves, but the unemployment rate remains still high or continues to increase over a prolonged period of time.

1.1.2. Jobless recovery' s episodes through recent history

This brief definition can be useful in order to identify a trend coming to the surface after the 1990s. In fact, even if a similar phenomenon has never been observed before, it has occurred in each of the latest three recessions affecting the US economy.

Before the 1990s, indeed, in a business cycle, every recession was supposed to be followed by a recovery of the output levels with a corresponding withdraw of the unemployment rate, since firms were expected to recover the job-places lost during the recession in order to face the raise in the production levels asked for by the consumptions recovery.

Something changed in the last twenty-five years: in fact, the three last recessive episodes - the 1990-1991 crisis, the 2000 "Dotcom bubble" and the 2008 Great Recession - presented very different causes and origins but the common trend that we can identify in each of them is that, after each of these episodes, the production recovery has not been accompanied by a reduction in the unemployment rate. Let us introduce now the causes originating these two episodes.

The recession hitting the US economy between July 1990 and March 1991, in fact, can be explained by many reasons, as exposed by Carl E. Walsh in his work "What caused the 1990-1991 recession?" published in 1993 by the *Federal Reserve Bank of San Francisco*: the loss of consumers and business confidence at the time of the Gulf crisis, the general weakness in the economy due to the restrictive monetary policy that served to lower inflation and some IS factors reducing the GDP over the whole 1990. In that scenario, the high public debt impeded the government to finance major works, the Savings & Loans crisis caused many credit institutes to fail and increased the private debt, which consumers were hardly facing, and the URSS collapse downsized the military orders and the industry connected with it. At the same time, many firms shifted from the industrial sector to the services one.

The "Dotcom bubble" (or "Information Technology bubble"), instead, hit many of the most developed countries between 1997 and 2000 and caused a fast increase in the value of the shares of firms investing in the emerging web sector. In that period, many firms arose and went bankruptcy and they all displayed some common features: they were low-capitalized, small-sized and they belonged to the informatics sector, which was very overvalued. The mixture between the rapid growth of the share

values and the markets' confidence in that expanding sector led many investors to neglect traditional financial and even legal principles in favor of the confidence in the technological progress, as reported by Lowenstein in his book Origins of the crash: "the great bubble and its undoing" (2004). After that the Federal Court emitted the sentence against Microsoft declaring that it operated in monopoly conditions, the bubble burnt. D. Aharon et al. in the article "Stock market bubble effects on mergers and acquisitions", published in 2010 in *The Quarterly Review of Economics and Finance*, reported that the majority of the firms born in that period went bankruptcy and many others have been merged or acquired: it has been calculated that only the 48% of the firms founded in that period survived after 2004, whereas only a small minority of them was going to become a giant of the world economy.

By looking again at the Bureau of Labor Statistics data, instead, we can observe the unemployment rates recorded during these two recessive episodes in order to identify and track the trend describing the jobless recovery phenomenon. In particular, as we did while describing the job-places loss during the Great Recession, we pick the unemployment rate before the beginning of the episode and its level at the heart of the crisis, then we record the moment when it peaks - which comes when the recession is yet over - and, last but not least, we measure how much time it takes to reach the pre-crisis level.

Before the 1990-91 crisis, say in 1989, the US unemployment rate was 5.3%, then it reached 6.8% level in 1991 while the recession was registering its lowest output rate. The unemployment rate peaked reaching 7.5% in 1992 - while the recession ended in March 1991 - and it started declining just in the following year, by reaching the pre-crisis level of 4.9% in 1997.

Before the burst of the 2000 Dotcom bubble, the US unemployment rate was 4.0% and when the crisis peaked the recorded rate was 4.7%. Even if production levels became again positive after November 2001, the unemployment rate continued to increase until the 6.0% level recorded in 2003, starting its decrease just in the following year (the recorded level in 2005 was of 5.5%). However, what comes up from this analysis, is that the US unemployment rate never came at the pre-crisis level after the Dotcom bubble: in fact, even if it continued to diminish in 2005 and 2006 - when it reached the 4.6% level - and it took stable in 2007, it started again increasing in the following year when the Great Recession effects came to the surface.

What emerges from these data is a new trend: latest data confirm that the US economy has never come back at its previous level in terms of unemployment rate (the last level recorded is 4.9% in July 2016 - seven years after the end of the crisis) and in many other countries the labor market has suffered even worse losses in terms of job-places than the US one.

Now, we try to identify the reasons why jobless recoveries have taken place in the last twenty-five years. Realizing these reasons will be crucial in order to in order to understand which are the dynamics driving the labor market, to acknowledge the new patterns characterizing the economic system and to identify better solutions driving to the common wellbeing.

First of all, we distinguish between two different phenomena. In fact, on one side we describe why a mismatching between the demand-side and the supply-side takes place on the labor market determining that, even existing employable workers and vacancies, they cannot exchange. On the other hand, we identify the dynamics driving to a job-places erosion and the reasons why it may be permanent.

1.1.3. Causes of jobless recoveries: search-matching frictions

Let us now introduce some theoretical references about the search-matching frictions operating in the labor market in order to understand the reasons why a mismatching between the supply-side and the demand-side may occur on the labor market.

We start doing so from introducing the studies of Peter Diamond (MIT), Dale Mortensen (Northwestern University) and Christopher Pissarides (London School of Economics), who were awarded with the Nobel prize in 2010 because of their precious contribution to the debate around the frictions operating on the labor market.

In fact, the market frictions' theory that they developed explains why, even if the labor market achieves an equilibrium point between the demand-side and the supply-side, at the same time we can identify a fraction of unemployed workers and a given amount of vacant job places. This fact may plunge its roots in many reasons: different needs for firms and workers, informational lacks which do not allow the two parts to learn about the other, physical distances' issues or the mismatching of other elements.

All these difficulties in meeting each other and in recognizing the counterpart as making up each for the other both from firms demanding for

labor-force and from workers supplying their performances are namely known as market frictions. They explain why, even in the presence of a market with high allocating efficiency, a given number of unemployed workers exists despite there are some vacant job-places.

According to the DMP studies, the existence of such frictions imply that both the parties, or the intermediates operating for them, should start reciprocal searching processes or try to trigger some matching mechanisms, whose outcome may not always be achieved.

The researchers highlighted the crucial differences between economies in which frictions do not operate and economies where they do. In fact, in the absence of market frictions, the market achieves its efficient equilibrium automatically, as the classical theory explains through the Walrasian auctioneer's example. The efficient equilibrium which such a market achieves represents a couple of values in which, generally speaking, the first one is the price and the other one is the quantity: clearly, applying this theory to the labor market, the first one is the wage, whereas the second one is the quantity of labor to be supplied. None of the parties can leave this equilibrium point without worsening the other one's situation and therefore nobody modifies his behavior. Two conditions guarantee the achievement of an equilibrium point: the first one is the perfect information about the price and the quantity from both the parties and the second one, which comes straightforward from this, is the perfect coordination of the exchanges which allows both the parties, once the price (i.e. the wage) is announced, to know the corresponding quantity (of labor) to be supplied.

Instead, in economies where frictions operate, there are some hindrances to the exchange, namely the frictions, which obstacle the transaction or, in extreme cases, forbid it. Such hindrances may be related to the access to the market, appearing sometimes as costs or as other kind of barriers: this is the case in which they are called search frictions. Differently, the matching frictions impede the achievement of an agreement between the parties, forbidding them to complete the transaction, despite the positive outcome of the searching process. When these frictions are so binding that they impede the conclusion of the exchange, it is possible to achieve different couples of values for prices (i.e. wages) and quantities (of labor) which do not correspond to the couple of values which would be generated in the absence of the friction itself. By focusing their attention on the outcomes produced by markets in which frictions cannot be overpassed since they are intrinsic in those markets, Diamond Mortensen and Pissarides developed basically three themes

linked with frictioned markets: prices formation, markets efficiency and exchanges coordination.

From the macroeconomic viewpoint, as long as concerns the prices formation in a frictioned market, what emerges is the so called “Diamond paradox”. Supposing that potential buyers of a given good look for this sequentially and have to pay a fixed cost for each analyzed seller, and supposing that sellers have chosen before the selling price, the market price will be a monopolistic one, and not a competitive one. The paradox is that even if there are many sellers the price is monopolistic, as if the seller were unique: this fact is due to imperfect information.

In order to introduce efficiency in frictioned markets, instead, it can be useful to resort to the so called “dating game”, analyzed by Mortensen: in this game, each agent looks for another agent being complementary to him – therefore, in the labor market unemployed workers will look for firms with vacancies, and vice versa. Externalities may interfere in the game, if the matching probabilities are influenced by the effort made by each of the agents to match and if each of them receives a pay-off on the basis of the effort made. Therefore, externalities are perfectly internalized if the value associated to the matching is divided on the basis of the contribution of each agent to the matching itself.

Diamond and Mortensen studies have been the starting point for the work of Pissarides, who elaborated the equilibrium unemployment theory (1985) and his contribution has been so clear that the model is known as the Diamond-Mortensen-Pissarides (DMP) model.

In the present formulation, equilibrium levels of employment and unemployment are not defined through the interaction of demand and supply and the salary determination is misaligned with respect to the employment level since it comes out in a following moment. vacancies supply (VS), in fact, replaces labor supply, whereas the Beveridge curve (BC), a relation between unemployment and vacancies highlighting inflows and outflows of the labor market, replaces labor demand; according to this definition and taking into account the market frictions, full employment is the equilibrium allocation of vacancies and unemployment.

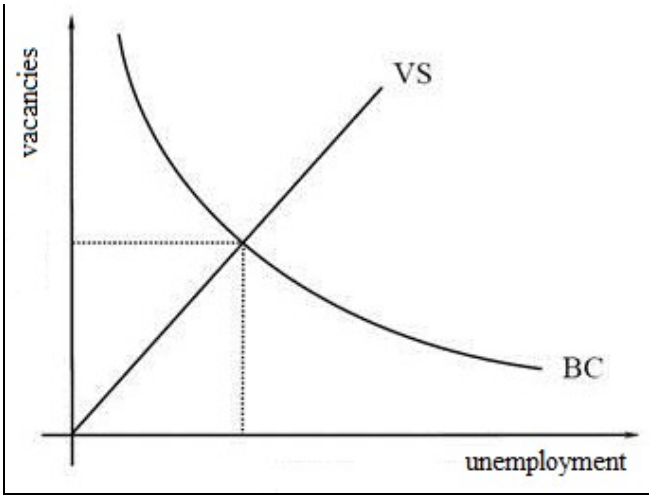

Fig. 1.1: *the equilibrium between vacancies and unemployment in DMP models. Sources: Guerrazzi, 2011.*

Beveridge curve is negatively sloped since it describes an externality, according to which the lower is the unemployment rate, the higher is the number of employed workers and the harder it is for a firm to fill the vacancies. The vacancies supply, instead, is a relation between unemployment and vacancies expressing the propensity of a firm to create new job-places and it is positively sloped since the higher the unemployment rate is, the higher the number of workers potentially filling the vacancies will be.

When the model is in equilibrium, unemployed workers and vacancies coexist and the equilibrium corresponds with the Beveridge definition of full employment (1944), that is when the vacancies supply is at 45°.

The coexistence of unemployed workers and vacancies opens for considerations about wages formation. In fact, if it is true that firms assign a given value to the gap between a vacancy and a filled job-place in terms of efficiency, on the other hand workers find out the gap between the value of a job-place and the value of unemployment.

In the dynamic model of Pissarides, wage determination comes down from the division of these two surplus between firms and workers, which is assumed to be calculated on the basis of the bargaining power of each party.

Therefore, it is possible to reach a non-efficient equilibrium point if one of the parties take the surplus of the other one without contributing to the formation of the surplus itself.

After analyzing the matching theory explaining demand and supply interactions in the labor market, now, instead, we inspect factors determining job-places erosion.

First of all, we have to distinguish between two types of causing factors: first ones depend on circumstances and may vary depending on the origins causing the recessive episode and on the interventions applied by policymakers to exit the crisis; whereas second ones are structural factors determined by irreversible changes investing economic, technological, cultural and social contexts where firms operate.

Clearly, factors depending on circumstances are different in each recessive episode and do not show patterns about structural changes investing the economic system: the credit crunch sticking the labor market during the Great Recession or the business reorganization leading to the loss of many job-places in the 1990-1991 crisis, especially in small-sized firms, may be some examples of this. Furthermore, a number of studies have demonstrated the importance of young firms for employment dynamics and document an alarming decline in the rate of new business formation: in fact, it is verified that young firms exhibit higher rates of job creation and destruction. It has also been shown that the trend decline in firm entry has reduced job creation during recessions and recoveries, confirming the jobless recoveries hypothesis.

1.1.4. Structural causes of jobless recoveries: why a fiscal stimulus may not decrease unemployment

Structural factors, instead, instead emerge from many phenomena investing society with permanent effects and, for this reason, we focus on them in order to underline causes of job-places erosion and potential implications it may imply.

Labor hoarding, industrial reallocation and job polarization are just some of these phenomena but the common pattern they display is clear: they all are a consequence of how crises and technological impact automating production processes combine and affect labor market modifying its structure. Let us analyze each of them.

In "Jobless recoveries: stagnation or structural changes?", an article published by J. Burger and J. Schwartz in June 2016 summing up many recent studies about jobless recoveries causes, the authors describe the labor hoarding phenomenon. A prominent example of the potential role of labor market frictions - they say - is traditional labor hoarding theory. During a recession firms may hoard labor if they wish to avoid the costs of firing workers during a recession and then rehiring/retraining workers during the subsequent recovery. If firms retain excess labor during a recession this can postpone the need for hiring during a subsequent recovery, thereby generating a jobless recovery. Somewhat related to the concept of labor hoarding is the reduction in labor market fluidity documented by Davis and Haltiwanger (2014). Although their study is primarily focused on longer-run trends in labor force participation, the reduction in job creation and destruction rates reported could also be linked to the phenomenon of jobless recoveries. A less dynamic labor market could be reflected in reduced separations during recessions (consistent with labor hoarding) and a slower pace of hiring during recoveries.

The US economist Robert Shimer, Professor at the Chicago University, combined wage rigidities and labor market frictions: his model predicts that employment is low during a recovery because firms cut back on hiring, not because the incidence of unemployment rises. He argues that this low hiring accounts for the majority of fluctuations in unemployment and his approach accounts for the simultaneous increase in unemployment and decline in vacancies that occurred in the past recession.

In January 2013 C. Cantore, P. Levine e G. Melina, FMI's economists, published "A Fiscal Stimulus and Jobless Recovery", a focus aimed at

verifying whether a fiscal stimulus can reduce the drop in the production and increase the job-places creation after a crisis.

They analyze the effects of a government spending expansion in a dynamic stochastic general equilibrium (DSGE) model with Mortensen-Pissarides labor market frictions, deep habits in private and public consumption, investment adjustment costs, a constant-elasticity-of-substitution (CES) production function, and adjustments in employment both at the intensive as well as the extensive margin. Their model is consistent with four empirical regularities that have arisen in the literature, namely that: (a) private consumption and (b) real wage increase following a public spending expansion; (c) the mark-up is countercyclical and falls following a government spending shock; (d) factor shares are time-varying at business cycle frequencies and capital and labor are gross complements in production.

The main results are that:

- output multipliers in the high range of empirical estimates even in the absence of nominal rigidities are obtained;
- a fiscal expansion with low job creation can be reproduced;
- a fiscal stimulus that mitigates the output collapse in a recession can be simulated, but contains the rise in unemployment only marginally.

This scenario is in line with what observed in the data in the aftermath of the Great Recession.

The combination of deep habits and CES technology is crucial for the jobless outcome of a fiscal stimulus. In fact, if the elasticity of substitution between capital and labor approaches one, i.e. the production function approximates a Cobb-Douglas, the presence of deep habits in consumption enables the model to deliver magnified responses of macroeconomic variables in response to a fiscal stimulus. As the elasticity of substitution is allowed to drop to values in the range of available estimates - i.e. the degree of complementarity between capital and labor increases - while the output multiplier falls only marginally, the unemployment multiplier experiences a sizeable contraction, allowing the model to produce a scenario compatible with the jobless recovery. In other words, factor complementarity proves to be a determinant of the jobless outcome of a fiscal stimulus.

The unequal effects on the output and unemployment multipliers depend on the fact that lowering the elasticity of substitution in the CES production function is equivalent to assuming that the technology is closer

to the Leontief case, i.e. capital and labor are more complements than substitutes.

Given that capital is unable to change instantaneously in response to the fiscal expansion - partly because it is a stock variable and partly because of the presence of adjustment costs to investment - firms have smaller incentives to create new jobs through vacancy posting, being this a costly process. However, both the negative wealth effect (coming from the absorption of resources by the government) and the substitution of leisure with consumption (coming from the decline in the mark-up due to the presence of deep habits) still act in the same direction of causing a substantial increase in the supply of hours of work per employee. In such a case, the expansion in output is driven relatively more by an increase in the hours of work of current employees rather than new job creation. Thus, the CES technology with an empirically supported elasticity of substitution proves to be a useful tool to simulate a fiscal stimulus that mitigates the output collapse in a recession but contains the rise in unemployment only marginally, allowing labor hoarding theory to come real.

Another of the effects generated by automating production processes is industrial reallocation, which, turning into a demand for more flexibility, forces many workers to adapt their role, to pass from one firm to another or to move house.

Many economists attribute jobless recoveries to the increasing need of firms for sectoral reallocation. In fact, according to the article "Can sectoral reallocation explain the jobless recovery?" published by D. Aaronson, E. R. Rissman, and D. G. Sullivan in 2004, the accelerating pace of these changing processes forced an increasing number of workers to accept more flexibility due to the job loss. Since looking for a new job in a different sector may ask for a significant lapse of time, the increased need of firms for sectoral reallocation turns into a temporary increase in the unemployment rate.

In the long-run sectoral reallocation may be positive: in a well-functioning economy, the growth in international trade shifts in product demand, and productivity growth that varies across sectors all imply that resources constantly need to be reallocated from one part of the economy to another. However, in the short run, reallocation is costly since workers displaced from contracting sectors of the economy need to spend time searching for new jobs. This can take substantial time and resources, especially if workers' old skills do not match those demanded by firms in expanding sectors. Thus, an increased need for sectoral reallocation may

temporarily increase the economy's natural rate of unemployment and lower its rate of employment growth.

In addition, increases in outsourcing, offshoring and other employment practices have increased workers' displacement: especially prominent have been claims that, because of the development of the Internet, workers in many service and technical occupations that were formerly relatively isolated from international competition have been replaced by workers in countries such as India or China since early 2000s.

Reallocation is always occurring in a dynamic economy, and it is easy to understand why it has occurred after that manufacturing has been severely impacted by recession, with a loss of jobs that has turned out to be permanent.

Moreover, the loss of jobs due to foreign competition occurred since early 2000s cannot be compared with any other in the history: in fact, even if in the US there has been a long history of concern over job losses to Japan, Korea, Mexico, and a host of other countries, globalization is playing its role and with automation reducing available job-places, rather unsurprisingly, the natural unemployment rate has increased.

1.1.5. Structural causes of jobless recoveries: job polarization

Another effect coming down from mechanizing productive processes is the job polarization, which is the decrease in the demand of middle-skilled workers in favor of high-qualified workers or low-skilled workforce accomplishing to basic tasks. This depends on the trade-off between the cost of an employee for the firm and the performances he (or she) can offer.

Middle-skilled workers, who once used to execute routine tasks, lost their roles over time because the introduction of computers and several other machines in the firms turned out to be more efficient and cheaper.

Low-skilled workers employed in strenuous and underpaid jobs seem to be still precious in the firms, as long as hyper-specialized workers, whose high cost is justified by the high level of skills they put into the productive process. For this reason, they actually represent the added value of the firm since their tasks, requiring a kind of creativity, cannot be repeated by machines or PCs.

"Explaining Job Polarization: routine-biased technological change and offshoring" is an article of M. Goos, A. Manning and A. Salomons published in 2014 on the *American Economic Review*. The authors, who

study the phenomenon for years and coined the term “job polarization” in 2003, show its pervasiveness in developed economies through estimates and quantitative evidences: the model they built is based on the previous SBTC (i.e. Skill Biased Technological Change) model of Katz and Murphy (1992). In particular, they focused on sixteen Western European countries over the period 1993-2010 and what emerges is that the employing structure of these countries has been strongly polarized over the time.

It is verified that job polarization is caused by the fact that technological development is oriented to replace employee’s routine tasks: this phenomenon, known as RBTC, i.e. Routine Biased Technological Change, also induced firms to offshore.

On the one hand, an industry affected by RBTC takes lower employment levels to produce a given output level and this will cause occupational employment shares to polarize even if output shares do not. On the other hand, industries intense in routine tasks will see a larger decrease in relative costs and output prices leading to a shift in product demand toward these industries (as was first pointed out by Baumol 1967).

Furthermore, the model can explain a large part of the changes in employment shares across occupations, both the total change and the split into within-industry and between-industry components and the authors confirmed the relevance of such a distinction.

All these clues show jobless recoveries as a *new normal*, a pattern becoming even more robust and displaying structural changes to be acknowledged.

In “Jobless recoveries: stagnation or structural changes?” (2016), J. Burger and J. Schwartz highlight the reasons why jobless recoveries may be considered structural changes: most studies point to a change in cyclical employment dynamics and seek to explore potential explanations - they assert before listing and explaining jobless recoveries causes.

A number of models emphasize reallocation across sectors rather than restructuring within firms or industries. Garin, Pries, and Sims (2013) emphasize an increase in the importance of reallocating shocks (relative to aggregate shocks) and Groshen and Potter (2003) find evidence to suggest structural change and reallocation of workers across industries contributes to the phenomenon of jobless recoveries. One potential source for this structural change and sectoral reallocation is the trend of job polarization documented by Autor and Dorn (2013).

If technological change is causing jobs in the middle of the skill distribution to be disproportionately slashed during recessions and replaced by automation, firms have less need to rehire during the ensuing expansion thus yielding a jobless recovery. In fact, Jaimovich and Siu (2015) and Gaggl and Kaufmann (2014) each find evidence that find evidence from national US data that declines in routine employment are concentrated in recessions and contribute to jobless recoveries.

To evaluate theories emphasizing dynamic structural change, Burger and Schwartz include the trend growth rate in labor productivity and find that states experiencing faster productivity growth are more likely to experience a jobless recovery. Finally, they also find that jobless recoveries are more likely following long expansions, which is consistent with theories of firm-level restructuring during recessions.

To evaluate the extent to which job market polarization might be responsible for jobless recoveries they include annual trend growth rates in routine and non-routine employment. As a proxy for the impact of globalization they included an index which measures the extent to which jobs in a particular state are offshorable and find striking results: states experiencing a trend decline in routine employment are more likely to experience a jobless recovery, while changes in non-routine employment do not have significant explanatory power. This result is consistent with the polarization theory where technological advances (e.g. automation) permanently reduce the demand for routine labor thus contributing to jobless recoveries.

It also appears the job reallocation measure was capturing sectoral reallocation (rather than fluidity): in fact, states with higher rates of reallocation may be those experiencing declines in routine employment.

Clearly the strongest and most robust results emerging from Burger's and Schwartz's work link jobless recoveries to polarization and weak macroeconomic conditions: they find empirical evidence to support both the stagnation and structural change theories of jobless recoveries.

On the stagnation side, they find evidence that weak macroeconomic conditions are significant predictors of jobless recoveries. But even after controlling for the vigor of an economic recovery at the state and national level, they find strong evidence that links the trend in routine employment at the state level to the likelihood of a jobless recovery. Their results are therefore consistent with those of Jaimovich and Siu (2015), but the state level data set they use allows for important new insights by leveraging the heterogeneity of state experiences with jobless recoveries and polarization:

in fact, they do not explicitly generalize their results to national jobless recoveries, but it emerges that there are clear implications for how job polarization may have impacted the last three U.S. recoveries.

Evidences coming out from this work and innovations that are going to upset production processes in a couple of years suggest us to think at jobless recoveries as structural changes and to rethink at the structure of the economic system.

1.1.6. The eternal return of technological anxiety

Debates about technological unemployment, however, are nothing of new in the human history. As J. Mokyr, C. Vickers, and N. L. Ziebarth report in "The history of technological anxiety and the future of economic growth: is this time different?" (2015), technology is widely considered the main source of economic progress, but it has also generated cultural anxiety throughout history. From generation to generation, literature has often portrayed technology as alien, incomprehensible, increasingly powerful and threatening, and possibly uncontrollable. The myth of Prometheus is nothing if not a cautionary tale of these uncontrollable effects of technology.

In 1930, even John Maynard Keynes was drawn into the debate and offered the following meditation on the future of technology and unemployment in his well-known essay, *Economic Possibilities for our Grandchildren*.

> We are suffering just now from a bad attack of economic pessimism. It is common to hear people say that the epoch of enormous economic progress which characterized the nineteenth century is over; that the rapid improvement in the standard of life is now going to slow down --at any rate in Great Britain; that a decline in prosperity is more likely than an improvement in the decade which lies ahead of us.
>
> I believe that this is a wildly mistaken interpretation of what is happening to us. We are suffering, not from the rheumatics of old age, but from the growing-pains of over-rapid changes, from the painfulness of readjustment between one economic period and another. The increase of technical efficiency has been taking place faster than we can deal with the problem of labor absorption; the improvement in the standard of life has been a little too quick; the banking and monetary system of the world has been preventing the rate of interest from falling as fast as equilibrium requires. […]

The prevailing world depression, the enormous anomaly of unemployment in a world full of wants, the disastrous mistakes we have made, blind us to what is going on under the surface to the true interpretation. of the trend of things. For I predict that both of the two opposed errors of pessimism which now make so much noise in the world will be proved wrong in our own time-the pessimism of the revolutionaries who think that things are so bad that nothing can save us but violent change, and the pessimism of the reactionaries who consider the balance of our economic and social life so precarious that we must risk no experiments. My purpose in this essay, however, is not to examine the present or the near future, but to disembarrass myself of short views and take wings into the future. What can we reasonably expect the level of our economic life to be a hundred years hence? What are the economic possibilities for our grandchildren?

From the earliest times of which we have record-back, say, to two thousand years before Christ-down to the beginning of the eighteenth century, there was no very great change in the standard of life of the average man living in the civilized centers of the earth. Ups and downs certainly. Visitations of plague, famine, and war. Golden intervals. But no progressive, violent change. Some periods perhaps So per cent better than othersat the utmost 1 00 per cent better-in the four thousand years which ended (say) in A. D. 1700. This slow rate of progress, or lack of progress, was due to two reasons-to the remarkable absence of important technical improvements and to the failure of capital to accumulate. [...]

For the moment the very rapidity of these changes is hurting us and bringing difficult problems to solve. Those countries are suffering relatively which are not in the vanguard of progress. We are being afflicted with a new disease of which some readers may not yet have heard the name, but of which they will hear a great deal in the years to come--namely, technological unemployment. This means unemployment due to our discovery of means of economizing the use of labor outrunning the pace at which we can find new uses for labor.

But this is only a temporary phase of maladjustment. All this means in the long run that mankind is solving its economic problem. I would predict that the standard of life in progressive countries one hundred years hence will be between four and eight times as high as it is to-day. There would be nothing surprising in this even in the light of our present knowledge. It would not be foolish to contemplate the possibility of a far greater progress still.

Anxieties over technology can take on several forms: Mokyr, Vickers, and Ziebarth focus on what they view as three of the most prominent

concerns. The first two worries are based on an "optimistic" view that technology will continue to grow and perhaps accelerate.

First, one of the most common concerns is that technological progress will cause widespread substitution of machines for labor, which in turn could lead to technological unemployment and a further increase in inequality in the short run, even if the long-run effects are beneficial.

Second, there has been anxiety over the moral implications of technological process for human welfare, broadly defined. In the case of the Industrial Revolution, the worry was about the dehumanizing effects of work, particularly the routinized nature of factory labor. In modern times, perhaps the greater fear is a world where the elimination of work itself is the source of dehumanization.

A third concern cuts in the opposite direction, suggesting that the epoch of major technological progress is behind us. In recent years, even in the face of seemingly dizzying changes in information technology, pessimists such as Gordon (2012), Vijg (2011), and Cowen (2010) have argued that our greatest worry should be economic and productivity growth that will be too slow because of, for example, insufficient technological progress in the face of "headwinds" facing western economies.

Mokyr, Vickers, and Ziebarth devoted part of their work to the analysis of the historical debate developing around technological unemployment issues. While many writers conceded possibly negative effects of machinery on employment in the short run - they note -, they typically distinguished short-run dislocations from possible long-run effects. For example, Sir James Steuart (1767), widely regarded as one of the most insightful writers on economics before Adam Smith, wrote that he would disapprove of machinery only in cases in which it "might force a man to be idle" who would have no other way of earning his bread than his current employment. But normally, Steuart argued, technological unemployment would occur only if the innovation was introduced very suddenly. Even then, the dislocation to employment would be temporary, while the advantages of higher productivity would be permanent. Karl Marx, from a rather different perspective, also argued that technological unemployment was a serious problem in the short run, in the broader context of the immiserating of workers under a capitalist system. But for Marx as well, technological improvement was part of a social and political process that would lead eventually to widespread prosperity.

Some of the most interesting thinking on the long-run effects of technology came from, for a lack of a better term, "reactionaries." These

writers, while conceding the power of technology, were deeply doubtful on whether it benefited society as a whole. Yet many resigned themselves to the change and even encouraged adoption for noneconomic reasons.

In 1930s, part of the warry that the surplus of workers may be eliminated was based not on rapid innovations in manufacturing, but on labor-saving changes in agriculture such as the tractor, which were one factor driving massive flows of people from rural areas to the cities.

Of course, grasping for a secular supply-side explanation of high unemployment is not unique to the Depression of the 1930s. Many people have been quick to jump to such an explanation in the Great Recession of 2007–2009 and its aftermath, even when a deficiency in aggregate demand may offer a more plausible explanation. But, in the end - as the authors suggest - one should be careful in dismissing the performance of earlier generations of economists in predicting the effects of technological development on employment. While the predictions of widespread technological unemployment were, by and large, wrong, we should not trivialize the costs borne by the many who were actually displaced. It is true that, in the long run, wages for laborers increased to reflect dramatically increased productivity. It is also true that, for the Industrial Revolution, by many estimates it took longer than an average working lifetime to do so, and in the long run, we are all dead.

Besides questions of employment and wages, technological innovation brings worries about the nature of work and the so-called alienation of labor: from our perspective, focusing on the alienation issue turns out to be crucial, since the basic income proposal we are going to introduce may represent an innovative solution to the problems raised by technologic unemployment.

Once again, insights coming from Mokyr, Vickers, and Ziebarth seem to get the point.

Even before the Industrial Revolution, and in between extolling the value of specialization, Adam Smith cautioned against the moral effects of this process, as when he wrote: “The man whose whole life is spent in performing a few simple operations…generally becomes as stupid and ignorant as it is possible for a human creature to become.” Karl Marx, more well-known than Smith as a critic of industrialization, argued that the capitalist system alienates individuals from others and themselves. In the *Economic and Philosophic Manuscripts of 1844*, Marx wrote, “The height of this servitude is that it is only as a *worker* that he can maintain himself

as a *physical subject,* and that it is only as a *physical subject* that he is a work".

For Marx and others, it was not just that new factory jobs were dirty and dangerous. Jeffersonian encomiums aside, the pastoral life of small shop owners or yeoman farmers had not entailed particularly clean and safe work either. Instead the point was that this new work was in a deeper way unfit for humans and the process of covert coercion that forced people into these jobs and disciplined them while on the job was debasing.

As the authors underline, one need not accept the reactionary view that such constraints on paid workers made 19thcentury wage labor not very different from slavery to recognize, as many social reformers of the time did, that a lack of personal control over work raises meaningful issues. While today people worry about the exact opposite phenomenon with the lines between spheres of home and work blurring this disjunction was originally a cause of great anxiety, along with the separation of place-of-work from place-of-leisure. effort and success as understood by artisans, the moral understanding of work was transformed with the disappearance of what has been called the "moral economy," making room for a market economy. The changing nature of work provided purchase to those who viewed the rising standard of living associated with industrialization as something of a poisoned chalice.

While we should not fault the lack of imagination of 19th century political economists in predicting the jobs of tomorrow, the limits they placed on the ways in which human labor could be used do seem peculiar from a modern viewpoint - the authors warn.

The mechanical innovations of the Industrial Revolution acted as a substitute for human (and animal) strength as well as dexterity, but the machines of that time could not reason, compare, compute, read, smell, sense, hear, or make snap decisions.

However, if artificial intelligence and robotics continue on their present trend, future machines will be able to carry out these human capabilities, at least in certain contexts and to a certain extent. Thus, it seems frighteningly plausible that this time will be different, and large sections of the labor market will be dislocated or "hollowed out," in the Katz and Margo (2013) terminology. Some scholars such as Beaudry, Green, and Sand (2013) have suggested that a peak in demand for high-skilled workers and cognitive tasks already occurred around the year 2000. In some theoretical models, as in Sachs, Benzell, and LaGarda (2015), a rise in "robotic productivity," which substitutes completely for labor, can result in declines in

consumption, at least in the short term. But it is worth recalling that such predictions have been made repeatedly in the recent past. As we peer into the hazy future, we find it useful to distinguish two possible effects of the substitution of capital for labor: 1) how much people will work on average; and 2) how that work will be distributed.

Leisure has increased over the medium term and the long term. Maddison's (2001) computations - report Mokyr, Vickers, and Ziebarth - show that between 1870 and 1998 the number of annual hours worked per employee in the highly industrialized western economies fell almost precisely by half, from roughly 2,950 hours per worker in 1870 to 1,500 hours per worker in 1998.

For economists, it would seem peculiar to fret too much about a long-term decline in work hours: indeed, the earlier discussion pointed out that there is a tradition of economists either forecasting or hoping that technology would reduce the need for working hours. On the other hand, some economists and other social theorists have suggested that a reduced workweek is not an unalloyed good, because of underlying preferences for accomplishment and labor for its own sake.

Coming back to the Keynes warnings (1930), he noted that with the decline of work, man must face the problem of how to occupy his leisure. Here technological progress has clearly changed the rules of the game. One of the underappreciated aspects of twentieth-century technological progress has been the increased marginal utility of leisure through increases in the variety of leisure and declines in the cost of leisure-directed techniques. However, it is no stretch to submit that it may be a net gain to human welfare to have fewer hours spent on a job: this modern difference between leisure and work is particularly striking when compared to "leisure" in the preindustrial past that involved a fair amount of sitting in the dark.

If this predicted decline in labor hours worked was spread evenly across the working population, that decline would be a minor concern, particularly with the rise of "quality" leisure. Instead, much like the distribution of income and wealth, work hours appear to be diverging across segments of the population.

Common pattern in recent years is that routine tasks with little unpredictable variability are more likely to be mechanized, while jobs that require continuous adjustment to new information and new physical settings along with fine sensory motor-coordination are more difficult to

automate. Many middle-skill jobs, both in manufacturing plants and in offices, have tended to be more susceptible to automation.

In this way, we are already seeing some of this labor-saving technology affecting the supply side of the lower-skilled labor force. (Jaimovich and Siu 2014; Charles, Hurst, and Notowidigdo 2014). Perhaps if these kinds of technological developments lead to an economy where an ever-larger share of the population works for relatively low wages but can still enjoy a high standard of living through a variety of low-cost leisure opportunities, political disruption may be minimal -Mokyr, Vickers, and Ziebarth suggest.

Even if ongoing technological developments do not spell the end of work, they will surely push certain characteristics of future jobs back toward pre-factory patterns. These changes involve greater flexibility in when and where work takes place. Part of this increase in flexibility is the breakdown of the separation between work and home life. The main way in which flexibility seems to be manifesting itself is not through additional self-employment, but instead through the rise of contract firms who serve as matchmakers, in a phenomenon often driven by technology. On one side, this greater flexibility can help in balancing work and family, but on the other side, it can be a backdoor for employers to extract more effort from employees with an expectation that they always be accessible, and also flexibility can often mean variable pay, leading to an increased precariousness of workers in the short-term.

From Mokyr, Vickers, and Ziebarth perspective, the more extreme of modern anxieties about long-term, ineradicable technological unemployment, or a widespread lack of meaning because of changes in work patterns seem highly unlikely to come to pass. As has been true now for more than two centuries, technological advance will continue to improve the standard of living in many dramatic and unforeseeable ways. However, fundamental economic principles will continue to operate. Scarcities will still be with us, most notably of time itself. The law of comparative advantage strongly suggests that most workers will still have useful tasks to perform even in an economy where the capacities of robots and automation have increased considerably.

The raise of each of these issues asks us for a more precise focus on the historical debate around them, which should be useful in order to identify some of the possible solutions that we are going to propose through our model.

1.2. The machinery question(s): historical outlines of the debate and the framework today

1.2.1. Machinery question over the past centuries

The debate around what we usually define as the "machinery question" cyclically assumes a central role in the discussion about the relationship between technological development and employment.

First posed by David Ricardo who devoted the chapter 31 of the third edition of his *Principles* (1821) to the theme (the chapter itself is named "On machinery"), the machinery question concerned the "influence of machinery on the interests of the different classes of society", and in particular the "opinion entertained by the laboring class, that the employment of machinery is frequently detrimental to their interests".

At that time, the English thinker commented the machinery question affecting the economic system during the Industrial Revolution as follows.

> Such an application of machinery to any branch of production, as should have the effect of saving labor, was a general good, accompanied only with that portion of inconvenience which in most cases attends the removal of capital and labor from one employment to another.
>
> Provided the landlords had the same money rents, they would be benefited by the reduction in the prices of some of the commodities on which those rents were expended, and which reduction of price could not fail to be the consequence of the employment of machinery. The capitalist was eventually benefited precisely in the same manner. He, indeed, who made the discovery of the machine, or who first usefully applied it, would enjoy an additional advantage, by making great profits for a time; but, in proportion as the machine came into general use, the price of the commodity produced, would, from the effects of competition, sink to its cost of production, when the capitalist would get the same money profits as before, and he would only participate in the general advantage, as a consumer, by being enabled, with the same money revenue, to command an additional quantity of comforts and enjoyments.
>
> The class of laborers also was equally benefited by the use of machinery, as they would have the means of buying more commodities with the same money wages, and no reduction of wages would take place, because the capitalist would have the power of demanding and employing the same quantity of labor as before, although he might be

> under the necessity of employing it in the production of a new, or at any rate of a different commodity.
>
> If, by improved machinery, with the employment of the same quantity of labor, the quantity of stockings could be quadrupled, and the demand for stockings were only doubled, some laborers would necessarily be discharged from the stocking trade; but as the capital which employed them was still in being, and as it was the interest of those who had it to employ it productively, it appeared to me that it would be employed on the production of some other commodity, useful to the society, for which there could not fail to be a demand.
>
> As, then, it appeared to me that there would be the same demand for labor as before, and that wages would be no lower, I thought that the laboring class would, equally with the other classes, participate in the advantage, from the general cheapness of commodities arising from the use of machinery.

Maybe, we should not talk about a machinery question but it seems to be more proper to talk about *machinery questions*: in fact, a new machinery question is now at the center of the public debate.

The Economist devoted the edition of June 25th, 2016 to the theme, since the rise of Artificial Intelligence poses new questions to be solved about the direction which the economy will take. As it reports in "March of the machines" (2016a), the ones who nowadays look at Artificial Intelligence (AI) as a threat to humanity or a "mighty power which has come before we knew how to employ it rightly" are not so different by the ones commenting mechanization and steam power two centuries ago or the ones who feared the so called "technological unemployment" in the 1960s when firms first installed computers and robots, or in the 1980s when PCs landed on desks.

"Automation and anxiety" (*The Economist*, 2016b) tracks clearly a historical framework of the debate.

Predictions that automation will make humans redundant have been made before, however, going back to the Industrial Revolution, when textile workers, most famously the Luddites, protested that machines and steam engines would destroy their livelihoods.

"Never until now did human invention devise such expedients for dispensing with the labor of the poor," said a pamphlet at the time. Subsequent outbreaks of concern occurred in the 1920s: "March of the machine makes idle hands", declared a *New York Time*s headline in 1928. The article reports some heavy accusations: "Here and there, however, one

sees an attempt to explain this paradox of prosperity and unemployment. More and more the finger of suspicion points to the machine. It begins to look as if machines had come into conflict with men - as if the onward march of machines into every corner of our industrial life had driven men out of the factory and into the ranks of unemployed". "For the god of the machine - it continues - ultimate perfection is a world which runs by itself, mechanically, with only here and there the human touch. But such a world would require infinite social readjustment and the first to be solved would be the problem of idle hands".

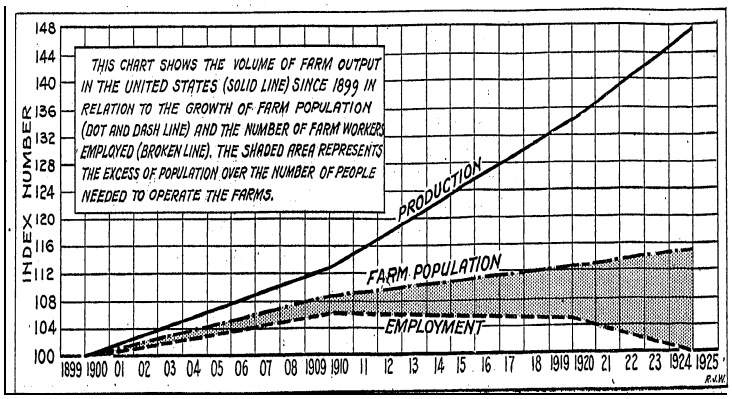

***Fig. 1.2**: Volume of farm output in relation to the growth of farm population and the number of farm workers employed.*
Sources: New York Times (26th February, 1928)

The same apocalyptic words were used in the 1930s when John Maynard Keynes coined the term "technological unemployment" to describe that situations and in the 1940s, when the *New York Times* referred to the revival of such worries as the renewal of an "old argument".

As computers began to appear in offices and robots on factory floors, President John F. Kennedy declared that the major domestic challenge of the 1960s was to "maintain full employment at a time when automation is…replacing men". In 1964 a group of Nobel prizewinners, known as the Ad Hoc Committee on the Triple Revolution, sent President Lyndon Johnson a memo alerting him to the danger of a revolution triggered by "the combination of the computer and the automated self-regulating machine". This - they said - was leading to a new era of production "which requires progressively less human labor" and threatened to divide society into a skilled elite and an unskilled underclass. According to Bowen (1966), thus technological change (along with other forms of economic change) is an important determinant of the precise places, industries, and people affected by unemployment. But the general level of demand for

goods and services is by far the most important factor determining how many are affected, how long they stay unemployed, and how hard it is for new entrants to the labor market to find jobs. The basic fact is that technology eliminates jobs, not work.

However, the Commission took the reality of technological disruption as severe enough that it recommended, as one newspaper (*The Herald Post*, 1966) reported, "a guaranteed minimum income for each family; using the government as the employer of last resort for the hard core jobless", as Professor David Autor highlights.

The advent of personal computers in the 1980s provoked further hand-wringing over potential job losses.

In fact, in the recent history, each time it seemed that widespread automation of skilled workers' jobs was just around the corner but, each time, instead, technology created more jobs than it destroyed, as the automation of one chore increased demand for people to do the related tasks that were still beyond machines. Automating a particular task, so that it can be done more quickly or cheaply, increased the demand for human workers to do the other tasks around it that have not been automated.

There are many historical examples of this and professor James Bessen reports some of them: during the Industrial Revolution more and more tasks in the weaving process were automated, prompting workers to focus on the things machines could not do, such as operating a machine, and then tending multiple machines to keep them running smoothly. This caused output to grow explosively. In America during the 19th century the amount of coarse cloth a single weaver could produce in an hour increased by a factor of 50, and the amount of labor required per yard of cloth fell by 98%. This made cloth cheaper and increased demand for it, which in turn created more jobs for weavers: their numbers quadrupled between 1830 and 1900. In other words, technology gradually changed the nature of the weaver's job, and the skills required to do it, rather than replacing it altogether.

In a more recent example, automated teller machines (ATMs) might have been expected to spell doom for bank-tellers by taking over some of their routine tasks, and indeed in America their average number fell from 20 per branch in 1988 to 13 in 2004. But that reduced the cost of running a bank branch, allowing banks to open more branches in response to customer demand. The number of urban bank branches rose by 43% over the same period, so the total number of employees increased.

Rather than destroying jobs, ATMs changed bank employees' work mix, away from routine tasks and towards things like sales and customer service that machines could not do. The same pattern can be seen in industry after industry after the introduction of computers: rather than destroying jobs, automation redefines them, and in ways that reduce costs and boost demand.

1.2.2. How technology innovation affects employment

Nonetheless, this example should not be taken as paradigmatic: technological change is not necessarily employment-increasing or Pareto-improving and three main factors can mitigate or augment its impact, as underlines Autor in his analysis.

First, workers are more likely to benefit directly from automation if they supply tasks that are complemented by automation, but not if they primarily (or exclusively) supply tasks that are substituted. Second, the elasticity of labor supply can mitigate wage gains. If the complementary tasks that given workers supply are abundantly available elsewhere in the economy, then it is plausible that a flood of new workers will temper any wage gains that would emanate from complementarities between automation and human labor input. Third, the output elasticity of demand combined with income elasticity of demand can either dampen or amplify the gains from automation. Even if the elasticity of final demand for a given sector is below unity - meaning that the sector shrinks as productivity rises - this does not imply that aggregate demand falls as technology advances; clearly, the surplus income can be spent elsewhere.

Over the very long run, gains in productivity have not led to a shortfall of demand for goods and services: instead, household consumption has largely kept pace with household incomes. We know this because the share of the population engaged in paid employment has generally risen over (at least) the past century despite vast improvements in material standards of living.

In any case, at first sight every machinery question seemed so vital and urgent, but eventually resolved itself. In the 19th century, despite the fears expressed by David Ricardo, among others, that "substitution of machinery for human labor may render the population redundant", the overall effect of mechanization turned out to be job creation on an unprecedented scale.

In 1900, 41 percent of the US workforce was employed in agriculture; by 2000, that share had fallen to 2 percent, mostly due to a wide range of

technologies including automated machinery. The mass-produced automobile drastically reduced demand for many equestrian occupations, including blacksmiths and stable hands. Successive waves of earth-moving equipment and powered tools displaced manual labor from construction. In more recent years, when a computer processes a company's payroll, alphabetizes a list of names, or tabulates the age distribution of residents in each Census enumeration district, it is replacing a task that a human would have done in a previous era. Broadly speaking, many -perhaps most- workplace technologies are designed to save labor.

Machines allowed individual workers to produce more, reducing the price of many goods, increasing demand and generating a need for more workers. Entirely new jobs were created to oversee the machines. As companies got bigger, they required managers, accountants and other support staff. And whole new and hitherto unimagined industries sprang up with the arrival of the railways, telegraphy and electrification. To be sure, all this took time. Industrialization caused pervasive labor-market upheaval as some jobs vanished, others changed beyond recognition and totally new ones emerged. Conditions in factories were grim, and it took several decades before economic growth was reflected in significant wage gains for workers (this delay is known as "Engels' pause").

By the end of the 19th century the machinery question had faded away, because the answer was so obvious. As *The Economist* reports in "Answering the machinery question" (2016c), in 1896 Arthur Hadley, an American economist, articulated the view of the time when he observed that rather than destroying jobs, mechanization had brought about "a conspicuous increase of employment in those lines where improvements in machinery have been greatest".

1.2.3. The occurring technological revolution: Artificial Intelligence

Historical analogies are never perfect, but they can be informative. Artificial intelligence is now prompting many of the same concerns as mechanization did two centuries ago. The 19th century experience of industrialization suggests that jobs will be redefined, rather than destroyed; that new industries will emerge; that work and leisure will be transformed; that education and welfare systems will have to change; and that there will be geopolitical and regulatory consequences.

Clearly, the past two centuries of automation and technological progress have not made human labor obsolete: the employment-to-population ratio

rose during the 20th century even as women moved from home to market; and although the unemployment rate fluctuates cyclically - explains Autor - there is no apparent long-run increase. But those concerned about automation and employment are quick to point out that past interactions between automation and employment cannot settle arguments about how these elements might interact in the future: in particular, the emergence of greatly improved computing power, artificial intelligence, and robotics raises the possibility of replacing labor on a scale not previously observed.

New technologies automate work in specific occupations, but it is hard to evaluate competing claims about their overall impact because technology can affect occupations in different ways. Technology can reduce demand for an occupation, or increase it, or change the skills needed to practice an occupation.

Occupations are an important unit of analysis because technologies tend to automate tasks in specific occupations and also because a considerable portion of human capital appears to be occupation specific.

Many people suppose that if technology automates tasks, as it did in these cases, then it must eliminate jobs generally, creating technological unemployment. According to a study of Bessen ("How Computer Automation Affects Occupation: Technology, Jobs and Skills", 2015) this view fundamentally misunderstands what has been happening. Overall, jobs have been growing faster in occupations that use computers. His analysis shows that computers have not been replacing workers on net; instead, workers using computers are substituting for other workers.

This inter-occupation substitution is similar to the substitution of skilled workers for unskilled in the canonical accounts of skill-biased technical change. But the canonical account only considers pre-existing skills, mainly college education. Results emerging from the Bessen's analysis suggest that computer use is associated with growing employment even in occupations where most workers do not have college degrees, suggesting a much richer pattern of change. Indeed, large-scale substitution between occupations implies considerable organizational change. According to the economist, workers need to learn new jobs and new ways of working. The nature of work also changes within occupations. A substantial literature finds evidence that computer adoption involves organizational change and investments in new skills, often learned on the job. The evidence associating computer use with wage dispersion reinforces the idea that computers require new skills that are difficult to acquire.

Thus, although computers do not cause major technological unemployment, the development of new skills is nevertheless a major challenge to the workforce. Of course, automation has been affecting occupations for a long time without apparently generating sustained unemployment. Economists sometimes explain this paradox by arguing that other sectors compensate for the job losses, for example, manufacturing grew to compensate for the loss of jobs in agriculture.

Bessen makes a different argument: in his opinion, in fact, automation *itself* sometimes brings growing employment to occupations and that is what is happening now. However, there is no guarantee that future computer technology will increase labor demand.

If history is a guide - he asserts - computers may eventually tend to reduce the number of jobs as more marginal computer applications are exploited that do not produce as much job growth. For example, automation in 19thcentury textile weaving was associated with growing employment of weavers through the 1920s because demand for cloth was highly elastic. Eventually, however, demand became more saturated and further technical improvements were accompanied by stable employment and then decline. Today, improvements in older manufacturing technologies contribute significantly to job losses.

Generally speaking, the Bessen's analysis emphasizes the importance of occupation for understanding the impact of technology on jobs and wage inequality.

The evidence highlighted suggests that new technologies are also significantly occupation-specific and often require new skills that are difficult to acquire. Another line of literature finds that a substantial portion of the growth in wage inequality is accounted for by differences between firms or establishments. The research of Bessen does not contradict the importance of occupation and, in fact, a number of papers find that much of the dispersion of wages across establishments is explained by differences in technology and organization.

According to Bessen, computers thus reallocate rather than displace jobs, requiring workers to learn new skills. Evidences show that this is true of a wide range of occupations, not just in computer-related fields such as software development, but also in administrative work, health care and many other areas. Only manufacturing jobs expanded more slowly than the workforce did over the period under analysis, but that had more to do with business cycles and offshoring to China than with technology.

So far, we cannot foresee if the same will be true of fields where AI is being deployed: definitely, in fact, we do not know whether AI will replace workers directly or it will require them to gain new skills to complement it, as it occurred with the introduction of computing into offices.

According to David Autor ("Why Are There Still So Many Jobs? The History and Future of Workplace Automation", 2015), given that these technologies demonstrably succeed in their labor saving objective and, moreover, that we invent many more labor-saving technologies all the time, "should we not be somewhat surprised that technological change has not already wiped out employment for the vast majority of workers? Why does not automation necessarily reduce aggregate employment, even as it demonstrably reduces labor requirements per unit of output produced?" - Autor wonders. These questions underline an economic reality that is as fundamental as it is overlooked: tasks that cannot be substituted by automation are generally complemented by it. Most work processes draw upon a multifaceted set of inputs: labor and capital; brains and brawn; creativity and rote repetition; technical mastery and intuitive judgment; perspiration and inspiration; adherence to rules and judicious application of discretion. Typically, each of these inputs plays an essential role; that is, improvements in one do not obviate the need for the other. If so, productivity improvements in one set of tasks almost necessarily increase the economic value of the remaining tasks.

Rather than putting workers out of work, therefore, technology increases capacity, which may help in the developing world, where there is a shortage of specialists. And while it is easy to see fields in which automation might do away with the need for human labor, it is less obvious where technology might create new jobs: as some industries decline, new ones will emerge and there will also be some new jobs created in the field of AI itself.

And no matter how advanced artificial intelligence becomes, some jobs are always likely to be better done by humans, notably those involving empathy or social interaction.

An analysis of the British workforce by Deloitte, a consultancy, highlighted a profound shift over the past two decades towards "caring" jobs: the number of nursing assistants increased by 909%, teaching assistants by 580% and care-workers by 168%.

However, even if job losses in the short term were likely to be more than offset by the creation of new jobs in the long term, we cannot deny

that the transition can be traumatic, as the experience of the 19th century has shown and maybe more.

The mood now is once again of caution. Advances in machine learning and enormous increases in storage, processing and communication capacity are enabling machines to tackle complex tasks involving thought and judgement, which were once the sole preserve of humans. Jobs are being automated more quickly, or made less labor-intensive.

The debate on technology has many aspects, encompassing everything from education to inequality, productivity to jobs.

Focusing on employment, the current discourse is biased towards the job-destroying effects of technological change due to the relative unpredictability of its creative aspects.

As Deloitte reports in its paper "Technology and people: the great job-creating machine", to make up for this human limitation, we identify four mechanisms (two of them are direct, the other ones are indirect) through which technology has led to overall job creation in the past:

1. technology substitutes labor, raising productivity and lowering prices;
2. sectors which are the source of technological innovation expand rapidly, increasing labor demand;
3. technology complements labor, leading to improved outcomes in sectors which subsequently expand and generate new demand for labor;
4. lower costs of production and prices enable consumers to shift spending to more discretionary goods and services, generating new demand for labor.

Furthermore, we should consider two basic aspects linked with the impact that such a technological revolution may exert: by one side, in fact, this time the transition is likely to be faster, as technologies diffuse more quickly than they did two-hundred years ago; by the other hand, instead, this may cause income inequality to grow further, because high-skilled workers benefit disproportionately when technology complements their jobs.

After the Industrial Revolution, governments took a century to respond with new education and welfare systems: nowadays a quicker response is required in order to allow employers and policymakers to deal with the twofold challenge of helping existing workers acquire new skills and preparing future generations for a workplace stuffed full of AI.

As highlighted by Autor, the number of jobs lost to more efficient machines is only part of the problem. What worries many job experts more is that automation may prevent the economy from creating enough new jobs: throughout industry, the trend has been to bigger production with a smaller workforce and many of the losses in factory jobs have been countered by an increase in the service industries or in office jobs. But automation is beginning to move in and eliminate office jobs too.

In the past, new industries hired far more people than those they put out of business. But this is not true of many of today's new industries. Today's new industries have comparatively few jobs for the unskilled or semiskilled, just the class of workers whose jobs are being eliminated by automation.

In his work, Autor begins by identifying the reasons why automation has not wiped out a majority of jobs over the decades and centuries. Automation indeed substitutes for labor - as it is typically intended to do. However, automation also complements labor, raises output in ways that lead to higher demand for labor, and interacts with adjustments in labor supply.

Changes in technology alter the types of jobs available and what those jobs pay. In the last few decades, one noticeable change has been "polarization" of the labor market, in which wage gains went disproportionately to those at the top and at the bottom of the income and skill distribution, not to those in the middle.

Even if automation does not reduce the quantity of jobs, it may greatly affect the qualities of jobs available.

For the three decades or so from the end of World War II and up through the late 1970s, the US experienced rapid automation and technological change. While it's difficult to paint an accurate picture of occupational change over a large time interval, Figure 1.3, which draws from Katz and Margo (2014), provides a high-level overview by depicting the average change per decade in employment for seven broad occupational categories, ranked from lowest to highest paid, for two periods: 1940-1980 and 1980-2010.

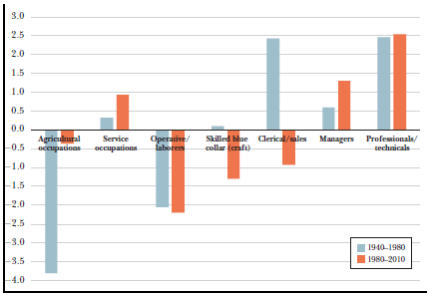

***Fig. 1.3**: Average change per decade in US occupational employment shares for 1940-1980 and 1980-2010. Sources: D. Autor (2015).*

As highlighted by Autor, in the first four decades after World War II, the thrust of occupational change skewed strongly away from physically demanding, dangerous, and menial work and towards skilled blue- and white-collar work. Agricultural employment declined by almost 4 percentage points per decade. Professional, technical, and managerial employment - the highest skill categories - grew by 3 percentage points per decade (2.5 for the professionals and technicians plus 0.5 for the managers). And among the vast middle group of workers between agriculture (at the bottom) and professional, technical, and managerial (the three groups at the top), service and skilled blue-collar occupations were stable, clerical/sales occupations rose, and operative and laborer occupations fell sharply. Thus, physically demanding, repetitive, dangerous, and cognitively monotonous work was receding, ushered out by extraordinary productivity gains in agriculture. Rising consumer affluence spurred demand for manufactured goods and leisure complements. Growth of technologically intensive corporations, health care services, and higher education created employment for credentialed professionals and a cadre of supporting clerical, administrative, and sales workers. Though automation was clearly reducing labor demand across a large swath of occupations, it is easy to see why overall job prospects appeared broadly favorable during this period.

But after the late 1970s, these favorable winds slowed and in some cases reversed. While jobs at the top of the skill ladder - professional, technical, and managerial occupations - grew even more rapidly between 1980 and 2010 than in the four decades prior, positive occupational shifts outside of these categories mostly halted. Skilled blue-collar occupations shrank rapidly and clerical and sales occupations, the vulnerable "production jobs" of the information age, sharply reversed course. While physically demanding operative and laborer jobs continued to atrophy, low-paid personal services began absorbing an increasing share of non-qualified labor. By this time, the vast movement away from agricultural

work had already played out. Many forces distinguish the labor markets of these two epochs of 1940–1980 and 1980–2010: a partial list would include changes in the relative supply of qualified and non-qualified labor, rising trade penetration, offshoring, and globalization of production chains, declines in labor union penetration, the changing "bite" of the minimum wage, and certain shifts in tax policy. Of course, many of these factors combine and interact as well such that attributing changes to a single cause would be foolish.

1.2.4. Information Technology and Job Polarization

To understand the role that information technology has played (and may play), it is useful to start from first principles: what do computers do? And how does their widespread adoption change what workers do? Fundamentally, computers follow procedures meticulously laid out by programmers. The typical pattern has been that for a computer to accomplish a task, a programmer must first fully understand the sequence of steps required to perform that task, and then must write a program that, in effect, causes the machine to simulate these steps precisely.

When a computer accomplishes a task, it is "simulating" a work process that would, in a previous era, have been done by humans using nearly identical procedures. The principle of computer simulation of workplace tasks has not fundamentally changed since the dawn of the computer era, but its cost has.

As Autor recalls, an ingenious 2007 paper by William Nordhaus estimates that the cost of performing a standardized set of computations has fallen by at least 1.7 trillion-fold since the manual computing era, with most of that decline occurring since 1980. Thus, firms have strong economic incentives to substitute ever-cheaper computing power for relatively expensive human labor.

It seems to be reasonable to focus our attention on the effects generated by this situation. One first-order effect is, of course, substitution. As the price of computing power has fallen, computers and their robot cousins have increasingly displaced workers in accomplishing explicit, codifiable tasks. Routine tasks are characteristic of many middle-skilled cognitive and manual activities: for example, the mathematical calculations involved in simple bookkeeping; the retrieving, sorting, and storing of structured information typical of clerical work; and the precise executing of a repetitive physical operation in an unchanging environment as in repetitive

production tasks. Because core tasks of these occupations follow precise, well-understood procedures, they are increasingly codified in computer software and performed by machines. This force has led to a substantial decline in employment in clerical, administrative support, and to a lesser degree, in production and operative employment.

If computers largely substitute for routine tasks, how do we characterize the non-routine tasks for which they do not substitute? Autor, Levy, and Murnane (2003) distinguish two broad sets of tasks that have proven stubbornly challenging to computerize. One category includes tasks that require problem-solving capabilities, intuition, creativity, and persuasion. These tasks, which they termed "abstract", are characteristic of professional, technical, and managerial occupations. They employ workers with high levels of education and analytical capability, and they place a premium on inductive reasoning, communications ability, and expert mastery. The second broad category includes tasks requiring situational adaptability, visual and language recognition, and in-person interactions, which we call "manual" tasks. While these activities are not high-skilled by the standards of the labor market, they present daunting challenges for automation.

Goos and Manning (2003) termed this overall phenomenon as "job polarization". A large body of international evidence confirms the presence of employment polarization at the level of industries, localities, and national labor markets and its consequences seem to be straightforward: the evidence that comes out from this scenario is that such a technological revolution is actually eroding a quota of the demand for labor, and in particular that quota which was supplied by middle-skilled workers accomplishing routine tasks.

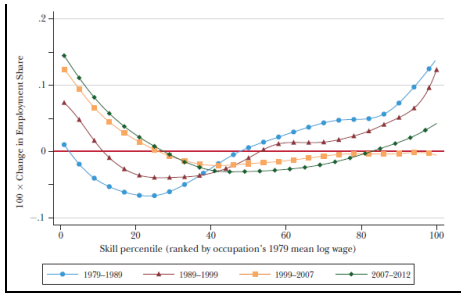

Fig. 1.4.: *Smoothed employment changes by occupational skill percentile, 1979–2012. Sources: D. Autor (2015)*

As Autor explains, Figure 1.4 contributes three nuances to the occupational polarization story exposed.

First, the pace of employment gains in low-wage, manual task-intensive jobs has risen successively across periods, as shown at the left-hand side of the figure.

Second, the occupations that are losing employment share appear to be increasingly drawn from higher ranks of the occupational distribution and evidences suggest that the locus of displaced middle-skill employment is moving into higher-skilled territories.

Third, growth of high-skill, high-wage occupations -those associated with abstract work- decelerated markedly in the 2000s, with no relative growth in the top two deciles of the occupational skill distribution during 1999 through 2007, and only a modest recovery between 2007 and 2012. Stated plainly, the growth of occupational employment across skill levels looks U-shaped earlier in the period, with gains at low-skill and high-skill levels. By the 2000s, the pattern of occupational employment across skill levels began to resemble a downward ramp.

What explains the slowing growth of abstract task-intensive employment?

One interpretation is that automation, information technology, and technological progress in general are encroaching upward in the task domain and beginning to substitute strongly for the work done by professional, technical, and managerial occupations.

So, to be clear, which jobs are most vulnerable?

In a widely noted study published in 2013, Carl Benedikt Frey and Michael Osborne examined the probability of computerization for 702 occupations and found that 47% of workers in America had jobs at high risk of potential automation. In particular, they warned that most workers in transport and logistics and office support “are likely to be substituted by computer capital”, and that many workers in sales and services also faced a high risk of computerization.

They concluded that “recent developments in machine learning will put a substantial share of employment, across a wide range of occupations, at risk in the near future”.

Subsequent studies put the equivalent figure at 35% of the workforce for Britain (where more people work in creative fields less susceptible to automation) and 49% for Japan.

What determines vulnerability to automation is not so much whether the work concerned is manual or white-collar but whether or not it is routine,

therefore it does not lay in the level of qualification, but only in the repeatability of the tasks required by the job. “Automation is blind to the color of your collar”, writes Kaplan (“Humans Need Not Apply: A Guide to Wealth and Work in the Age of Artificial Intelligence”, 2015).

According to Ford (“Rise of the Robots: Technology and the Threat of a Jobless Future”, 2015), those jobs that are truly repetitive or rote - doing the same thing again and again - in advanced economies like the United States or Germany, are long gone. They have already been replaced by robots years and years ago.

So what we have seen in manufacturing is that the jobs that are actually left for people to do tend to be the ones that require more flexibility or require visual perception and dexterity. Very often these jobs kind of fill in the gaps between machines.

Economists are already worrying about what we have named as “job polarization”, where middle-skill jobs are declining, but both low-skill and high-skill jobs are expanding since middle-skilled jobs are those more characterized by routine tasks.

In effect, the workforce bifurcates into two groups doing non-routine work: highly paid, skilled workers on the one hand and low-paid, unskilled workers on the other.

1.2.5. An outlook over future: why may this time be different

But what we are seeing now in robotics is that finally the machines are coming for those jobs as well, and this is being driven by advances in areas like visual perception.

We now have got robots that can see in three-dimension and that are getting much better and also becoming much less expensive. So we are beginning to see machines that are starting to have the kind of perception and dexterity that begins to approach what human beings can do.

This process seems to be unstoppable and relentless. A lot more jobs are becoming susceptible to this trend and that is something which is going to continue to accelerate over time: more and more of those jobs are going to disappear and factories are just going to relentlessly approach full-automation where there really are not going to be many people at all.

Studies published by the Federal Reserve Bank of St. Louis and reported by *The Economist* (2016b) show that in America, employment in non-routine cognitive and non-routine manual jobs has grown steadily

since the 1980s, whereas employment in routine jobs has been broadly flat, as we can see by observing the chart depicted in Figure 1.5. As more jobs are automated, this trend seems likely to continue.

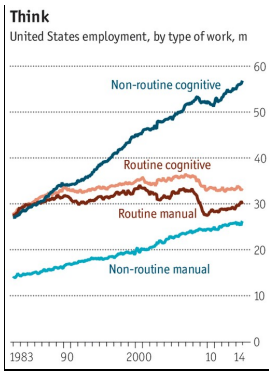

Fig. 1.5: *US Population Survey, Federal Reserve Bank of St. Louis. Sources: The Economist (2016b)*

In previous waves of automation, workers had the option of moving from routine jobs in one industry to routine jobs in another; but now the same "big data" techniques that allow companies to improve their marketing and customer-service operations also give them the raw material to train machine-learning systems to perform the jobs of more and more people.

During previous waves of automation, workers could switch from one kind of routine work to another; but, this time, many workers will have to switch from routine, unskilled jobs to non-routine, skilled jobs to stay ahead of automation.

As remarked by Autor, the frontier of automation is rapidly advancing, and the challenges to substituting machines for workers in tasks requiring flexibility, judgment, and common sense remain immense. In many cases, machines both substitute for and complement human labor. Focusing only on what is lost misses a central economic mechanism by which automation affects the demand for labor: raising the value of the tasks that workers uniquely supply.

In his last book, Martin Ford explains why the current technological revolution is different from earlier ones. Most economists would disagree: their view is that today's displacement is similar to the shift from agriculture to industry. Roughly half of Americans were employed on farms in 1900. Today they account for just 2 per cent of the workforce. Just as ex-farm laborers found work in the factories, so laid-off manufacturing

workers were re-employed in the service industries. The IT revolution will not be different, economists say. It is all part of the natural cycle of creative destruction.

Ford finds two big holes in this "Panglossian" outlook. In contrast to earlier disruptions, which affected particular sectors of the economy, the effects of today's revolution are "general-purpose". From janitors to surgeons, virtually no jobs will be immune. Whether one is training to be an airline pilot, a retail assistant, a lawyer or a financial trader, labor-saving technology is whittling his (or her) numbers, in some cases drastically so - asserts Ford.

He takes the social media example: in 2006, Google bought YouTube for $1.65bn. It had 65 employees. The price amounted to $25m per employee. In 2012, Facebook bought Instagram, which had 13 employees, for $1bn. That came to $77m per employee. In 2014, it bought WhatsApp, with 55 employees, for $19bn, at a staggering $345m per employee.

Such riches are little comfort to the thousands of engineers who cannot find work. Facebook's data servers are now managed by Cyborg, a software program. It requires one human technician for every 20,000 computers. Almost any job that involves sitting in front of a screen and manipulating information is either disappearing, or will do soon. Offshore workers in India are just as vulnerable as their counterparts in the West. China is the fastest- growing market for robots. No human can compete with the relentlessly falling costs of automation.

But it is Ford's second point that is the clincher.

By skewing the gains of the new economy to a few, robots weaken the chief engine of growth, that is the middle-class demand. As labor becomes uneconomic relative to machines, purchasing power diminishes. The US economy produces more than a third more today than it did in 1998 with the same-sized labor force and a significantly larger population. It still makes sense for people to obtain degrees. Graduates earn more than those who have completed only high school. But their returns are falling. The median pay for US entry-level graduates has fallen from $52,000 in 2000 to $46,000 today. It has stagnated for postgraduates. Education is by no means a catch-all solution, says Ford. Not everyone can get a PhD. Assuming that highly skilled jobs can take up the slack is "analogous to believing that, in the wake of the mechanization of agriculture, the majority of displaced farm workers would be able to find jobs driving tractors".

The consequent mass unemployment will lead to even greater inequality. And without work how will people have enough money to support the mass consumerism on which any remaining jobs might depend?

All these considerations stimulate us to investigate innovative solutions, which we will explore in the next sections of this work.

1.3. Updating welfare systems and a basic income proposal

1.3.1. Why to talk about basic income?

Technological change issues return us one of the most dangerous paradoxes of our time: in fact, if on a side we can observe evidences coming from job-places disruption, on the other it seems to be clear that it enlarges inequalities even among the working class.

As Standing ("The growing Precariat: why we need a universal basic income", 2015) notices, globalization, technological change, and government policies have produced a class structure with a tiny plutocracy of billionaires coexisting with a dwindling salariat, with employment security, pensions and paid vacations, and a rapidly growing precariat, living bits-and-pieces lives, without occupational careers and experiencing declining real wages. Telling the precariat that they must obtain more schooling and training is disingenuous. Millions are currently over-qualified for the labor and work they can expect to be doing.

The reality is that the income distribution system of the 20th century has broken down. Real wages in the US and in other rich countries will continue to stagnate and fall. More people, however hard they try, will earn incomes that will not enable them to avoid poverty and insecurity. They will find it impossible to insure against that insecurity. They are not underemployed in the conventional sense. An irony of recent labor market developments is that the precariat has to do more and more work, much of which is unrecorded, unrecognized and unremunerated.

This is why, technology at the same time substitutes for human labor in some cases and asks for more work to many individuals who are yet employed exacerbating precariat.

All this makes it more important than ever to update welfare systems: policymakers should contrast growing economic inequalities due to such a situation, smooth the transitions between jobs and support workers while

they pick up new skills by rethinking education but also the pensions' systems.

As long as concerns the educational system, even outside the AI community, there is a broad consensus that technological progress, and artificial intelligence in particular, will require big changes in the way education is delivered, just as the Industrial Revolution did in the 19th century. As factory jobs overtook agricultural ones, literacy and numeracy became much more important. Employers realized that more educated workers were more productive, but were reluctant to train them themselves because they might defect to another employer. That prompted the introduction of universal state education on a factory model, with schools supplying workers with the right qualifications to work in factories. Industrialization thus transformed both the need for education and offered a model for providing it. The rise of artificial intelligence could well do the same again, making it necessary to transform educational practices and, with adaptive learning, offering a way of doing so.

Both economic insecurity conditions experienced by the precariat and concerns about AI and automation have also led to calls for a stronger safety net in order to deal with growing social inequalities and to protect people from labor-market disruption and help them switch to new jobs, as *The Economist* reports in "Re-educating Rita" (2016d): in fact, both labor market scholars and AI commentators support the idea of a universal basic income as a right. This, recalling Standing, means that every man, woman and child should have a monthly basic income, without imposing arbitrary behavioral conditions and not being dependent on marital, sexual or work status.

Similar ideas were touted during the Industrial Revolution by Thomas Paine and John Stuart Mill, among others. Its chief merit, say its supporters, is that people who are not working, or are working part-time, are not penalized if they decide to work more, because their welfare payments do not decline as their incomes rise. It gives people more freedom to decide how many hours they wish to work, and might also encourage them to retrain by providing them with a small guaranteed income while they do so. Those who predict apocalyptic job destruction see it as a way to keep the consumer economy going and support the non-working population. If most jobs are automated away, an alternative mechanism for redistributing wealth will be needed.

1.3.2. From an academic definition of basic income to the philosophical debate around social justice

According to Van Parijs ("Redesigning Distribution: basic income and stakeholder grant as alternative cornerstones for a more egalitarian capitalism", 2003), a basic income is "an income paid by a political community to all its members on an individual basis, without means test or work requirement".

After providing this synthetic but powerful definition, the author himself analyzes it step by step. Let us start from his definition in order to sketch up the theoretical debate around basic income.

i) An income

Paid in cash, rather than in kind. One can conceive of a benefit that would have all other features of a basic income but be provided in kind, for example in the form of a standardized bundle of food, or the use of a plot of land. A basic income, instead, is provided in cash, without any restriction as to the nature or timing of the consumption or investment it helps fund. In most variants, it supplements, rather than substitutes, existing in-kind transfers such as free education or basic health insurance.

Paid on a regular basis, rather than as a one-off endowment. That is because a basic income consists in purchasing power provided at regular intervals, such as a week, a month, a term or a year, depending on the proposal. One can also conceive of a benefit that would have all other features of a basic income but be provided on a one-off basis. There is a significant difference between a regular basic income and such a basic endowment.

ii) Paid by a political community

By definition, a basic income is paid by a government of some sort out of publicly controlled resources. But it need not be paid by a Nation-state. Nor does it need to be paid out of redistributive taxation. In most proposals, the basic income is supposed to be paid, and therefore funded, at the level of a Nation-state, but it can in principle also be paid and funded at the level of a politically organized part of a Nation-state, such as a province or a commune or a super-national political unit. It may have redistributive or merely distributive aims.

iii) To all its members

There can be more or less inclusive conceptions of the membership of a political community. It is much discussed whether such a policy should be made available even for non-citizens, children or pensioners. However,

most advocates of basic income especially among those who view it as a policy against exclusion, do not want a restrictive entitlement to basic income to further deepen the dualization of the labor market.

iv) On an individual basis

Paid to each. The basic income is paid to each individual member of the community, rather than to each household taken as a whole, or to its head, as is the case under most existing guaranteed minimum schemes.

Uniform. Even if a benefit is paid to each individual, its level could still be affected by the composition and the size of the household. A basic income, instead, is paid on a strictly individual basis. Not only in the sense that each individual member of the community is a recipient, but also in the sense that how much (s)he receives is independent of what type of household she belongs to. Precisely because of its strictly individualistic nature, a basic income tends to remove isolation traps and foster communal life.

v) Without means test

Irrespective of income. Relative to existing guaranteed minimum income schemes, the most striking feature of a basic income is no doubt that it is paid, indeed paid at the same level, to rich and poor alike, irrespective of their income level. In this sense, existing schemes operate ex post, on the basis of a prior assessment, be it provisional, of the beneficiaries' income. A basic income scheme, instead, operates ex ante, irrespective of any income test. The benefit is given in full to those whose income exceeds the stipulated minimum no less than to those whose income falls short of it. Nor are any other means taken into account when determining the level of benefit a person is entitled to. Taxable "means" may need to be taxed at a higher average rate in order to fund the basic income. But the tax-and-benefit system no longer rests on a dichotomy between two notions of "means": A broad one for the poor, by reference to which benefits are cut, and a narrow one for the better off, by reference to which income tax is levied.

vi) Without work requirement

Irrespective of present work performance. The right to a guaranteed minimum income is by definition not restricted to those who have worked enough in the past, or paid in enough social security contributions to be entitled to some insurance benefits. Being unconditional, a basic income sharply contrasts with those forms of guaranteed income intimately linked to guaranteed employment and marks it off from any type of employment subsidy, however broadly conceived.

Irrespective of willingness to work. It also marks it off from conventional guaranteed minimum income schemes, which tend to restrict entitlement to those willing to work in some sense. The exact content of this restriction varies a great deal from country to country, indeed sometimes from one local authority to another within the same country. It may involve that one must accept a suitable job if offered, with significant administrative discretion as to what "suitable" may mean in terms of location or skill requirements; or that one must give proof of an active interest in finding a job; or that one must accept and respect an "insertion contract," whether connected to paid employment, to training or to some other useful activity. By contrast, a basic income is paid as a matter of right to anyone.

In the previous section of this work, we have summarized some of the practical reasons why a basic income is needed. Here, instead, we analyze this same issue from a more philosophical point of view, by taking in account the Van Parijs' basic income proposal that we have just described in order to sketch the philosophical debate developed around this issue.

First of all, by starting from the Van Parijs contribution, it seems crucial to underline that if we want no means test, it is important to drop the work test. In fact, bringing together the last two unconditionalities discussed - the absence of the means test and the absence of the work test - makes it possible to briefly formulate - according to Van Parijs - the core of what makes basic income particularly relevant under present circumstances. At first sight, there is total independence between these two unconditionalities, between the absence of an income test and the absence of a work test. But the strength of the basic income proposal crucially hinges on their being combined. The abolition of the means test, as we have seen, is intimately linked to the removal of the unemployment trap, and hence to the creation of a potential for offering and accepting low-paid jobs which currently do not exist. But some of these jobs can be lousy, degrading dead-end jobs, which should not be promoted. taking even at low pay because of their intrinsic value or the training they provide. Who can tell the difference? Not legislators or bureaucrats, but the individual workers who can be relied upon to know far more than what is known "at the top" about the countless facets of the job they do or consider taking. They have the knowledge that would enable them to be discriminating, but not always the power to do so, especially if they have poorly valued skills or limited mobility. A work-unconditional basic income endows the weakest with bargaining power in a way a work-conditional guaranteed income does not. Put differently, work-unconditionality is a key instrument

to prevent means-unconditionality from leading to the expansion of lousy jobs.

Plugging this line of reasoning in the rapid technological growth context led by AI coming seems to be crucial in order to shed light on the liberating power that technological innovation may assume in this process. In fact, by providing everyone with a universal basic income results into allowing him (or her) to refuse those jobs that Van Parijs defines “lousy” and Marx “alienating”. Combining this with the AI development allows for the possibility to imagine machineries substituting for those jobs and individuals freed by them. By going further in building hypotheses around this scenario, it sounds reasonable to imagine that firms may be stimulated in investing in technological innovation substituting for such jobs, due to the fact that everyone is provided with a universal basic income and can therefore refuse to perform those jobs. We believe that, if this is the case, it sounds not exaggerating to talk about an emancipatory power of basic income.

At the same time, according to Van Parijs, if there is no means test, no work test is needed. In fact, the work incentives associated by means-unconditionality make work conditionality less tempting as a way of alleviating the fear that benefits without a counterpart would nurture an idle underclass. In the absence of a means test, the tax and benefit structure can be expected to be such that beneficiaries can significantly increase their disposable incomes by working, even at a low rate and on a part-time basis, and without being trapped in such jobs once their skills improve or once they can improve their working time.

This seems to be consistent with many empirical studies demonstrating that basic income does not turn its recipients into lazy do-nothings.

The most popular study on the effects of basic income took place in Manitoba between 1974 and 1979 where everyone received a “Mincome” (minimum income) of $9,000 a year (by today's standards) from the government, no strings attached. Evelyn Forget, the economist and professor at the University of Manitoba who looked over the data from the study, shows that reduction in working hours was significantly low: working hours drop by 1% among men, by 3% among married women and by 5% among non-married women. But, by interviewing people taking part to the experiment, the emerging reasons explaining the reduction in working hours give insight into how basic income can dramatically change the course of someone's life: young mothers were using their additional income to extend their maternity leaves and spend more time with their

infants, and teenage boys and girls were using that income to stay in school rather than abandoning it in order to look for a job to get self-sustaining.

Coming back to the Van Parijs basic income proposal, moving (back) into the work sphere will therefore be facilitated and encouraged, and, for those who fear a dualization of society into workers and non-workers, there will therefore be far less of a need to insist on coupling the right to the benefit to some obligation to (be available for) work. To put it (somewhat too) succinctly: just as work-unconditionality prevents means-unconditionality from unacceptably supporting exploitation (which it would do by subsidizing unworthy low-paid jobs accepted under the threat of losing the benefit), similarly means-unconditionality prevents work-unconditionality from unacceptably fostering exclusion (which it would do by inviting one to no longer regard as problematic a system that durably disconnects the less productive from any labor participation by effectively killing off low-productive jobs). The two key unconditionalities of basic income are therefore logically independent, but they are intrinsically linked as components of strong proposal.

As Van Parijs underlines, what the basic income does is “activating while liberating”. In fact, this solidarity between the two unconditionalities underlies the central case for basic income as a specific way of handling the joint challenge of poverty and unemployment.

Compared to guaranteed income schemes of the conventional sort, the clincher in favor of the desirability of basic income rests on the widely shared view that social justice is not only a matter of right to an income, but also of access to (paid and unpaid) activity. The most effective way of taking care of both the income and the activity dimension consists in maintaining the income transfer (in gross terms) whatever the person’s activity, thereby “activating” benefits, i.e. extending them, beyond forced inactivity, to low-paid activity. It can correctly be objected that there are other schemes - such as earned income tax credit or employment subsidies - that could serve better, or more cheaply, the objective of securing the viability of low-productive jobs and thereby providing a paid job to the worst off. However, if the concern is not to keep poor people busy at all cost, but rather to provide them with access to meaningful paid activity, the very unconditional nature of a basic income is a crucial advantage: it makes it possible to spread bargaining power so as to enable (as much as is sustainable) the less advantaged to discriminate between attractive or jobs and lousy ones.

The preceding argument implicitly appeals to a conception of social justice as the fair distribution of the real freedom to pursue the realization of one's conception of the good life, whatever it is.

In this framework, it seems to be proper introduce Rawls' theoretical contribution to the debate around social justice: in fact, utilitarian doctrine, fits perfectly in this groove and is still nowadays one of the most relevant referring points in the field of the political philosophy, such that it forms the basis for a large part of normative economics. Let us recall here Rawls' word of his "Justice as fairness" (1985):

> One thing I failed to say in A Theory of Justice, or failed to stress sufficiently, is that justice as fairness is intended as a political conception of justice. While a political conception of justice is, of course, a moral conception, it is a moral conception worked out for a specific kind of subject, namely, for political, social, and economic institutions. In particular, justice as fairness is framed to apply to what I have called the "basic structure" of a modern constitutional democracy. (I shall use "constitutional democracy" and "democratic regime," and similar phrases interchangeably.) By this structure I mean such a society's main political, social, and economic institutions, and how they fit together into one unified system of social cooperation.
>
> It should also be stressed that justice as fairness is not intended as the application of a general moral conception to the basic structure of society, as if this structure were simply another case to which that general moral conception is applied. In this respect justice as fairness differs from traditional moral doctrines, for these are widely regarded as such general conceptions. Utilitarianism is a familiar example, since the principle of utility, however it is formulated, is usually said to hold for all kinds of subjects ranging from the actions of individuals to the law of nations.
>
> The essential point is this - as a practical political matter no general moral conception can provide a publicly recognized basis for a conception of justice in a modern democratic state. […]
>
> Justice as fairness tries to adjudicate between these contending traditions first, by proposing two principles of justice to serve as guidelines for how basic institutions are to realize the values of liberty and equality, and second, by specifying a point of view from which these principles can be seen as more appropriate than other familiar principles of justice to the nature of democratic citizens viewed as free and equal persons.
>
> What must be shown is that a certain arrangement of the basic structure, certain institutional forms, are more appropriate for realizing

the values of liberty and equality when citizens are conceived as such persons, that is (very briefly), as having the requisite powers of moral personality that enable them to participate in society viewed as a system of fair cooperation for mutual advantage. So to continue, the two principles of justice (mentioned above) read as follows:

i) Each person has an equal right to a fully adequate scheme of equal basic rights and liberties, which scheme is compatible with a similar scheme for all.

ii) Social and economic inequalities are to satisfy two conditions: first, they must be attached to offices and positions open to all under conditions of fair equality of opportunity; and second, they must be to the greatest benefit of the least advantaged members of society.

Each of these principles applies to a different part of the basic structure; and both are concerned not only with basic rights, liberties, and opportunities, but also with the claims of equality; while the second part of the second principle underwrites the worth of these institutional guarantee the two principles together, when the first is given priority over

the second, regulate the basic institutions which realize these values.

By borrowing words from Amartya Sen, who - among the other things -focused much of his work in analyzing Rawls' considerations and in elaborating them, a fair society should provide all individuals with the tools allowing them to flourish.

And, indeed, by combining this clincher with Rawls' arguments, we cannot disagree with Van Parijs when he asserts that the starting point of his considerations for basic income as a first-best must adopt some notion of "real freedom" (not only the right but also the means to do what one may wish) as the distribuendum of social justice and combine it with some strongly egalitarian criterion of distribution. The particular "real-libertarian" conception proposed here gives a key role to the view that the substratum of our real freedom essentially consists in very unequal combinations of gifts we have received throughout our existences, among them the opportunities that enable us to hold our jobs. As a result, there are massive "employment rents" incorporated in our jobs which can and must be (partly) captured through predictable and sustainable revenue-maximizing income taxation whose proceeds are to be used to fund a universal and unconditional basic income.

1.3.3. Basic income and welfare systems

Compared with the complexity of overhauling the education system, a basic income appears to offer a simple, attractive and easily understood solution, and, in a world of rapid technological change, it could help ensure "a smooth transition to the jobs of the future". According to *The Economist* (2016d), the idea of a basic income seems to appeal also to techie types because of its simplicity and elegance: replacing existing welfare and tax systems, which are like badly written programming code, with a single line.

Though the idea sounds to be attractive in principle, the devil is in the details. Indeed, a universal basic income that replaced existing welfare budgets may be steeply regressive: divide existing spending on social, pension and welfare schemes (excluding health care) equally, and each citizen would get a basic income of around $6,000 a year in America and $6,200 in Britain, for example (at purchasing-power parity). Compared with existing welfare schemes, that would reduce income for the poorest, while giving the rich money they do not need, and clearly this would make no sense.

Even being true that in most proposals the introduction of a basic income is combined with a partial abolition of existing benefits and tax reductions, we reply to this argument by recalling again Van Parijs. In fact, if the proposed reform simply consisted in spreading more thinly among all citizens the non-contributory benefits currently concentrated on the poor, the latter would clearly lose out. But, as Van Parijs points out, this would be an absurd proposal. In most proposals that rely on direct taxation, the basic income replaces only the bottom part of the noncontributory benefits, but also the exemptions or reduced tax rates on every taxpayer's lower income brackets. The immediate impact on the income distribution can then be kept within fairly narrow bounds for a modest basic income. But the higher its level, the higher the average rate of income tax and therefore the greater the redistribution from the comparatively rich to the comparatively poor.

In fact, conversely to what one can think, the idea of distributing a basic income irrespectively of one's income does not make the rich richer. From the fact that rich and poor receive the same basic income, it does not follow, however, that the introduction of a basic income would make both rich and poor richer than before. A basic income needs to be funded and this would be done through taxation.

If a basic income were simply added to existing tax-and-benefit systems, it is clear that the comparatively rich would need to pay both for their own basic income and for much of the basic income of the comparatively poor. This would clearly hold if the funding were through a progressive income tax, but would also hold under a flat tax or even a regressive consumption tax. For the ex nihilo introduction of a basic income to work to the financial advantage of the poor, the key condition is simply that, relative to their numbers (not necessarily to their incomes), the relatively rich should contribute more to its funding than the relatively poor.

Indeed, let us recall that the conditions promoting the creation of European welfare state and briefly sketch its evolution in order to understand why a further step such the introduction of a universal basic income may be required nowadays.

Actually, European welfare state's creation is strictly connected with poverty conditions involving working classes during the massive industrialization in the late 19th century. This translated basically into the introduction of the first government spending quotas devoted to social security, social care, education and health care in order to ensure a basic level of wellbeing to the working classes. During the last two decades of the 19th century, the Prussian Chancellor Otto Von Bismarck introduced some social reforms based on the insurance principle and providing a range of support instruments financed by the workers themselves through the subscription and payment of insurance fees proportionate to the work done.

However, modern welfare state was consolidated only after World War II rand it was based on social care, public health care and pensions: starting from those years, welfare states used to be financed both through insurance principles (i.e. through contributions paid by the workers themselves) and through general taxation guaranteeing public intervention in order to sustain workers.

The overcoming of the economic Fordist model during the 1970s and the dismantling of public policies during the 1980s, combined with rapid social transformations affecting society in those years, were undermining the welfare state basis.

Indeed, those years were characterized by the women's massive entrance in the labor market, the tech revolution, and the information and communication one and the employment relationships' transformation in the sense of the flexibility. But, most of all, the most striking social issues coming from the 1980s were the growing number of active workers ejected

by the labor market and the blurring of the boundary between employed and unemployed. The welfare state, which was born to guarantee a minimum level of wellbeing under a Fordist labor model, was firstly experiencing its impotence when those structural changes stroke society.

To be honest, the impression is that still nowadays an effective solution to face growing social fragmentation and challenges related to changes in the labor market: in such a framework it seems to be proper wonder whether it will be able in reacting to the new wave of changes that is going to invest society, and it seems to make sense to look for innovative solutions.

In such a context, a basic income proposal as the one described may not be a panacea to all social ills, but, if well combined with a renewed welfare system able to face growing social inequalities, may show a desirable direction to go into.

1.3.4. Criticisms to the basic income model

One of the most frequent doubts arisen by commentators criticizing basic income proposals is about the feasibility of such a measure in the terms of costs. As Van Parijs points out, phrased in this very general way, the question makes no sense. Let us bear in mind that it is not part of the definition of a basic income that it should be sufficient to satisfy the beneficiaries' basic needs: consistently with its definition, the level of the basic income could be more and it could be less. Nor is it part of the definition of a basic income that it should replace all other cash benefits: a universal benefit need not be a single benefit.

A meaningful answer can only start being given to the question of affordability if one specifies the level at which the basic income is to be pitched and stipulates which benefits, if any, it is to replace. Every serious proposal lies somewhere in between, and whether some basic income proposal is affordable must therefore be assessed case by case.

Another legitimate question that may be posed is whether basic income is more expensive because work-unconditional. That is, rephrasing, are there some general reasons why a basic income would not be affordable at a level at which a conventional guaranteed income would? One obvious reason might simply be that a basic income is given to all, whether or not they are willing to work, whereas a conventional guaranteed minimum income is subordinated to a willingness-to-work test. As a result, it is claimed, more poor people will be receiving a basic income than a

conventional guaranteed income, or, if the number of beneficiaries is not much greater, they will be doing less work than would be the case under a work-conditional benefit system. In net terms, therefore, a basic income scheme is certain to cost more.

However, it is relevant to underline how a basic income would integrate the existing system made of taxes and subsides, and, therefore, it would harmonize different interventions by balancing them each other and by filling gaps of existing policies. Of course, the very added cost in resorting to basic income would be represented by including all those being excluded by any kind of social safety net. But this transition would also imply large savings on the administrative management, constituting a large part of the cost of implementing measures that reckon on means tests or other kinds of conditionality.

Furthermore, while evaluating the costs in establishing a basic income, it should be taken in account of all those traditional welfare systems' biases yielded by their selective and conditional attitude: in fact, differently from guaranteed minimum income, basic income would be entirely summed up with working salary rather than disappearing as the latter grows up, and this would avoid poverty trap and unemployment trap by stimulating individuals to work rather than providing a disincentive. This would yield positive consequences both on income levels and on returns in the terms of taxation.

All these evaluations drive to the second critique that some move against basic income: they assert that since it is not linked with any kind of working oblige, it would encourage laziness by causing a collapse in labor supply. However, no evidences about intrinsic laziness of individuals has been found (Standing, 2003). Human beings' nature takes them to develop constantly their capabilities in order to better their conditions off: if one is affected by poverty consequences, perceiving a continuative and durable subside may allow him (or her) to gather sufficient energies in order to focus, accumulate skills and be engaged in labor.

In order to introduce this analysis into the correct framework, it is necessary to observe what is the context where this discussion is plugged: nowadays labor market is made up of fragmentation, temporary and discontinuous employments, constantly growing unemployment rates. In such a scenario, a universal basic income may provide a solid social and working glue, avoiding precariousness to condition individuals' life.

As Standing ("CIG; COAG and COG: a comment on a debate", 2003) suggests, there are two ways in order to face the issue whether basic

income reduces availability to work: first one is pragmatic, the other one is normative, taking in any case into consideration that the majority of the basic income proposals supposes to guarantee just the amount sufficient to cover primary needs, equivalent to the minimal social performance tutored in welfare systems applied in many European countries.

Pragmatic answer proposed by Standing underlines that negative effects of introducing a basic income on the availability to work would minimum and irrelevant: in fact, many surveys show that human beings work for many reasons and would keep on working even being provided with a sufficient income guaranteeing to survive (Standing, 2003). Few people indeed may be satisfied about living at minimum subsistence standards, because majority aims to get more.

Therefore, in many cases basic income seems to be the necessary condition to substantiate this aim, which may not be realized without guaranteeing adequate tools.

On the other side, normative answer empowered by Standing sinks its roots on the evidence that globalization and financialization of the economic system are eroding the welfare state institutes built during the 20th century.

Even though the so called "European social model" sometimes turned out to be inadequate in facing renewed individuals' needs, governments and super-national organisms should rethink at welfare state as to respond to structural changes occurred and occurring and, most of all, refinance it.

In a social context such the present one, where on a side individuals are constrained by the imperative of consuming more and more and, therefore, working more and more, and on the other hand technological innovation makes labor totalizing, as for cognitive jobs, when it does not substitute for it, as for physical jobs, the safety of a basic income as right would guarantee a safety net for people, enabling them to feel more in control of their time, which means they must feel less insecure and it would open for more rational choices, giving them more freedom in deciding how to spend their time. (Standing, 2013).

1.4. How to promote innovation

1.4.1. The role of innovation in creating value

After sketching the reasons why occurring technological changes are so crucial in order to define the global macroeconomic framework and, consequently, the reasons why they require a deep rethinking of the welfare systems, in this section we focus on innovation, as it is the pivot boosting these relevant structural changes.

Here we provide a very a general definition of innovation, which may be useful in order to develop our line of reasoning around all the processes we are discussing. We define as innovation the process of translating an idea or invention into a good or service that creates value or for which customers will pay.

To be called an innovation, an idea must be replicable at an economical cost and must satisfy a specific need. Innovation involves deliberate application of information, imagination and initiative in deriving greater or different values from resources, and includes all processes by which new ideas are generated and converted into useful products. In business, innovation often results when ideas are applied by the company in order to further satisfy the needs and expectations of the customers.

In this work, we recalled several times the historical debate around innovation and the role of technological issues in determining labor market's dynamics. However, it may be useful to report here also the contribution given by Marx, since it gives us a well-defined framing of mechanisms through which fixed capital takes part to the value creation process and it is crucial for us to have an insight of how innovation breaks into this process. Therefore, let us report a bit of the "Fragment on machines" (K. Marx, from the "Grundrisse", 1857-1858).

> Capital which consumes itself in the production process, or fixed capital, is the means of production in the strict sense. In a broader sense the entire production process and each of its moments, such as circulation as regards its material side is only a means of production for capital, for which value alone is the end in itself. Regarded as a physical substance, the raw material itself is a means of production for the product etc.
>
> But the determination that the use value of fixed capital is that which eats itself up in the production process is identical to the proposition that it is used in this process only as a means, and itself exists merely as an agency for the transformation of the raw material into the product. As such a means of production, its use value can be that it is merely the technological condition for the occurrence of the process (the site where the production process proceeds), as with buildings etc., or that it is a

direct condition of the action of the means of production proper, like all *matières instrumentales*. Both are in turn only the material presuppositions for the production process generally, or for the employment and maintenance of the means of labor. The latter, however, in the proper sense, serves only within production and for production, and has no other use value. […]

As long as the means of labor remains a means of labor in the proper sense of the term, such as it is directly, historically, adopted by capital and included in its realization process, it undergoes a merely formal modification, by appearing now as a means of labor not only in regard to its material side, but also at the same time as a particular mode of the presence of capital, determined by its total process as fixed capital. But, once adopted into the production process of capital, the means of labor passes through different metamorphoses, whose culmination is the machine, or rather, an automatic system of machinery (system of machinery: the automatic one is merely its most complete, most adequate form, and alone transforms machinery into a system), set in motion by an automaton, a moving power that moves itself; this automaton consisting of numerous mechanical and intellectual organs, so that the workers themselves are cast merely as its conscious linkages. In the machine, and even more in machinery as an automatic system, the use value, i.e. the material quality of the means of labor, is transformed into an existence adequate to fixed capital and to capital as such; and the form in which it was adopted into the production process of capital, the direct means of labor, is superseded by a form posited by capital itself and corresponding to it. In no way does the machine appear as the individual worker's means of labor. Its distinguishing characteristic is not in the least, as with the means of labor, to transmit the worker's activity to the object; this activity, rather, is posited in such a way that it merely transmits the machine's work, the machine's action, on to the raw material supervises it and guards against interruptions. […]

The transformation of the means of labor into machinery, and of living labor into a mere living accessory of this machinery, as the means of its action, also posits the absorption of the labor process in its material character as a mere moment of the realization process of capital. The increase of the productive force of labor and the greatest possible negation of necessary labor is the necessary tendency of capital, as we have seen. The transformation of the means of labor into machinery is the realization of this tendency. In machinery, objectified labor materially confronts living labor as a ruling power and as an active subsumption of the latter under itself, not only by appropriating it, but in the real production process itself; the relation of capital as value which appropriates value - creating activity is, in fixed capital existing as machinery, posited at the same time as the relation of the use value of

capital to the use value of labor capacity; further, the value objectified in machinery appears as a presupposition against which the value - creating power of the individual labor capacity is an infinitesimal, vanishing magnitude; the production in enormous mass quantities which is posited with machinery destroys every connection of the product with the direct need of the producer, and hence with direct use value; it is already posited in the form of the product's production and in the relations in which it is produced that it is produced only as a conveyor of value, and its use value only as condition to that end. In machinery, objectified labor itself appears not only in the form of product or of the product employed as means of labor, but in the form of the force of production itself. The development of the means of labor into machinery is not an accidental moment of capital, but is rather the historical reshaping of the traditional, inherited means of labor into a form adequate to capital. The accumulation of knowledge and of skill, of the general productive forces of the social brain, is thus absorbed into capital, as opposed to labor, and hence appears as an attribute of capital, and more specifically of fixed capital, in so far as it enters into the production process as a means of production proper. Machinery appears, then, as the most adequate form of fixed capital, and fixed capital, in so far as capital's relations with itself are concerned, appears as the most adequate form of capital as such. In another respect, however, in so far as fixed capital is condemned to an existence within the confines of a specific use value, it does not correspond to the concept of capital, which, as value, is indifferent to every specific form of use value, and can adopt or shed any of them as equivalent incarnations. In this respect, as regards capital's external relations, it is circulating capital which appears as the adequate form of capital, and not fixed capital. […]

In machinery, the appropriation of living labor by capital achieves a direct reality in this respect as well: It is, firstly, the analysis and application of mechanical and chemical laws, arising directly out of science, which enables the machine to perform the same labor as that previously performed by the worker. However, the development of machinery along this path occurs only when large industry has already reached a higher stage, and all the sciences have been pressed into the service of capital; and when, secondly, the available machinery itself already provides great capabilities. Invention then becomes a business, and the application of science to direct production itself becomes a prospect which determines and solicits it. But this is not the road along which machinery, by and large, arose, and even less the road on which it progresses in detail. This road is, rather, dissection through the division of labor, which gradually transforms the workers' operations into more and more mechanical ones, so that at a certain point a mechanism can step into their places. (See under economy of power.) Thus, the specific

> mode of working here appears directly as becoming transferred from the worker to capital in the form of the machine, and his own labor capacity devalued thereby.

Here, Marx gives a sketch of what how both labor and capital enter the value creation process, and he depicts why a contradiction between these two factors arise. Innovation, in such a vision, is the process which "transforms the workers' operations into more and more mechanical ones, so that at a certain point a mechanism can step into their places".

Innovation breaks into productive processes and modifies them by behaving like this, and since it seems to be an ineluctable process - and it makes no sense to act in order to contrast it -, we believe it is more helpful to reason in the perspective of exploiting such a progress in order to rise standard livings and contrast social inequalities, moving along the pattern that we exposed in the previous section.

By following this line of reasoning, it seems to be proper to imagine how to exploit technological innovation in order to boost this process.

1.4.2. How public institutions promote innovation

If it makes sense to imagine technological innovation as fostering the reduction in social inequalities - and it does -, it seems to be proper focusing on how public institutions can behave in order to promote technological innovation to boost such a virtuous circle.

Mazzucato ("The entrepreneurial State", 2013) focuses her work exactly in this direction, starting from the present framework to provide some insights about the role of innovation in promoting a development both from the private and public sectors' points of view.

Actually, cross the globe we are hearing that the state has to be cut back in order to foster a post-crisis recovery, unleashing the power of entrepreneurship and innovation in the private sector. This feeds a perceived contrast that is repeatedly drawn by the media, business and libertarian politicians of a dynamic, innovative, competitive private sector versus a sluggish, bureaucratic, inertial, 'meddling' public sector. So much so that it is virtually accepted by the public as a 'common sense' truth.

However, while business as a whole may not see the virtues of anything that does not have a clear and positive impact on its bottom line, and nor arguably should it, there is a danger when a general desire to reduce the size of the state translates into weak and non-ambitious economic policy.

When that happens, we are all losers: policy is not as effective as it could be and the potential to create greater prosperity is not fulfilled. In what follows, we sketch a different standing point, by focusing on the dangers of that happening in the field of innovation policy is greatly limiting its impact on economic growth. The mainstream view, which has been implemented - and still now is being - implemented by many governments throughout the world, is that the role of the state in spurring innovation is simply to provide the conditions for innovation to flourish.

We believe that the view underpinning that if it the state invests in skills and a strong science base, ensures a strong legal framework within an amenable macroeconomy, and supports entrepreneurial clusters, then the market will do the rest through the incentive of the profit motive is a minimalist view of the state in the field of economic policy, and we argue that a far more proactive role is required. The role of the government, in the most successful economies, has gone way beyond creating the right infrastructure and setting the rules. It is a leading agent in achieving the type of innovative breakthroughs that allow companies, and economies, to grow, not just by creating the 'conditions' that enable innovation. Rather the state can proactively create strategy around a new high growth area before the potential is understood by the business community (from the internet to nanotechnology), funding the most uncertain phase of the research that the private sector is too risk-averse to engage with, seeking and commissioning further developments, and often even overseeing the commercialization process. Indeed, it is a case for a targeted, proactive, entrepreneurial state, able to take risks, creating a highly networked system of actors harnessing the best of the private sector for the national good over a medium to long-term horizon. It is the state as catalyst, and lead investor, sparking the initial reaction in a network that will then cause knowledge to spread. The state as creator of the knowledge economy.

It is about admitting that in many cases, it has in fact been the state, not the private sector, that has had the vision for strategic change, daring to think - against all odds - about the 'impossible', creating a new technological opportunity, making the large necessary investments, and enabling a decentralized network of actors to enable the risky research, and to allow the development and commercialization process to occur in a dynamic way.

It is only by creating a so-called national system of innovation built on sharing knowledge that the necessary, if not sufficient, conditions start to be established.

As Mazzucato highlights, Systems of innovation are defined as the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies, or the elements and relationships which interact in the production, diffusion and use of new, and economically useful, knowledge… and are either located within or rooted inside the borders of a nation State. National systems of innovation. The emphasis here is not on the stock of R&D but on the circulation of knowledge and its diffusion throughout the economy. Institutional change is not assessed through criteria based on static allocative efficiency but rather on how it promotes technological and structural change. The perspective is neither macro or micro, but more meso, where individual firms are seen as part of a broader network of firms with whom they cooperate and compete. The system of innovation can be inter-firm, regional, national or global. The network is the unit of analysis (not the firm) in the "meso" perspective. The network consists of customers, subcontractors, infrastructure, suppliers; competencies or functions; and links or relationships. The point is that the competencies for innovation are distributed throughout a network of actors and their links or relationships.

Furthermore, the lack of knowledge in the public domain about the central entrepreneurial role that government plays in the growth of economies worldwide, beyond Keynesian demand management and 'creating the conditions for growth, currently putting the successful model in major danger.

The state's role would then be limited to that of initially underwriting radical new discoveries, until they are generating profits that can fund ongoing discovery. But private-sector behavior suggests that public institutions cannot pass the R&D baton in this way. And that the state's role cannot be limited to that of planting seeds that can be subsequently relied on to grow freely.

Mazzucato argues that to make growth "fairer" and for the gains to be better shared is for economists, policy makers, and the general public to have a broader understanding of which agents in society take part of the fundamental risk-taking that is necessary to bring on innovation-led growth.

As has been argued, risk-taking and speculation are absolutely necessary for innovations to occur. The real Knightian uncertainty that innovation entails are, in fact, the reason that the private sector, including venture capital, often shies away from it.

Understanding the dynamics of innovation must be brought in line with our understanding of dynamics of inequality. These areas of economic thought have been separated since David Ricardo's study of the effect of mechanization on the wage-profit frontier distribution.

Recently, the relationship has come back in vogue with studies on how skill-biased technological change affects wages. This work explains inequality through how wages are affected by technologies like IT that favor skilled over unskilled labor by increasing its relative productivity and, therefore, its relative demand and wages. Inequality is thus explained here as a result of how economic incentives shaped by relative prices, the size of the market, and institutions create biases in factors of production, which then affect their returns.

The idea of an entrepreneurial state suggests that one of the core missing links between growth and inequality lies in a wider identification and understanding of the agents that contribute to the risk-taking required for that growth to occur.

In seeking innovation-led growth - Mazzucato concludes - it is fundamental to understand the important roles that both the public and private sector can play. This requires not only understanding the different ecologies between the public and private sector, but especially rethinking what it is that the public is bringing to that ecology. The assumption that the public sector can at best incentivize private sector led innovation (through subsidies, tax reductions, carbon pricing, green investment banks and soon) fails to account for the many examples in which the leading entrepreneurial force came from the state rather than from the private sector.

1.4.3. Creating networks to spread innovation

The network we were referring to just above has the basic objective of building links between different agents in the society. In order to do so, it is needed to introduce a new approach to growth, development and social progress, as Stiglitz and Greenwald underline ("Creating a learning a society", 2014).

Creating a dynamic learning society has many dimensions: individuals have to have a mindset and skills to learn. There has to be some motivation for learning. Knowledge is created by individuals, typically working within organizations, and transmitted to others within the organization. it is then transmitted from one organization and individual to another. But the extent,

ease, and rapidity of transmission of knowledge is itself one of the central features of a learning society: for the new knowledge spurs new thinking; it is the catalyst as well as the input out of which new ideas and creativity emerge. Some societies are better at learning than others—both in ensuring that the gap between best and average practices is smaller and in the pace with which the knowledge frontier moves out.

Although economists, such as Schumpeter (1943), had identified the major source of transformative developments as technological progress, it was not until Robert Solow (1957) that there was a way of quantifying the relative importance of capital accumulation versus technical progress. Changes in capital intensity could account for at most a third of changes in output per worker. The remainder was attributable largely to various forms of technical progress. Subsequent literature suggested that the quantification was perhaps less robust than seemed initially the case, partly because the measurement of key inputs (capital, human capital) was more difficult and problematic than had at first been realized, partly because the underlying model, entailing a constant returns to scale aggregate production function and full competition, seemed more questionable.

Some of the difficulties of parsing out the sources of growth was that they were intertwined - new machines (investment) were required to implement new technologies. Still, there is no doubt that there have been enormous increases in productivity and that advances in technology as well as "learning to do things better" have played a critical role in these increases in productivity.

For our purposes, that is all that matters not only is the pace of learning (innovation) the most important determinant of increases in standards of living, the pace itself is almost surely partially, if not largely, endogenous. The speed of progress has differed markedly both over time and across countries, and while we may not be able to explain all of this variation, it is clear that government policies have played a role. Learning is affected by the economic and social environment and the structure of the economy, as well as public and private investments in research and education. The fact that there are high correlations in productivity increases across industries, firms, and functions within firms suggests that there may be common factors (environmental factors, public investments) that have systemic effects or that there may be important spillovers from one learner/innovator to others. But the fact that there are large, persistent differences across countries and firms—at the microeconomic level, large discrepancies between best, average, and worst practices—implies that knowledge does

not necessarily move smoothly either across borders or over firm boundaries

All of this highlights that one of the objectives of economic policy should be to create economic policies and structures that enhance both learning and learning spillovers; creating a learning society is more likely to increase standards of living than is making small, one time improvements in economic efficiency or sacrificing consumption today to deepen capital and this is even more so for developing countries. much of the difference in per capita income between these countries and the more advanced is attributable to differences in knowledge. Policies that transformed their economies and societies into "learning societies" would enable them to close the gap in knowledge, with marked increases in incomes. Development entails learning how to learn (Stiglitz 1987c).

As Stiglitz and Greenwald argue, if this contention that the success of modern economies is due to innovation and learning is correct, then understanding the processes of learning and innovation, and how policy can affect its pace, should be at the center of economic analysis.12 We can think of an economy's "innovation system" broadly as running from basic research – typically financed by government, occasionally by a government sanctioned monopoly, and typically produced by research universities and government research laboratories - to applied research, sometimes building on these basic ideas, at other times refining and developing "prior art".

Ideas have to be disseminated and put into practice: much of the increase in productivity occurs as firms learn from each other or as technology improves through practice more of our analysis ought to focus on how such learning occurs.

Kenneth Arrow was a pioneer in examining the economics of these "learning processes"- the factors which promote or retard them, their likely response to normal market incentives, and their relationship to the broader macro and microeconomic environment - notably in his papers on the economics of R&D and learning-by-doing (1962a,1962b). He called attention to the fact that while some knowledge was produced as a result of the deliberate allocation of resources to research and development, much of technical progress was a by-product of production or investment.

One of the advances in modern economies has been improvement in the processes by which they learn - they have learned how to learn. There is not a single breakthrough that led to enhanced learning capacities, but rather a series of organizational innovations.

Consistent with this, subsequent work, including that of Nordhaus (1969a, 1969b), identified the greater part of such progress as arising from the continuous accumulation of small improvements in production processes rather than from dramatic technological breakthroughs, though some, perhaps many, of these small improvements may be based on or related to transformative changes.

So too, the separation between capital accumulation and "learning" is not a clean one: it is often through new investments that new ideas are discovered and new research is "embodied". If the pace of investment determines the pace of learning, then of course it is impossible to neatly separate out what part of the increase in productivity is a result of capital accumulation and what part is a result of improvements in technology, because the two are inextricably intertwined.

Furthermore, it has to be noticed that the most successful economies are those that have succeeded in not only moving out their production possibilities curve more rapidly, but also ensuring that the gap between "average" and "best" practices is small. There is more diffusion of knowledge, more learning; and it I these achievements in learning that largely account for the ever-rising standards of living in these successful economies.

In short, the transformation to "learning societies" which occurred around 1800 for Western economies, and more recently for those in Asia, appears to have had a greater impact on human well-being than improvements in allocative efficiency or resource accumulation. If this is so, understanding how to create a learning society should be one of the central preoccupations of economists and other social scientists. As Stiglitz and Greenwald point out, success in this endeavor can have a far greater impact on increasing long-term living standards than ascertaining how to increase resource accumulation or reduce short-term allocative inefficiencies.

2. THE MODEL

2.1. The “set-up” button

2.1.1. The “create world” procedure

In the first phase of the work, the basic aim beyond our model is to analyze the relationship between the level of technological development of a given firm and its capacity of creating or destroying job places.

In the attempt of doing so, we start this work by analyzing how this relationship operates in the real world, and by using NetLogo we sketch a simplified model which should give us some useful insights through agent-based simulation techniques.

The set-up process is then composed by two phases: during the first one, named “create world”, we just define the agents and their features; whereas in the following one, named “hire”, we set up the hiring process through which firms and workers interact at the first time.

```
to setup
ca
  reset-ticks
  createWorld
  hire
end
```

First of all, let us introduce the agents interacting in the model and their main features. The model reckons on two different breed of agents: firms and population.

Firms' features appearing during the setup process are the following:

- productivity of capital (K)
- productivity of labor (L)
- capital endowment
- number of hirings.

As long as concerns the productivity of capital and labor, in the present model they are not meant as complements in order to measure how much each of these factors contributes to a unit of product, but they measure how much investments on capital and labor of each firm are efficient if compared with other firms' ones. By quoting Moretti, productivity is the

amount of output which a worker (or a machine) generates for each worked hour. To be more precise, in the present simplification they display a value included between zero and one, showing us the level of efficiency of each of these factors.

As long as concerns with capital endowment, from a theoretical viewpoint we can identify it as a proxy of savings, which evolves over time depending on the results which a firm earns on the market. In the setting up phase of the model, this variable is randomly defined and it can take values included between 500 and 1000.

Furthermore, firms' size is another important feature which allows us to differentiate firms among them: as widely acknowledged in the economic literature, we distinguish between small-sized firms, middle-sized firms and big firms and the main consequence of this differentiation is the capacity of the firm in terms of job-places. We represent this differentiation in the NetLogo interface just by applying different sizes to the firms' breed.

```
     create-firms numberOfFirms
                 [set shape "house"
                  set capitalEndowment 500 + random 500
                  set size 1.5
                  set color red
                  set productivityOfK (0 + random-float 0.5)
                  set productivityofL (0 + random-float 0.5)

                   let firmsCreated firms
                           if [productivityOfK] of firmsCreated =
      [productivityOfK] of firms with [who != [who] of firmsCreated]
                     and [productivityOfL] of firmsCreated =
      [productivityOfL] of firms with [who != [who] of firmsCreated]
[set productivityOfK (0 + random-float 0.5)
 set productivityofL (0 + random-float 0.5)]
setxy (productivityOfK * 32) (productivityOfL * 32)
set exogenousShock false]
ask n-of (0.50 * count firms) firms [set size 2.5]
              ask n-of (0.15 * count firms) firms with [size != 2.5] [set
                                                                  size 3.5]
```

Of course it is important to underline that characterizing the firms as described allows the model for a wide heterogeneity which guarantees the non-linearity of the model.

Population's features appearing during the setup are, instead, the following:

- level of skills
- employed/not employed
- personal endowment.

We represent population in the model by using different colors in order to differentiate the level of skills of each individual: we identify as low-skilled workers the agents marked by the grey color, as middle-skilled workers the agents marked by the cyan color and the high-skilled workers the agents marked with the blue color. In the initial phase of the model, population is equally distributed between these three groups.

Notice that in the present simplification population is referred to as population in working age and, therefore, each agent composing the population can potentially be employed by firms: we have therefore created the dummy variable "employed" which can take "true" or "false" values.

Personal endowment, instead, is initially defined randomly and can take value between 13 and 40. In the following phases it will depend on the typology of employment (which it depends on the skills of each worker) and on agents' consumption decisions.

```
create-population sizeOfPopulation
                      [set shape "person"
                       set size 1.5
                       setxy random-xcor random-ycor
                       set employed false
                       set personalEndowment 13 + random 27
                       set underPovertyLine false

                       set wage 0
                      set skills 0
                       set color grey
                      set rehired false]

 ask n-of (count population / 3) population
                                          [set color cyan
                                           set skills 1]
 ask n-of (count population / 3) population
                             with [color != cyan] [set color blue
                                                   set skills 2]
```

The basic assumption that the model is built on comes from the combination of two couples of situations, which can occur in the global labor market:

1. areas with low levels of technological development and low levels of employment rates;
2. areas with low levels of technological development and high levels of employment rates;
3. areas with high levels of technological development and low levels of employment rates;
4. areas with high levels of technological development and high levels of employment rates.

We reproduce this situation by building a semiotic map in the NetLogo interface: let us assume that the abscissa axis represents the productivity of capital (K) whereas the ordinate axis represents the productivity of labor (L), both representing increasing values included between zero and one. By following this line of reasoning, it is straightforward that:

- the bottom-left sided quarter represents an area with low productivity of both K and L (and firms which display this feature are marked with the red color);
- the bottom-right sided quarter represents an area with low productivity of capital and high productivity of labor (and the corresponding firms are marked with the orange color);
- the top-left sided quarter represents the opposite situation, i.e. an area with high productivity of K and low productivity of L (and the corresponding firms are marked with the yellow color);
- the top-right sided quarter represents an area with high productivity of both K and L (with the corresponding firms marked with the green color).

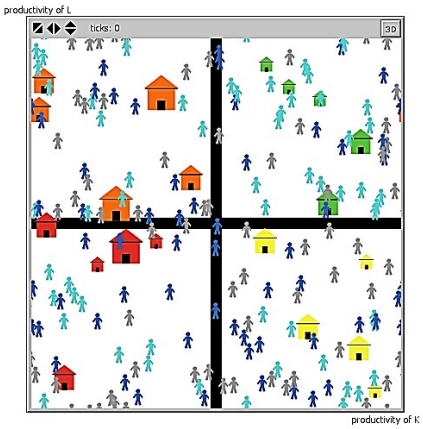

Fig 2.1: *the semiotic map tracking firms' coordinates.*

As we can easily observe, by representing the geographical space of the NetLogo interface as described, we impose some spatial constraints only upon the firms, whereas population can freely move on the display with no constraints.

It can also be useful to specify that we distribute an equal number of firms for quarter of the map and an equal number of workers for each level of skills.

After sketching the main features of the agents operating in the model, we have to make them interacting in the hiring process. In the basic version of the model we simulate a labor market where search- matching frictions yet exist and therefore it may be that a firm does not saturate all its job-places, with some workers still remaining unemployed: as previously said, the main cause of this phenomenon is the informational asymmetry present in the market, which does not allow demand and supply to know each other about the existence of the counterparty and does not allow them to meet. A further assumption is that workers are employed by firms precisely for the typology of employment guaranteed by their level of skills and therefore this kind of friction is not represented in the model.

2.1.2. The "hiring" procedure

The hiring process comes from the creation of a variable which belongs to the firms, namely the number of hirings: it represents the capacity of job-places for each firm.

```
   ask firms [if size = 1.5
   [set numberOfHirings (capitalEndowment * 0.01)
   * (1 - productivityOfL)]
                if size = 2.5
[set numberOfHirings (20 + capitalEndowment * 0.09)
* (1 - productivityOfL)]
                if size = 3.5
[set numberOfHirings (150 + capitalEndowment * 0.1)
* (1 - productivityOfL)]
              ]
```

This variable is heterogeneous since it is different for each firm in the model and it is endogenously defined since it depends on three firms' features, that are the firm's size, its capital endowment and its productivity of labor. Including productivity of labor in this process seems to be crucial

since allow us to assume that the higher this variable is, the more workers of a given firm result efficient and, therefore, the less a firm has to employee.

Assuming that small-sized firms' capacity cannot be greater than ten workers, that medium-sized firms' one cannot be greater than one- hundred workers and that big-sized firms can employ more than one-hundred workers, we define the number of hirings on the basis of the capital endowment by using different multipliers which yield the following classification:

- for small-sized firms, the number of hirings is included between five and ten, i.e. it is calculated via the formula

  capital endowment * 0.01 * (1 – productivity of L)

- for middle-sized firms, the number of hirings is included between 55 and 100, i.e. it is calculated through the formula

  10 + capital endowment * 0.09 * (1 – productivity of L)

- for big-sized firms, the number of hirings is included between 150 and 200, i.e. it is calculated through the formula

  100 + capital endowment * 0.1 * (1 – productivity of L).

  It may occur that the number of workers written in this variable so defined does not correspond precisely with the number of workers hired by each firm: we attribute this fact to search-matching frictions operating in the model, even if this occurs for technical reasons of NetLogo.

The following step is straightforward: once that the number of workers employed by each firm is given, we define how many workers for each level of skills a firm does require. In order to define this, we apply different percentages on the basis of the semiotic map that we have built in the first phase of the setting up process, assuming as a characterizing feature in defining the number of workers of each typology required by firms the combination between the productivity of labor and the productivity of capital.

Following this line of reasoning, we define that:

- firms with low productivity of capital and low productivity of labor (i.e. red firms) distribute their workers in a 50% of low-skilled workers, a 40% of middle-skilled workers and a 10% of high skilled workers since we assume that firms with such features do not display high levels of technological development

and therefore require mainly low-skilled and middle-skilled workers to start the production cycle;

- firms with low productivity of capital and high productivity of labor (i.e. orange firms) distribute their workers in a 50% of low-skilled workers, a 30% of middle-skilled workers and a 20% of high skilled workers since we assume that due to the low productivity of K (i.e. the low level of technological development) these firms still need a high quota of low-skilled workers, even if smaller than the quota required by red firms because the higher productivity of L;
- firms with high productivity of capital and low productivity of labor (i.e. yellow firms) distribute their workers in a 25% of low-skilled workers, a 15% of middle-skilled workers and a 60% of high skilled workers since we assume that due to the high productivity of capital the labor-force demand shifts from low-skilled to high-skilled workers who display competences on dealing with the increased technological level of the tools used by the firm;
- firms with high productivity of capital and high productivity of labor (i.e. green firms) distribute their workers in a 20% of low-skilled workers, a 15% of middle-skilled workers and a 65% of high skilled workers since the labor-force demand is focused on high-skilled workers endowed with the capability of dealing with the technological tools of the firm, but a quota of low-qualified workers dealing with basic tasks is still required.

Once that we identified these levels, we build the code by applying the same structure for all the different type of firms and workers: the basic idea is that, if the firms' capability of number of workers is not yet saturated, each firm employs the chosen number of workers among the ones who still are not employed, by following a random process. This means that we assume that workers do not choose the firm where they are employed, but if they are still not employed they can only accept the first offer they get.

```
ask firms with [color = green]
[if numberOfHirings < count population with [not employed and
color = grey]
[let myGreyOfGreen n-of (numberOfHirings * 0.20) population
with [not employed and color = grey]
if myGreyOfGreen != nobody
```

```
[create-links-with myGreyOfGreen
 ask myGreyOfGreen[set employed true
                   set wage 1
                   set myFirm myself
                   set xcor ([xcor] of myFirm - 2)
                   set ycor ([ycor] of myFirm - 2)]
               ]](. . .) ]
```

The technical tool that we used in order to represent the employment process is the link: therefore, when a worker is employed by a firm, we create a link between these agents.

As a further step, we assign a wage to the workers depending on their level of skills and we added wage to the features owned by population: the wage for low-skilled workers is equal to 1, middle-skilled workers' wage is 2 and high-skilled workers are paid 3. Of course, wage is summed up to the personal endowment of each individual.

From the graphical viewpoint, we represent that, once they are hired, workers are placed under their firms in the interface: in particular, low-skilled workers lie at the bottom-left side of the firm, middle-skilled ones under the firm at the center and high-skilled ones at the bottom-right side.

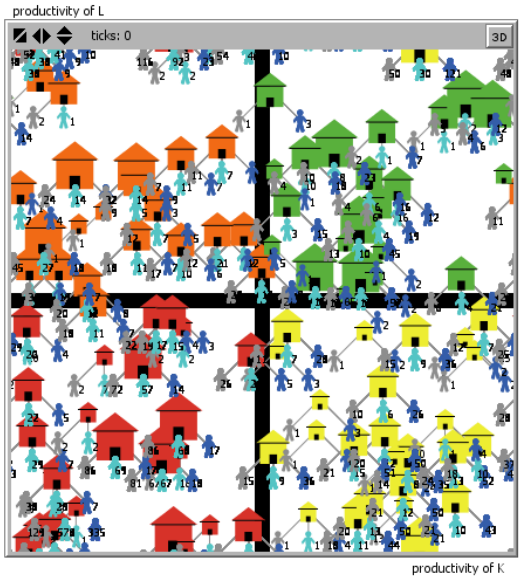

Fig. 2.2: *the output of the interface at the end of the setup process.*

At the end of this procedure, we recall that unemployed workers have a zero-wage and we set them in the bottom-left corner of the graphical interface in order to keep it tiny. Since we assume that search-matching

frictions are operating in the market, we also clear the model by eliminating firms with no employees because we assume that firms need at least one employee in order to be on the market (at least in the first phase of the model when technological shocks have not yet affected firms).

2.2. The "go" button

2.2.1. The "produce and consume" procedure

Once that world is created, we build the "go" button, which is cyclical and contains many procedures: it represents all those processes taking place in each cycle of our economy.

To be more precise, we set a main procedure recalled by the "go" button, which is the "produce & consume" procedure, and we plug other procedures in it: we do so because each of the other processes taking place in the "go" cycle affects variables operating the "produce & consume".

```
to go
  tick
  produce&consume
  if stop-ticks? [if ticks >= numberOfTicks [stop]]
  if count population = 0 or count firms = 0 [stop]
end
```

The general attitude of this procedure is describing consumption decisions of individuals and production decisions of firms. Let us go deeper into the details.

As a first step, we define the consumption function of individuals by expressing it in the terms of quantity of endowment that individuals are willing to pay to get the quantity they decide to consume. Since for each level of skills we define a type of employment and a corresponding wage, we assume that individuals make their consumption decisions according to the budget constraint defined by wages and, therefore, quantities they decide to consume vary on this basis. Furthermore, for each level of income they perceive, we set the level of wage as a fixed quota of minimum consumption, letting the other part of the consumption up to the individual choices of the agents: this ensures the non-linearity and, therefore, the heterogeneity of individuals' behaviors. In particular, we ask that the part of consumption that each individual choices to consume is

distributed as a random normal with a known mean and a variance equal to the half of the mean.

Since summing up the minimum consumption with the individual consumption decided by the individual individual's total consumption is higher than his (or her) wage, by running the model we will observe that first cycles are characterized by decreasing levels of individuals' endowments. This strong assumption is built in order to ensure non-zero profits for firms, since we would represent a perfect competition otherwise and, of course, it is not the case we are willing to represent. As a consequence of this fact, it may occur that an individual ends up under the poverty line when his or her consumptions erode all the personal endowment.

```
ask population [ifelse not employed
[set myConsumption myBenefit + random-normal 0.6 0.3]
[set myConsumption wage + random-normal 0.6 0.3]
ifelse employed
[set yearIncome (wage -myConsumption)
set personalEndowment (personalEndowment + yearIncome)]
[set yearIncome (myBenefit – myConsumption)
set personalEndowment (personalEndowment + yearIncome)
if personalEndowment < 0 [set underPovertyLine true]
   ]
```

As a following step, we define the production decisions of the firms, choosing minimum quantity that each firm produces depending on its size and defining the remaining part according to a random normal distribution. In particular, we set values as follows:

- small firms' minimum production quantity is 80, whereas the remaining part is given by a random normal with mean 20 and variance 10;
- middle-sized firms' minimum production quantity is 140, whereas the remaining part is given by a random normal with mean 40 and variance 20;
- small firms' minimum production quantity is 300, whereas the remaining part is given by a random normal with mean 100 and variance 50.

We also define the element entering the cost function of firms:

- cost of labor, defined as the product between number of workers and corresponding wages (of course, depending on

type of employment, which is assumed to depend on the level of skills);

- fixed costs, proportional to the productivity of capital (clearly we assume that the higher productivity of capital is, higher is the cost that a firm will bear to maintain its machinery);
- a contribution for unemployment benefits, which represents a kind of taxation and a first raw element of welfare subside for unemployed individuals (actually, this element exists only if the switch of the unemployment benefit that we are going to discuss below is on).

```
ask firms [if size = 1.5 [set myProduction 80 + random-normal
20 10]
          if size = 2.5 [set myProduction 140 + random-normal
40 20]
          if size = 3.5 [set myProduction 300 + random-normal
100 50]
         set fixedCosts (productivityOfK * 10)
         let myEmployee population with [myFirm = myself]
         set costOfLabor sum [wage] of myEmployee]
```

What should be noticed is that, differently from individuals' consumption's functions, quantities produced are expressed in terms of units of goods: this ensure a price formation mechanism changing at any cycle and coming from the ratio between total consumption of individuals with total production of firms, where, of course, the former represents the aggregate demand function, whereas the latter is the aggregate supply.

Furthermore, prices give back both to firms and individuals process with memory. In fact, agents modify quantities they demand and supply by comparing prices in the two previous cycles: in particular, if the prices trend is increasing, firms will produce higher quantities whereas consumers will demand lower quantities of goods, otherwise, with decreasing prices the opposite will occur.

```
set priceT-2 priceT-1
set priceT-1 price
if priceT-2 != 0 [ask firms [if priceT-1 > priceT-2 [set
myProduction (myProduction + myProduction * random-normal 0.1
0.2)]

 if priceT-1 < priceT-2
```

```
[set myProduction (myProduction - myProduction * random-
normal 0.1 0.2)]]

ask population [if priceT-1 > priceT-2
[set myConsumption
(myConsumption - myConsumption * random-normal 0.1 0.2)]
if priceT-1 < priceT-2
[set myConsumption
(myConsumption + myConsumption * random-normal 0.1 0.2)]
 ]]
 set TotalProduction sum [myProduction] of firms
 if count population != 0  and count firms != 0
[set price (TotalConsumption / TotalProduction)]
```

In order to complete the cycle, we define firms' profits in the terms of difference between revenues (given by the product between quantity produced and prices) and costs and we ask firms whose capital endowments go to zero to quit the model.

```
ask firms
[set profits (myProduction * price)
      - costOfLabor - fixedCosts – contributionForBenefit

set capitalEndowment (capitalEndowment + profits)
if capitalEndowment <= 0 [ask my-links [die]
                          die]]
```

The last lines of this procedure are devoted to the "unemployment benefit" switch. This sets a benefit assigned to all unemployed individuals and whose value is fixed at 0.6 (i.e. 60% of the minimum wage).

Since in the model we do not create an extra breed of agents representing public institutions, also public intervention passes through the interaction between firms and individuals: in fact, even if still not sufficient to guarantee that no individual ends up under the poverty line, this mechanism seems to be a first track of a welfare policy, which will be implemented in a more exhaustive way by introducing a universal basic income.

Technically speaking, the size of the withdrawal imposed to each firm is determined by summing up the benefits required by all the unemployed individuals divided by the number of the firms operating in the market.

The contribution for benefit is subtracted to the profits of each firm and therefore it lowers them.

```
if unemploymentBenefit?
[ask population with [not employed] [set myBenefit 0.6]
(. . .)
ask firms
[set contributionForBenefit (sum[myBenefit] of population /
count firms)]
]
```

2.2.2. The "firing" procedure

As mentioned before, we nest other three procedures in the "produce & consume" one since they directly affect variables operating in this cycle: two of these procedures are related to adjustments taking place in the labor market - namely the firing process and the rehiring one -, whereas the last one describes an exogenous technological shock hitting the economy.

The first one is the "fire" procedure, through which we set the decision rule driving firms' choices in applying structural reorganizations.

The line of reasoning we apply while building this procedure is the following: firms attaining negative profits or firms whose capital endowment is very low (i.e. lower than 150) will fire some of their employees in order to cut part of the costs they have to bear (and of course costs of labor are the highest ones in the firms' cost functions). Productivity of labor enters this process since it determines the number of workers that a firm decides to fire: in fact, firms with high productivityOfK labor (i.e. greater than 0.5) is more reluctant to fire their workers due to the high added value that each worker gives as a contribution to the productive process; conversely, firms with low productivity of labor fire their workers more.

Productivity of capital instead affects the type of employment that a firm is more reluctant to cut: in particular, firms with high productivity of capital will cut the cost of labor firing some of the middle-skilled and low-skilled workers, since we assume that a job polarization process occurs due to productive processes mechanization; whereas we exclude firings on high-qualified workers due to the high level of added value they have, and of course also due to the training costs that a firm has to bear in order to prepare them for the tasks they have to accomplish. As long as concerns with firms with low productivity of capital, we assume them firing lower

number of middle-skilled and low-skilled workers since they still need them due to the lower level of mechanization of their processes, but they may cut some of the high-skilled workers since they need to make structural reorganization.

Given this setting, we define the number of workers fired in the terms of percentages computed on the total number of workers employed by firms, as follows:

- firms with low productivity of L fire 20% of their low-skilled and 20% of their middle-skilled workers if they display a high productivity of K, or 10% of middle-skilled or low-skilled workers and 10% of high skilled workers if they display a low productivity of K;

```
ask firms with [productivityOfL < 0.5]
[if profits < 0 or capitalEndowment < 150
             [ifelse productivityOfK > 0.5
[ask n-of (0.2 * count my-links with [[color] of end1 = grey
or [color] of end2 = grey]) my-links with [[color] of end1 =
grey or [color] of end2 = grey] [die]

ask n-of (0.2 * count my-links with [[color] of end1 = cyan
or [color] of end2 = cyan]) my-links with [[color] of end1 =
cyan or [color] of end2 = cyan] [die]
   ]

[ask n-of (0.1 * count my-links with [[color] of end1 = cyan
or [color] of end2 = cyan or [color] of end1 = grey or
[color] of end2 = grey]) my-links with [[color] of end1 =
cyan or [color] of end2 = cyan or [color] of end1 = grey or
[color] of end2 = grey] [die]

ask n-of (0.1 * count my-links with [[color] of end1 = blue
or [color] of end2 = blue]) my-links with [[color] of end1 =
blue or [color] of end2 = blue] [die]
   ]]]
```

- firms with high productivity of L fire 10% of their low-skilled and 10% of their middle-skilled workers if they display a high productivity of K, or 5% of middle-skilled or low-skilled workers and 10% of high skilled workers if they display a low productivity of K.

```
ask firms with [productivityOfL > 0.5]
```

```
[if profits < 0 or capitalEndowment < 150

            [ifelse productivityOfK > 0.5

[ask n-of (0.1 * count my-links with [[color] of end1 = grey
or [color] of end2 = grey]) my-links with [[color] of end1 =
grey or [color] of end2 = grey] [die]

ask n-of (0.1 * count my-links with [[color] of end1 = cyan
or [color] of end2 = cyan]) my-links with [[color] of end1 =
cyan or [color] of end2 = cyan] [die]
   ]

[ask n-of (0.05 * count my-links with [[color] of end1 = cyan
or [color] of end2 = cyan or [color] of end1 = grey or
[color] of end2 = grey]) my-links with [[color] of end1 =
cyan or [color] of end2 = cyan or [color] of end1 = grey or
[color] of end2 = grey] [die]

ask n-of (0.05 * count my-links with [[color] of end1 = blue
or [color] of end2 = blue]) my-links with [[color] of end1 =
blue or [color] of end2 = blue] [die]
   ]]]
```

2.2.3. The “rehiring” procedure

The second procedure nested in the “produce & consume” is the rehiring process, which follows a specular line of reasoning with respect to the previous one: in fact, firms performing good results on the market may decide to invest in new employees in order to expand themselves. We set that, in order to increment the number of employees by hiring new workers, firms have to achieve a level of profit higher than the average profits of all the firms in the model or a level of capital endowment higher than 150% of the average capital endowment of all the firms.

The rehiring mechanism follows the same decision rule set for the firing process: therefore, productivity of labor enters the procedure by defining how many workers to employee (and of course, as productivity of labor increases, this number will be lower and vice versa); whereas productivity of capital gives some hints about the typologies of employments that a firm may require: as yet mentioned, capital intensive firms prefer high-skilled workers due to the knowledge they may bring in the firms, whereas firms displaying a lower productivity of capital invest on workers accomplishing basic tasks because they do not employ machineries substituting for human labor.

In particular, we define that, satisfied the other conditions:

- each firm with high productivity of labor hires a high-skilled worker if they display a high productivity of K, or a middle-skilled or low-skilled worker if they display low productivity of K;
- each firm with high productivity of labor hires two high-skilled workers if they display a high productivity of K, or one middle-skilled and low-skilled worker if they display low productivity of K.

```
ask firms with [(profits > mean[profits] of firms) or
(capitalEndowment > 1.5 * mean[capitalEndowment] of firms]
[ifelse productivityOfL > 0.5

[if productivityOfK > 0.5
[let myNewEmployed n-of (1) population with [not employed
and skills = 2]

if myNewEmployed != nobody
 [create-links-with myNewEmployed
  ask myNewEmployed [set employed true
                     set wage 3
                       set myFirm myself
                       set xcor ([xcor] of myFirm - 2)
                set ycor ([ycor] of myFirm - 2)
                       set rehired true
                        ]]
```

2.2.4. The “technology shock” procedure

The third procedure nested in “produce & consume” describes the technological shock hitting the economy and, technically speaking, it differs by the other ones since it is recalled in two different parts of the code, depending on the value assumed by the global dummy variable representing firms’ choices in order to react to the technological shock: this global dummy variable is built through a chooser in the interface, and it may assume “fire” or “implement production” as values.

```
If reactionToShock = "fire" [technologyShock]
(. . .)
  if reactionToShock = "implementProduction" [technologyShock]
```

First of all, the “technology shock” procedure does not occur at any cycle, but only after that a certain number of ticks has yet been run: we fix this number through a slider in the interface and we arbitrarily set that this number must be bounded between 10 and 30. This returns us a sufficient number of observations such that we can analyze trends characterizing the model before and after the shock.

Let us now make a step back in the setup procedure, where we define the probability that a firm is affected by the technological shock, which is meant to be an exogenous shock. This local variable is defined in the setup - and to be more precise in the “create world” phase - since it is a feature owned by the firms that does not vary over time by running cycles, but we want it to be constant because it measures firms’ attitude in being adaptive to the shock.

```
ask firms
[ifelse productivityOfK < 0.5
   [set probabilityOfShock 0 + random-float 0.5]
   [set probabilityOfShock 0 + random-float 1]
          ]
```

This parameter may take values between zero and one and is different for firms with low or high productivity of capital: in fact, we assume that firms with high productivity of capital display a higher attitude in catching the effects of a technological shock and exploiting them by plugging them in their productive process rather than low productivity of capital firms. Then, we create a slider representing the pervasiveness of the shock hitting firms in the interface and we define that this parameter, which is bounded between zero and one, is a threshold to be exceeded in order to benefit from the shock. By reasoning according to this line, we define that probability of shock has to be higher than the complement of this parameter: this means that if pervasiveness of the shock is equal to one, technological shock will affect all the firms in the model since all firms display a probability of shock greater than zero, whereas if pervasiveness is equal to zero none of the firms will benefit from the shock.

```
if ticks > ShockWhen? [ask firms
     [if probabilityOfShock > (1 - pervasivenessOfShock)
      and not exogenousShock
                            [set exogenousShock true]]
```

Furthermore, we create another slider defining the size of the shock: it represents the intensity at which firms' productive processes are modified by the shock. In particular, we have that size of shock gives us a measure of the increment in productivity of capital hit by the shock (and this of course enlarges fixed costs by changing a parameter involved in the "produce and consume" procedure).

Now things get a bit more complicated: in fact, we introduce two different scenarios by creating the global dummy variable representing how firms may react to the shock. In order to simplify the model, we define that all the firms choose the same reaction strategy and, therefore, they all behave the same when the exogenous technological shock hit them. Firms may decide to exploit the technological shock either by implementing the production or by firing workers.

In the first scenario, since the exogenous shock opens the door to an increment in the productivity of capital, firms decide to exploit this increment in order to implement their production by the measure of the size of the shock. Therefore, we plug this procedure in the "produce &consume" cycle just after defining the quantities of production chosen by firms: by doing so, firms immediately adapt production's decisions on the basis of the implementation choice and this modifies the structure of the following events.

The second scenario, instead, implies that firms' choice is to keep production's levels fixed and exploiting technological development in order to get rid of part of costs of labor, which represent the heaviest items in firms' cost functions.

Again the size of shock gives us a hint about how much drastic will be the cut of the number of employees, but we assume that firms also take in account levels of skills of workers who they are going to fire: in fact, it makes sense to assume that a technological shock leads to a massive firing of middle-skilled workers and low-skilled ones, whereas it is reasonable to imagine that firms may be interested in preserving some of the high-qualified workers. According to this line of reasoning, we use the size of shock as a multiplier and define that low-skilled workers are fired in a proportion given by (size of shock * 0.8); middle-skilled workers are fired in a proportion given by (size of shock * 0.9); low-skilled workers are fired in a proportion given by (size of shock * 0.4).

```
   if ticks = ShockWhen?
[ask firms with [exogenousShock]
```

```
      [set productivityOfK productivityOfK + sizeOfShock]
                  ]

          if ticks > ShockWhen?
         [ask firms with [exogenousShock]
          [if reactionToShock= "implementProduction"

          [set myProduction myProduction * (1 + sizeOfShock * 100)]

         if reactionToShock= "fire"
[ask n-of (sizeOfShock * 0.8 * count my-links with [[color] of
          end1 = grey or [color] of end2 = grey] my-links with [[color]
          of end1 = grey or [color] of end2 = grey] [die]

ask n-of (sizeOfShock * 0.9 * count my-links with [[color] of
end1= cyan or [color] of end2 = cyan]) my-links with [[color]of
end1 = cyan or [color] of end2 = cyan] [die]

ask n-of (sizeOfShock * 0.4 * count my-links with [[color] of
end1 = blue or [color] of end2 = blue]) my-links with [[color]
of end1 = blue or [color] of end2 = blue] [die]
(. . .)
           ]
]
]
```

2.2.5. The "basic income" switch

Once that all the scenario is set, we can finally introduce a basic income hypothesis. Clearly, from the temporal perspective, we cannot introduce basic income before observing the technological shock since we assume it to be a welfare policy that may be proposed as a reaction to the increasing unemployment led by a sudden technological growth: this is the reason why we directly plug this command into the "technology shock" procedure, by completing other adjustments with some lines of code in the "produce & consume" cycle.

Furthermore, we set the model in order to get a delay between the moment when the technology shock takes place and the moment when basic income is introduced, and we arbitrarily fix this delay in five cycles: in this way, we can observe some of the trends occurring in the meanwhile.

As long as concerns with the use of the switch, this tool turns out to be very proper since it allows us to perform some tests in order to check how the outcome changes as the scenario changes.

The basic idea beyond this hypothesis is that, since the exogenous shock is led by a rapid technological growth replacing workers with machineries, automatization ejects workers from productive processes by determining a structural reduction in the demand for labor. At the same time, this phenomenon allows firms to keep constant production's levels while reducing significantly costs of labor and, therefore, enlarging profits. Clearly, a significant problem may arise: it is reasonable to assume that if a large portion in the population suddenly becomes unemployed, average consumption will drop. The idea of basic income is to take part of firms' surplus off and divide it among all the individuals in the model.

```
if ticks > (ShockWhen? + 5) [if basic-income?
[ask population [set myBasicIncome LevelOfBasicIncome]
(. . .)
]
```

Here a politically relevant choice has to be done: how to divide the contribution that each single firm should give in order to finance this welfare policy? We introduce some different scenarios aiming at comparing them and observing which different outcomes they drive to. We build hypotheses on four different principles and the preferred one can be selected via a slider in the interface:

- a taxation equally divided among all the firms;
- a taxation based on the amount of profits gained by each firm;
- a "robot tax" based on the productivity of capital (i.e. the higher the productivity of capital of a given firm is, the higher is the taxation it will bear);
- a taxation based on stimulating firms in investing even more in technologies, with higher contributions for firms displaying lower productivities of capital (of course, it is the opposite idea of the "robot tax").

```
if contributionForBasicIncome = "equalForAllFirms"

[ask firms [set taxForIncome (sum[myBasicIncome] of
population / count firms)
```

```
    set profits (profits - taxForIncome)]
    ]

    if contributionForBasicIncome = "robotTax"

    [ask firms [set taxForIncome sum[myBasicIncome] of population
    * (productivityOfK / sum[productivityOfK] of firms)
    set profits (profits - taxForIncome)]
    ]

    if contributionForBasicIncome = "incentiveToInnovation"  [ask
    firms [set taxForIncome sum[myBasicIncome] of population *
    ((1  - productivityOfK) / sum[productivityOfK] of firms)
    set profits (profits - taxForIncome)]
     ]

    if contributionForBasicIncome = "profitBased"
    [ask firms [set taxForIncome sum[myBasicIncome] of population
    * (profits / sum[profits] of firms)
    set profits (profits - taxForIncome)]
     ]
```

Since one of the reasons why introducing a basic income may turn out to be an efficient choice is that it would avoid a collapse in the consumption levels, we also introduce an adjustment mechanism while defining individuals' consumption functions by plugging it into the "produce and consume" procedure in order to make these adjustments effective within choices defined in this cycle.

```
if ticks > (ShockWhen? + 5) and reactionToShock = "fire"
         [if basic-income?

         [set myConsumption
            (myBasicIncome + wage - random-normal 0.3 0.15)

        if mean[myBasicIncome] of population > mean[profits] of firms
         [set myConsumption myConsumption + random-normal 0.3 0.15]

         set yearIncome (myBasicIncome + wage – myConsumption)
          set personalEndowment (personalEndowment + yearIncome)
         ]
          ]
```

3. RESULTS

3.1. A methodological remark

Before to go into the analysis of the results produced through our model, we would like to recall some of the theoretical reasons beyond the methodical choice of resorting to Agent-Based Modeling (ABM), which drove us through this whole work. In order to do so, we borrow some of the Epstein's words ("Why model?", 2008):

> The first question that arises frequently - sometimes innocently and sometimes not - is simply, "Why model?" Imagining a rhetorical (non-innocent) inquisitor, my favorite retort is, "You *are* a modeler." Anyone who ventures a projection, or imagines how a social dynamic - an epidemic, war, or migration - would unfold is running *some* model.
>
> But typically, it is an *implicit* model in which the assumptions are hidden, their internal consistency is untested, their logical consequences are unknown, and their relation to data is unknown. But, when you close your eyes and imagine an epidemic spreading, or any other social dynamic, you are running *some* model or other. It is just an implicit model that you haven't written down (see Epstein 2007).
>
> This being the case, I am always amused when these same people challenge me with the question, "Can you validate your model?" The appropriate retort, of course, is, "Can you validate yours?" At least I can write mine down so that it can, in principle, be calibrated to data, if that is what you mean by "validate," a term I assiduously avoid (good Popperian that I am).
>
> The choice, then, is not whether to build models; it's whether to build *explicit* ones. In *explicit* models, assumptions are laid out in detail, so we can study exactly what they entail. On these assumptions, *this* sort of thing happens. When you alter the assumptions *that* is what happens. By writing explicit models, you let others replicate your results.
>
> You *can* in fact calibrate to historical cases if there are data, and can test against current data to the extent that exists. And, importantly, you can incorporate the best domain (e.g., biomedical, ethnographic) expertise in a rigorous way. Indeed, models can be the focal points of teams involving experts from many disciplines.
>
> Another advantage of explicit models is the feasibility of sensitivity analysis. One can sweep a huge range of parameters over a vast range of possible scenarios to identify the most salient uncertainties, regions of robustness, and important thresholds. I don't see how to do that with an

implicit mental model. It is important to note that in the policy sphere (if not in particle physics) models do *not* obviate the need for judgment. However, by revealing tradeoffs, uncertainties, and sensitivities, models can *discipline the dialogue* about options and make unavoidable judgments more considered.

No sooner are these points granted than the next question inevitably arises: "But can you predict?" For some reason, the moment you posit a model, prediction - as in a crystal ball that can tell the future - is reflexively presumed to be your goal. Of course, prediction might be a goal, and it might well be feasible, particularly if one admits statistical prediction in which stationary distributions (of wealth or epidemic sizes, for instance) are the regularities of interest. I'm sure that before Newton, people would have said "the orbits of the planets will never be predicted." I don't see how macroscopic prediction - *pacem* Heisenberg - can be definitively and eternally precluded.

But, more to the point, I can quickly think of *16 reasons other than prediction* (at least in this bald sense) to build a model. In the space afforded, I cannot discuss all of these, and some have been treated *en passant* above. But, off the top of my head, and in no particular order, such modeling goals include:

1. Explain (very distinct from predict)
2. Guide data collection
3. Illuminate core dynamics
4. Suggest dynamical analogies
5. Discover new questions
6. Promote a scientific habit of mind
7. Bound (bracket) outcomes to plausible ranges
8. Illuminate core uncertainties.
9. Offer crisis options in near-real time
10. Demonstrate tradeoffs / suggest efficiencies
11. Challenge the robustness of prevailing theory through perturbations
12. Expose prevailing wisdom as incompatible with available data
13. Train practitioners
14. Discipline the policy dialogue
15. Educate the general public
16. Reveal the apparently simple (complex) to be complex (simple)

[…]

> To me, however, the most important contribution of the modeling enterprise - as distinct from any particular model, or modeling technique - is that it enforces a scientific habit of mind, which I would characterize as one of *militant ignorance* - an iron commitment to "I don't know." That is, all scientific knowledge is uncertain, contingent, subject to revision, and falsifiable in principle. (This, of course, does not mean readily falsified. It means that one can in principle specify observations that, if made, would falsify it). One does not base beliefs on authority, but ultimately on evidence. This, of course, is a very dangerous idea. It levels the playing field, and permits the lowliest peasant to challenge the most exalted ruler - obviously an intolerable risk.
>
> This is why science, *as a mode of inquiry*, is fundamentally antithetical to all monolithic intellectual systems. In a beautiful essay, Feynman (1999) talks about the hard-won "freedom to doubt." It was born of a long and brutal struggle, and is essential to a functioning democracy. Intellectuals have a solemn duty to doubt, and to teach doubt. Education, in its truest sense, is not about "a saleable skill set." It's about freedom, from inherited prejudice and argument by authority. This is the deepest contribution of the modeling enterprise. It enforces habits of mind essential to freedom.

Of course, the basic idea beyond our model is to provide explanations about how demand and supply match in the labor market conditional to structural changes driven by technological development: by writing a model, as Epstein suggests, we explicit the assumptions that the model is built on and we guide and promote data collection through this fact.

Dealing with complexity also allows us to enlarge our focus and to observe the ecology we create under different standing point, by looking at the emergent economic system as a whole. Furthermore, this help us illuminate core dynamics and core uncertainties by including some features that, even being not the core of our analysis, turn out to be crucial in highlighting long-run trends generated by the initial conditions we assume and, vice versa, by resizing the role of variables that turn out to be irrelevant.

Another important feature of ABM is that it makes us able to bound outcomes to plausible ranges: this becomes possible through the calibration of the model, which allows us to identify robustness' regions where our results are consistent. In this way, we can also challenge the robustness of prevailing theory through perturbations and expose prevailing wisdom as incompatible with available data.

Of course, once that consistency of our model has been verified – and it has through calibration -, we use it in order to show tradeoffs and suggest efficiencies, to suggest dynamical analogies, to discover new questions, to offer crisis options in near-real time and, last but not least, to discipline the policy dialogue -of course, we do so by analyzing a basic income proposal as a welfare tool that may be implemented: we expose these emerging results in the next section of this work.

Once that we went deeper in the reasons why to model, let us introduce the last methodological remarks, which concern with choices in presenting results observed from the model.

The line of reasoning which we move along is to expose results coming from the basic model as a first step, and then to add the elements of complexity characterizing it step by step. The reason why of this choice is that we want to observe how interaction among agents evolve by introducing new elements: this allows us to classify scenarios from the simplest one to the most complex ones, which involve policy-making decisions.

3.2. The starting point of our analysis

As a very first step, we look at the starting situation generated by running the setup button, which identifies the initial conditions that the model is built on. In order to ensure that all experiments are run under the same conditions, we fix a seed guaranteeing that all random variables are equal while running different tries.

Let us show first results emerging by setting up the model: clearly many of the variable involved in the model do not show significant results since they do not affect the setup phase but enter only the “go” phase of the model. Therefore, now we only look at the initial situation, when world is just created.

Let us still recall some of the parametrization choices made up while writing the model: population is divided on the basis of their level of skills in three groups of equal size and the same holds for the four types of firms. We define a size population of 5000 agents and a number of firms of 100 as optimal in order to run our model. Clearly this choice is arbitrary and it seems to be up to the user: outcomes of the experiments run change by changing these two parameters via the sliders in the interface.

By running the setup button of the model, we can observe how employment choices of firms are taken and their first consequences.

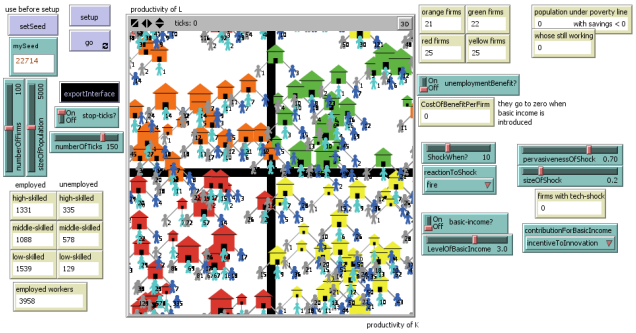

Fig. 3.1: *graphic interface after the "setup" procedure.*

Fig. 3.1. shows the top side of the graphical interface of our model: we can observe the space where agents interact and its structure displaying how many workers (and, of course, which ones) are employed by each firm. Graphs reporting trends are at the bottom side of the interface, which does not appear in the figure since not meaningful during the setup phase.

Let us focus on analyzing first results returned by the setting up procedure: we can observe a global unemployment rate of 20.84%, which means that firms absorb 3958 workers over the all 5000 in the market. This data can be decomposed by looking at the number of workers employed per typology of skills: so, we can observe that 1331 high-skilled workers over 1666 are employed (which corresponds to 79.89%); 1088 over 1666 are employed among the middle-skilled workers (corresponding only to 65.31%) and 1539 low-skilled workers over 1667 are absorbed by firms (corresponding to 92.32% of available workforce).

What we can sketch up now is a labor market yet polarized, which deeply reckons on low-skilled workers and, even if in a smaller size, on high-skilled workers. From the very starting phases of the model, middle-skilled workers seem to be partially ejected from the market and experimenting unemployment as a condition.

The second element which can be observed during this phase is the composition of labor-force divided by typology of firms.

Nevertheless, before doing so it may be proper to highlight that firms with high productivity of labor (green ones and orange ones) are the ones suffering more from informational symmetries on the labor market. In fact, there are three green firms and four orange ones disappearing from the market due to no hiring.

In fact, by focusing on the composition of labor-force divided by typology of firms we record that the ratio of employment between firms displaying a low productivity of labor and firms displaying a high productivity of labor is 2:1: in particular, green firms employ 500 workers; orange firms employ 590 individuals; yellow firms employ 1186 workers and red ones 1682.

We do not recall again how many workers of each level of skills are employed by each typology of firms since this distribution follows percentages defined through the code described before and the economic meaning of this distribution should appear clear.

The last data we would like to record in the analysis of the setting up phase is that average saving (or average personal endowment) of individuals is 26.09: since this value is randomly defined and workers have not still perceived their first salary, it is not meaningful now to make further analysis by decomposing this value per class of workers.

3.3. The impact of a technological shock: a general framework

As we mentioned, the line of reasoning we are moving along is to expose scenarios yielded by our model starting from the simplest one to the most complex ones.

As a first complexity element, we introduce an unemployment benefit as a first kind of welfare intervention. Since public institutions do not exist in the model, contribution for unemployment benefits are directly withdrawn by taxing firms' profits, and contributions for unemployment benefits are equally divided among all the firms operating in the market. We introduce it from the very beginning (i.e. at the first cycle of the model) since it is reasonable to assume that a basic tool of welfare is provided in order to guarantee adequate living standards to unemployed population, a fortiori given a high initial unemployment rate as in the present case.

The basic aim beyond present section is to investigate the impact of a technological exogenous shock hitting our ecology by considering the two different scenarios yielded by firms' reaction choices to the shock.

Of course, now we could perform many experiments based on different hypotheses about the time when the technological shock occurs, its entity and its pervasiveness with respect to the firms operating in the model, and of course we can set each of these variables through the sliders lying in the interface: since a huge number of experiments could be run by combining

these parameters in different ways, we suggest a set of calibrations highlighting the most interesting results.

i) As a first step, we arbitrarily identify a technological shock affecting our system after ten cycles and we keep this value constant while running each experiment. Let us add some further considerations about these choices: the idea of running the model for ten cycles before introducing the shock allows us to get a sufficient number of observations in order to make comparisons between the scenarios before and after the shock;

ii) the idea of keeping this value constant while running many experiments (where, of course, other variables change) allows us to build consistent comparisons when we check how outcomes change.

3.3.1. The impact of a technological shock: what if scarcity disappeared?

Let us now introduce a first scenario, where firms' reaction choice of responding at the technological shock is the decision of implementing production. In this case, we propose a calibration that pushes the model at its extreme consequences by setting the maximum value available (which is fixed at 1) both for the pervasiveness of the shock and for its size.

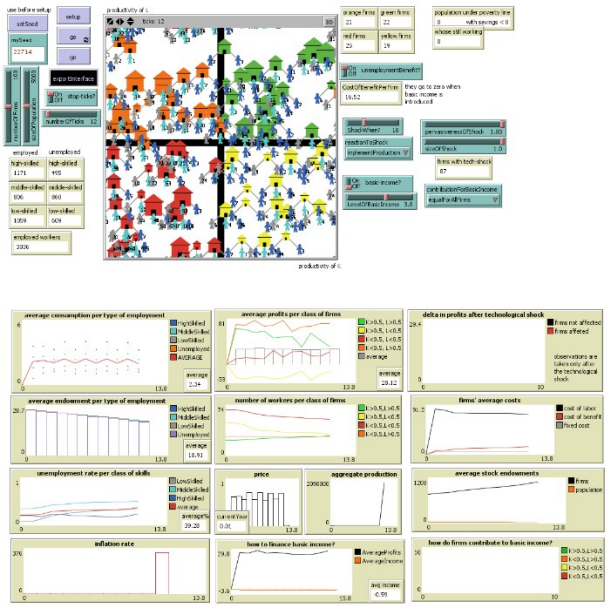

Fig. 3.2.: *the graphic interface while running the "firms-implementing-production" scenario.*

The basic idea we want to show is that if all firms are affected by a huge technological shock and their reaction decision is to increment production levels, since price formation mechanism occurs by comparing individuals' consumption functions - i.e. demand for goods, which does not vary - with firms' production functions- i.e. supply for goods, which increments by a very large size - prices level tends to zero.

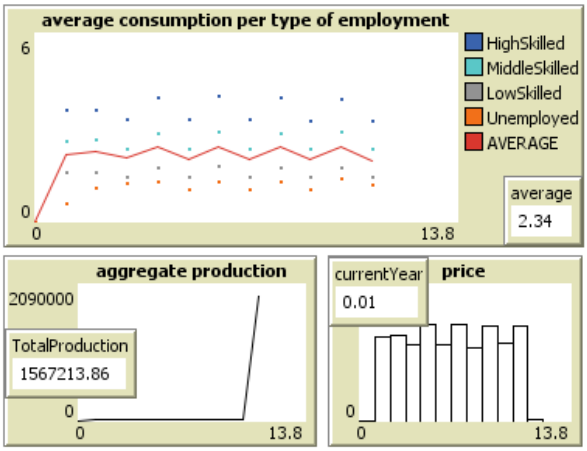

Fig. 3.3.: *details of price formation mechanism.*

The economical meaning beyond this result is that, given a price formation mechanism as the one just recalled characterizing our model, a significant boost in production levels turns out to reveal that prices become meaningless and, therefore, determines a failure in the market economy.

Clearly, this idea comes down from an exasperation of our model. Nevertheless, the theoretical framework we aim to recall here is that economics is often referred to as the science which studies human behavior as a relationship between ends and scarce means which have alternative uses (Robbins, "An Essay on the Nature and Significance of Economic Science", 1932), and, by introducing our hypothesis, we would like to launch a provocation about which could be the perspectives of market economies by removing the idea of scarcity itself.

By following this line of reasoning - which, of course, may sound to be a bit crazy - other results turn out to be irrelevant since both profits and income levels become meaningless: in fact, the scenario represented shows that individuals can catch goods in the market for free. This is the reason why we stop the model running after the eleventh observation: in fact, by

exasperating parameters of our model, consequences of this huge shock upset our ecology with an immediate effect.

3.3.2. The impact of technological shock: when technological unemployment becomes real

Let us now introduce an alternative scenario, where firms choose to react to the technological exogenous shock by keeping constant their production levels: of course, in the case they make this decision, they will not need any more for all that labor-force and, therefore, they will fire part of their employees. By doing so, the unemployment rate will dramatically increase whereas firms' cost functions will suddenly decrease.

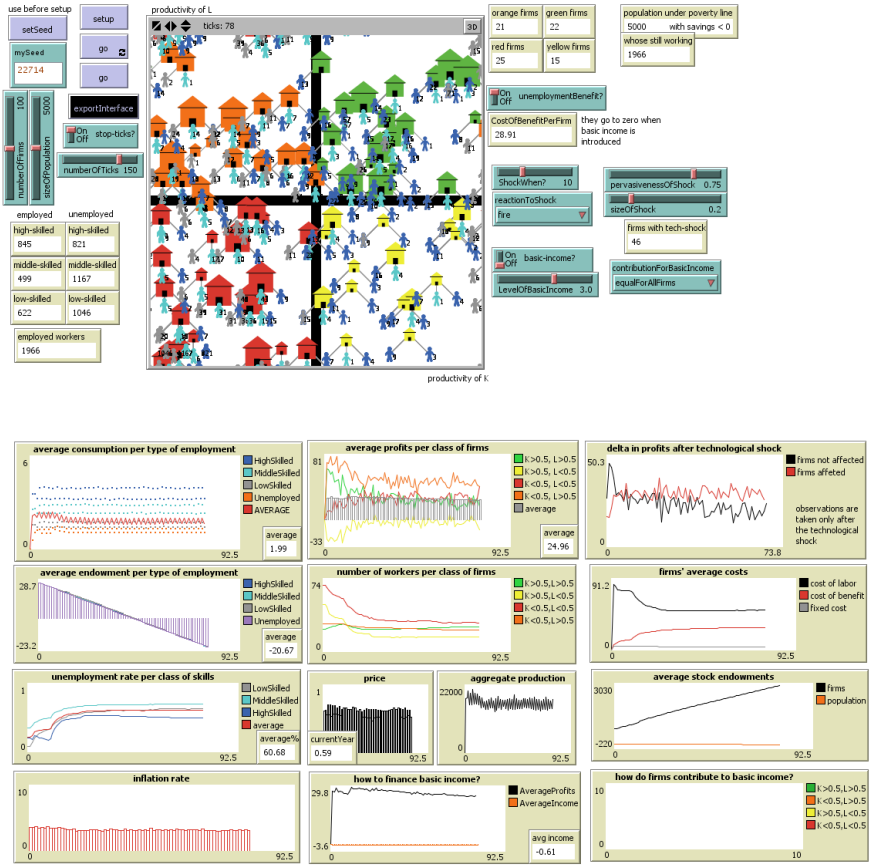

Fig. 3.4.: *the graphic interface while running the "firms-firing-workers" scenario*

As long as concerns with the calibration of the model in this step, we set the pervasiveness of the shock at 0.75, meaning that three firms displaying high productivity of capital over four and half of the firms displaying low

productivity of capital are on average affected by the technological shock. This implies that the shock observed is sufficiently deep to modify the structure of our economic system. Vice versa, an isolated shock hitting only a small portion of the market would affect only choices – and, therefore, results - performed by a limited number of firms without influencing the global outcome of the model.

As long as regards the size of the shock, we notice that even setting different values for the measure of this parameter does not affect the robustness of the outcome recorded. In fact, the increased unemployment rate, combined with the fact that individuals' consumption functions allow for expenditures higher than the in-flows that they gain, always drives to the same creepy scenario: all the individuals in the model end up under the poverty line within less than eighty cycles.

Setting different level for the size of the shock only affects values of parameters that we measure, but the global outcome does not change. Therefore, in the following experiments, we will assume a 0.2 size of shock, which means that productivity of firms is incremented by 20%.

By introducing the "firms-firing-workers" scenario, such an increment in firms' productivity translates into a significant reduction in their cost functions due to the raise in firing (cost of labor is in fact the most relevant liability in firms' balance-sheets). In fact, as Fig. 3.5 (below) shows, we can observe a sudden increase in the unemployment rate, which from 34.24%reaches a peak of 60.68% unemployment rate when the model stops.

We can easily observe how the increment in unemployment rate results both into the cost of labor function of firms (with the inverse relationship that we have just mentioned above) and into the cost of unemployment benefit function of firms (which enlarges as the unemployment rate does since firms have to bear the cost of financing this welfare tool). By observing the pictures in Fig. 3.5, we can also easily notice how the two cost functions seem to be specular each to the other and tend to very close values in the long-run, meaning that as the unemployment rate becomes stable they both do so.

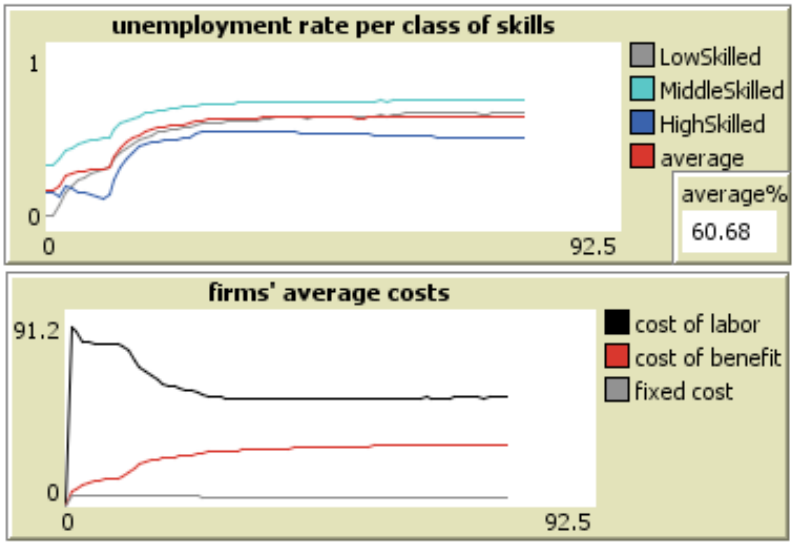

Fig. 3.5.: *the sudden increase in unemployment rates after the technological shock and the consequences on firms' cost functions.*

Let us go further into the analysis of unemployment rate. In particular, by observing Fig 3.6. (below), which depicts the number of workers per class of firms, we can observe all firms experiencing a drastic reduction in number of employees, with a higher incidence in firms displaying a low productivity of labor: this can be explained since these ones get less incentive in withdrawing their workers because they did not invest on them as much as firms with high productivity of labor did.

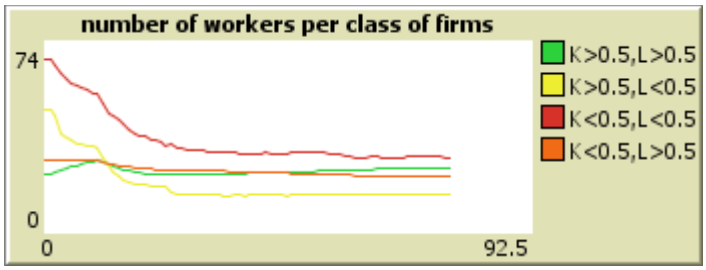

Fig. 3.6.: *number of workers per class of firms.*

Given this framework, we should expect to observe a peak in firms' profits after that the technological shock occurs, but this is not the case. However, by going deeper in our line of reasoning, this result should not upset us because it seems to be clear that the increment in profits due to the reduction in cost of labor is immediately offset by the reduction in profits

driven by a dramatic drop in consumptions level. Fig. 3.7. points it out by depicting firms' profits divided by classes of firms: as we can observe, all these values keep constant over time, even also the technological shock.

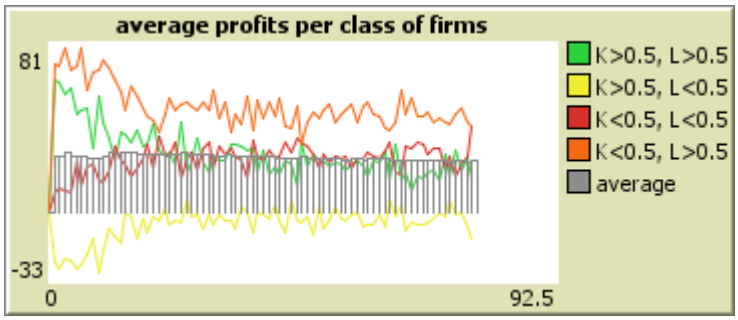

Fig. 3.7.: *average profits divided by class of firms.*

Let us now go deeper into the causes driving this drop in the consumption levels: when workers switch from employed to unemployed, they change their budget constraints in order to face the loss of their wages. Of course, since individuals' consumption functions allow for expenditures higher than the in-flows they gain from working or from perceiving an unemployment benefit, they still continue purchasing goods on the market - even if according to a lower consumption function. As we can observe by looking at Fig. 3.8, employed workers do not change their consumption function: clearly what is causing the drop in the average consumption is driven by the fact that unemployed population is hugely enlarging.

As largely predictable, this implies a twofold effect: the first one, which we have just described above, is that firms' profits are dramatically reduced and, secondly, since individuals consume (and, of course, purchase!) more than their budget constraint, they reduce their endowment cycle by cycle, and they soon end up under the poverty line (i.e. the total amount of their savings becomes negative).

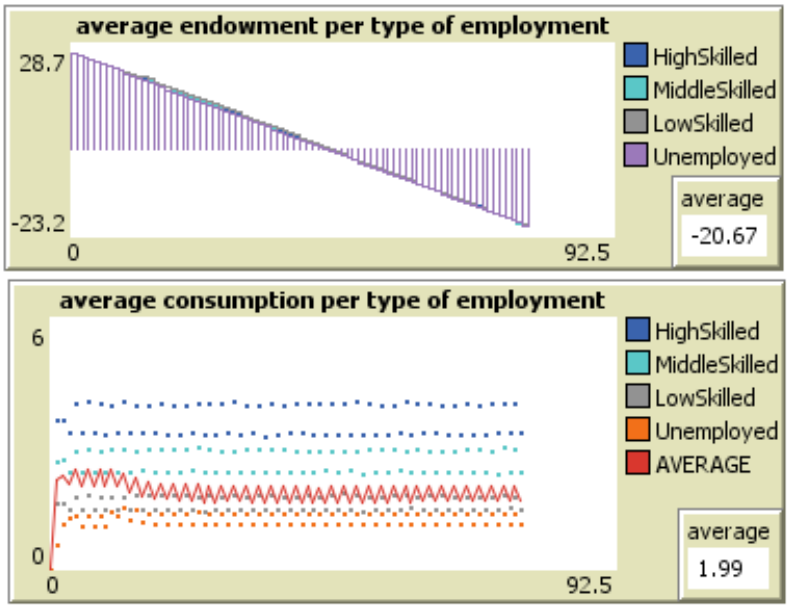

Fig. 3.8.: *the drop in average consumption and the consequent shift of population over the poverty line.*

We can add some further information about global trends implied by the drop in consumption level we just observed: in fact, now we focus on analyzing how prices level and aggregate production behave in the presence of a technological shock that firms reacting to by keeping production levels constant and firing workers. Of course, it is straightforward due to the price formation mechanism that a drop in consumption level implies a drop in prices. Since we assumed that firms' production choices are sensitive to changes in prices, this explains the slight drop observed in aggregate production levels.

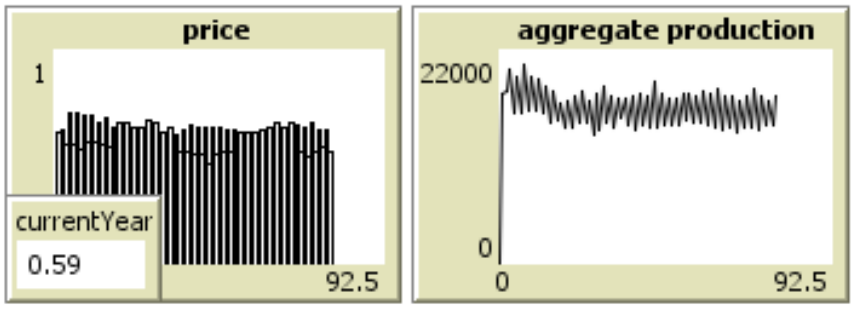

Fig. 3.9.: *aggregate production and prices level reaction to the technological shock.*

3.4. A basic income hypothesis: a safety net to cope with technological unemployment issues

While working under the condition that firms' response to a technological shock is the choice of keeping production level constant and firing workers, the scenario drawn still now seems to be a bit creepy.

The aim idea of this section is to introduce a basic income hypothesis providing a feasible welfare policy in order to cope with issues yielded by technological unemployment. There are many theoretical ideas underpinning this proposal:

- technological shocks that are going to hit the economic system in the next years through the introduction of AI are supposed to imply structural changes in the labor market;
- since massive automation of productive processes is substituting for human labor, it seems to be more efficient for firms in the terms of costs to invest in machineries rather than in human resources;
- furthermore, since automatized processes are more efficient, they allow for reducing prices of goods purchased on the market, generating a collective gain;
- labor that can be substituted by machinery tends to be routine-biased and alienating, this means that providing those individuals with a basic income allows them to be freed by alienating labor. This leads a twofold implication:
    i) of course, individuals may decide whether to reintegrate in the productive processes in a better position by investing basic income in training, or to enjoy their basic income lying outside the productive process;
    ii) by providing individuals who were involved in alienating jobs with an income, a self-sustaining virtuous circle may be implemented. In fact, since a basic income is available for those individuals, they may refuse to perform alienating jobs and these may stimulate firms to invest further in technological development substituting for alienating labor.

All these reasons trigger us to investigate deeper the basic income issue and suggest us to plug it as a possible solution in order to enlighten the bleak scenario depicted by the model until now. In order to do so, we run

our model under the same conditions that we imposed while performing the previous experiments, but we finally add the basic income hypothesis by setting it switched on. Let us recall the starting conditions set while calibrating parameters:

- a market composed of 100 firms and of a population of 5000 individuals;
- a technological shock occurring after running ten cycles under "normal" conditions, which affects firms with a 0.75 level of pervasiveness (meaning that three firms displaying high productivity of capital over four and half of the firms displaying low productivity of capital are on average affected by the technological shock) and with a 0.2 level of intensity of the shock (meaning that firms' productivity enlarges by 20%);
- an unemployment benefit of size 0.6 provided to all the unemployed workers (this goes to zero when the basic income hypothesis is introduced);
- the firms' reaction choice to the shock is to keep production levels constant and to fire part of their workers.

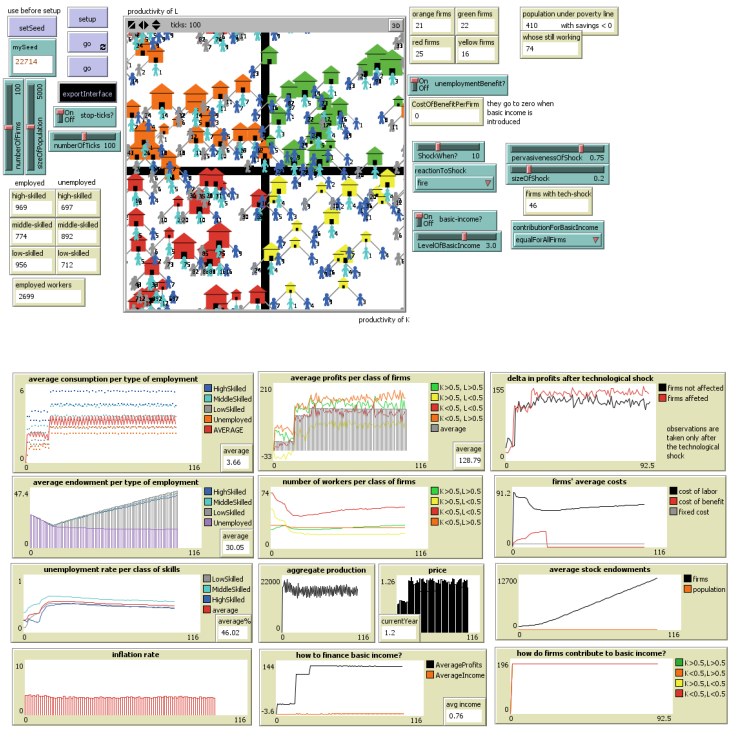

Fig. 3.10.: *the graphic interface for the basic income hypothesis with taxation equally divided among all firms*

Now, let us write down the conditions under which we perform our basic income experiment:

i) basic income is introduced five cycles after that the technological exogenous shock affects firms in the model;

ii) we set the optimal basic income level at 3, corresponding at the wage level of high-skilled workers - i.e. the maximum wage set in the model (clearly, individuals who still work after that basic income is introduced continue to perceive their salary according to the typology of employment they are hired for);

iii) since public institutions do not appear in the model, basic income is performed by imposing a taxation directly upon firms' profits. The way through which firms divide among them the total amount to be contributed in order to finance basic income is defined via a chooser in the interface. This allows us to run different experiments in order to observe which are the effects of different taxation choices upon firms' profits;

iv) since the model is stable it could be run potentially for an infinite number of cycles. We arbitrarily fix at 100 the number of cycle to be run since it ensures us a sufficient number of observations in order to sketch reliable results.

Let us now take a view of general results performed by the model, and then we will focus on comparing different taxation policies.

As in the previous analysis, we start by analyzing unemployment rates per typology of employment, and its consequences on firms' cost function.

As recorded in the previous cases, we can observe high levels of job-polarization with middle-skilled workers suffering from job-places disruption significantly more than other. Furthermore, high-skilled workers seem the ones with higher probabilities to keep on working: we can explain it by considering that they may be the ones adding innovation to productive processes and therefore their work is still required by firms, a fortiori when productivity of capital arises, whereas low-skilled workers are still required since machines cannot substitute for all those tasks they can accomplish at low costs.

As long as concerns with the average unemployment rate, we can observe that is sensitively lower than the one recorded in the absence of a basic income policy (47.34% at the time when in the other experiment we recorded 60.68%): we can interpret this fact by observing that given a more efficient system there is a lower number of firms disappearing from the market (16 vs 15), but also by supposing that individuals may invest their basic income in order to train to enter again productive processes in better positions, as many empirical studies are confirming.

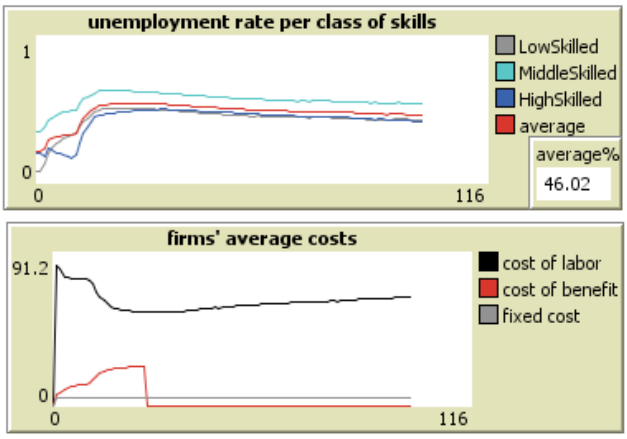

Fig. 3.11: *the unemployment rate long-run trend and its consequences on firms' cost function under a basic income hypothesis*

As long as concerns the firms' cost function we can observe how the unemployment rate trend perfectly fits with the cost of labor, whereas the cost of unemployment benefit clearly disappears when basic income is introduced.

By going deeper into the details, we can analyze how workers per firms are distributed (Fig. 3.12.). Firms with high productivity of labor (i.e. green ones and orange ones) follow pretty similar patterns. An interesting data is instead that yellow firms (high productivity of capital and low productivity of labor) are the ones displaying a lower number of workers: this can be explained by the fact that yellow firm are the ones performing the lowest results in the market and quitting it. As long as concerns with red firms displaying low values both productivity of capital and of labor, they are for this reason the ones displaying still the highest demand for workers. Furthermore, the shape of the curve and the weight they have on the market suggest that they are the ones driving unemployment rates down in the long-run since raises in consumption levels allow them to survive by gaining profits in the market.

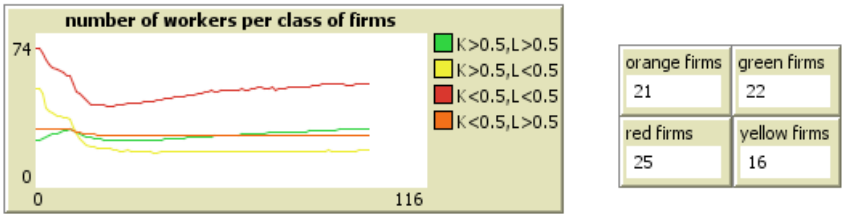

Fig. 3.12.: *number of workers per class of firms and number of firms divided per class still on the market*

Now the scenario becomes more interesting since here the basic income introduction turns out to be crucial. If in the previous case we did not observe a peak in firms' profits because the positive effect of reductions in cost of labor was offset by a dramatic drop in consumption levels, here we can observe the opposite: since basic income underpins individuals' consumption function, as this measure is introduced its effects are clear on the labor market.

In particular, we have to observe that firms with low productivity of capital and high productivity of labor (i.e. orange firms) are the ones better performing on the market since their cost function is the lightest one, even if it is also interesting to observe that the distance with green firms (displaying high values of productivity both for K and L) seems to be lower after the shock and this may that green firms take comparative advantages from the technological shock. In any case, it seems to be pretty clear that productivity of capital and labor are the determinants of profits' levels.

On the right side of Fig. 3.13 we display that firms affected by technological shock acquire a comparative advantage with respect to firms being not affected: of course, this has to be attributed to the reductions in cost functions. It may be interesting come back to observe this plots while setting different policies in distributing costs of financing basic income among firms: in fact, profits here are shown net of taxation.

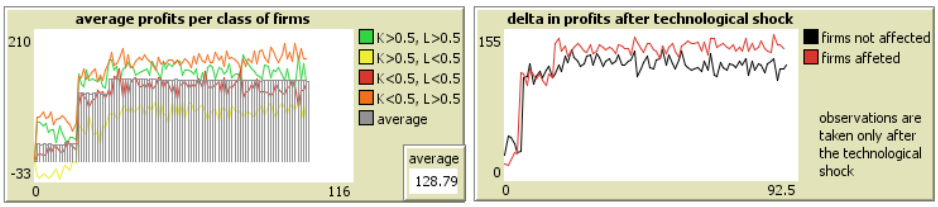

Fig. 3.13: *average profits per class of firms and delta in profits between firms affected by technological shock and not*

Let us now shift to the consumers' side of the market, which is the one displaying better news. In fact, as we can observe in Fig. 3.14, the introduction of a basic income hypothesis turns out to be crucial in guaranteeing economic stability to individuals: in fact, as we can observe endowment levels decrease cycle by cycle (as it occurred in the case previously analyzed) until cycle 15, when individuals are provided with basic income. This allows them to increase their savings in the case they work (and therefore perceive a further wage plus to the basic income) or to keep them constant around the same level of endowment otherwise, and individuals ending up under the poverty line are very fewer (8.2%) with respect to the previous case, where the whole population ended up under the poverty line (and even sooner!). Clearly this implies positive consequences for consumption levels, since individuals belonging to each category are enlarging their consumption consistently, and this of course boost a virtuous circle since in this way they enlarge firms' profits.

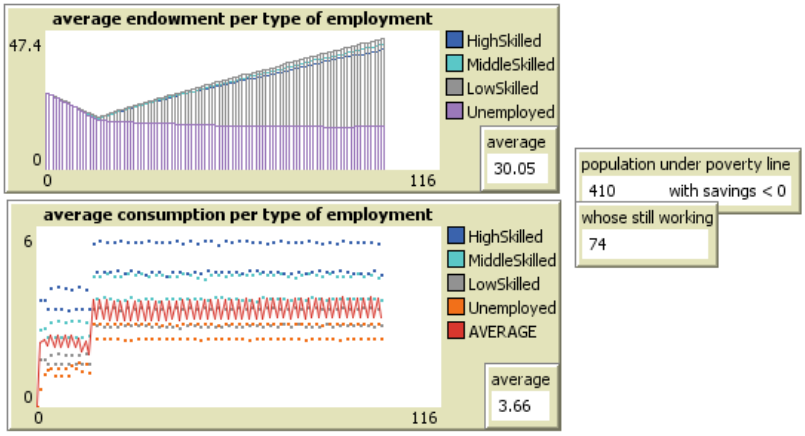

Fig. 3.14.: *average savings and average consumption levels per type of employment*

However, it may be interesting again to look at the global trends behavior, in order to observe how prices level and aggregate production react to this novelty. Fig. 3.15 shows an interesting pattern: in fact, the slight reduction in aggregate production after the technological shock may sound counter-intuitive, but it is not because that is the period where we record the highest number of firms quitting the market (in particular the yellow ones). For this reason, aggregate production reduces, by triggering, together with the boost in consumption levels due to the basic income, a huge increase in prices level.

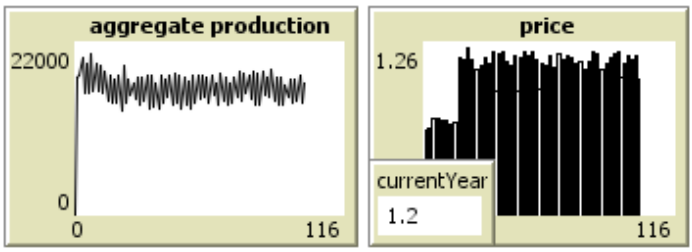

Fig. 3.15.: *prices level and aggregate production*

By observing consumption levels and price dynamics, it seems that talking about boost in consumption may sound too optimistic: in fact, by plotting the graph depicting consumption levels expressed in terms of units of goods purchased we can observe that it keeps constant over time. This means that actually no boost in consumption has taken place, but it seems to be more proper to talk about an inflation occurring: clearly the hypothesis that this has been triggered by the introduction of a universal basic income should be considered.

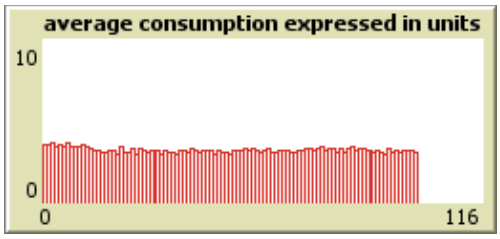

Fig. 3.16*: average consumption in terms of unit highlighting an inflation*

Nevertheless, the general framework sketched up through the introduction of a universal basic income seems to be rather positive: in fact, observed datas highlight an increment in individuals' economic stability through the increment in savings - and made sure that consumption levels are not decreased - and a consistent increment in firms' profits. Furthermore, it seems that increased stability of the economic system as a whole has pushed down unemployment rate if compared with the experiment where a basic income was not available.

What we have done until now is showing the feasibility of basic income in an economic environment under certain conditions and some of the benefits that an economy may experience by introducing such a policy.

Further experiments may focus on basic income as an incentive for firms in order to invest more and more in technologic development by triggering self-sustaining virtuous circles where machineries substitute for alienating human labor and on basic income as a source of investment in training for individuals who want to lie within the productive processes.

3.4.1. How to finance basic income?

Once that feasibility and benefits coming from introducing a universal basic income are verified, we investigate different way which basic income may be financed through. First of all, let us recall that feasibility is ensured by financing basic income by taxing firms' profits: if firms profits are such that part of them can be withdrawn in order to finance this policy, the tool is feasible.

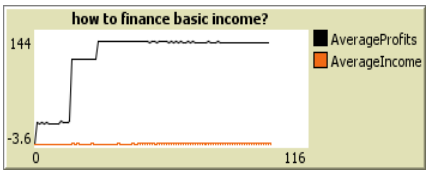

Fig. 3.17.: *basic income feasibility is ensured through firms' profit*

Once that the destination and the method of distribution are clarified, we discuss possible ways to define how to withdraw from each firm in order to make it contribute to this policy tool.

We identify here four different methods:

- to divide the total amount equally among all the firms (Fig. 3.18.);
- to divide the total amount asking to firms performing higher profits to contribute more (Fig. 3.19.);
- to apply a "robot tax" based on the level of productivity of capital of each firm (Fig. 3.20.);
- to incentive firms to invest in technology by taxing firms displaying lower levels of productivity of capital (Fig. 3.21.).

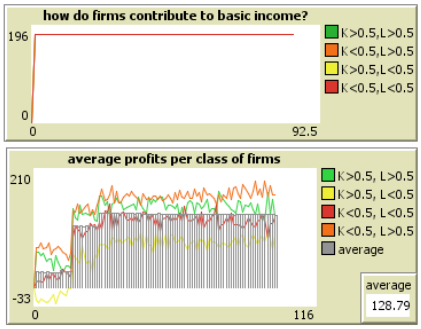

Fig. 3. 18.: *contribution for basic income equally divided among firms.*

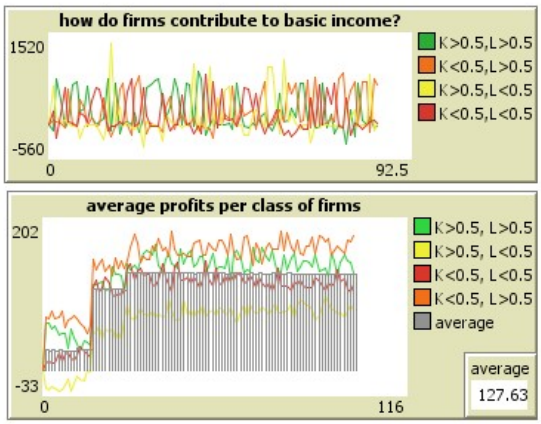

Fig. 3. 19.: *contribution for basic income divided on profits and its effects on firms' profits.*

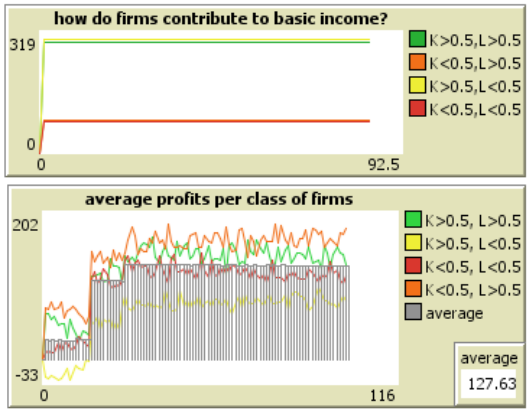

Fig. 3. 20.: *contribution for basic income by using a robot tax and its effects on firms' profits.*

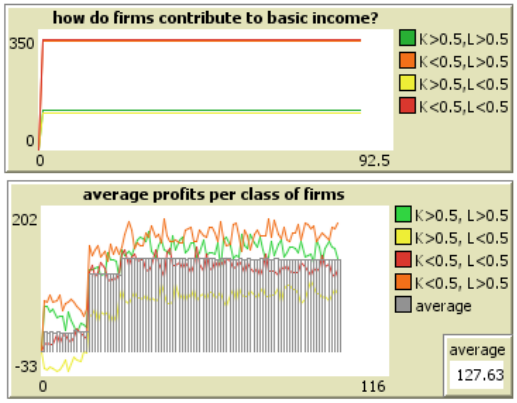

Fig. 3. 21.: *contribution for basic income by offering incentives for innovation and its effects on firms' profits.*

By looking at the first plot displayed in each of the figures above, we can observe that, excluding the second hypothesis (the profit-based one), the withdrawing choice is constant over time since it is based on parameters keeping the same over time. As long as concerns the first experiment (an equal taxation divided among all the firms), this means that after that basic income is introduced there are no firms quitting the market. As long as concerns third and fourth experiments (robot tax and incentive to innovation), they keep constant over time since a unique technological shock is performed in the model and, therefore, after that it occurs, productivity of capital - the parameter that this two withdraws are built on - keeps constant over time. Profit-based taxation, instead, among a huge variability since profits' level displayed by firms in each cycle varies hugely.

By comparing results of applying different taxation policies on firms' profits, the first element we can notice is that profits' average keeps equal in each of the experiments, as we expected it did: this occurs because the amount of the withdraw is equal, and we only change the method through which this amount is divided among firms. The second information that this analysis returns us is that average profits per class of firms, even displaying slightly different results (they are very hard to be noticed!), keep equal while running different experiments: so, we can conclude that switching from a policy to the other is not particularly relevant for firms, but, of course, applying such an intervention has a redistributive effect shifting financial flows from firms to population. What is rather

surprisingly is that doing so produce large benefits both for population and firms, since it gives robustness to the economic system by sustaining demand for goods.

Therefore, what we can conclude after this analysis is that, under certain conditions, basic income seems to be a feasible tool to apply redistribution, and it looks to provide large benefits on an economic system by giving stability to all the agents interacting in it.

CONCLUSIONS

We started this work aiming at exploring the relationship existing between technological innovation and dynamics driving labor market. By working according to a vision both economical and sociological, we strongly believe that such an analysis could not avoid to take into account that the effects of such a relationship yield structural changes in the society, and, consequently, we built our analysis in order to introduce a basic income proposal updating welfare systems as to face such changes.

Moving along this line of reasoning, we introduced the theoretical references recalling such a global vision and in particular, this analysis developed basically four issues: technological unemployment as a condition coming from structural changes affecting labor market, the historical outlines of the debate around machinery questions, the emerging need of updating welfare systems by introducing a basic proposal as a welfare tool, and the role of innovation within this process.

These four building blocks are the basis which our Agent Based Model (ABM) is built on. In fact, by using NetLogo, we have run some simulations performing a market where firms and individuals (in the role of both workers and consumers) interact, both in the sense of the goods market and of the labor market.

As a crucial step of our model, we plugged an exogenous technological shock as to analyze which are the effects it yields on our ecology recalling the technological unemployment issue.

This brought us to develop some ideas about which solutions could be performed in order to update welfare systems as to face such a structural change affecting the labor market, and this is the reason why we imagined to introduce a basic income proposal as a policy tool in order to create a safety net coping with this issue.

Our simulation displays the feasibility of such a proposal under certain conditions and gives us some insights about the benefits it may yield to the economic system as a whole: in particular, applying such a redistribution policy seems to give a larger stability to the economic system as a whole by sustaining demand on the goods market, triggering therefore a self-sustaining virtuous circle.

Furthermore, we have built a comparative analysis on the effects driven by walking different ways in order to finance such a solution, starting from the idea that this has to be done by taxing some of the firms' profits.

Clearly, many further specifications of this model may be run: in particular, it would be interesting to focus on the role of basic income in stimulating innovation in an economic system both on the firms' side (focusing on how to stimulate firms to invest more in substituting alienating labor with technology) and on the individuals' side - investigating whether individuals use basic income in order to train and enter again productive processes being employed in less alienating jobs.

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APPENDIX I

The NetLogo code of our model

```
globals [TotalConsumption
         TotalProduction

         price
         priceT-1
         priceT-2]


breed [firms firm]
breed [population person]



firms-own [capitalEndowment
           productivityofK
           productivityofL
           numberOfHirings

           myProduction
           costOfLabor
           fixedCosts
           profits

           contributionForBenefit

           exogenousShock
           probabilityOfShock

           taxForIncome]


population-own [personalEndowment
                employed
                skills
                myFirm

                wage
                myConsumption
                yearIncome

                underPovertyLine
                myBenefit

                ;rehired

                myBasicIncome]
```

```
to setSeed

  random-seed mySeed

end



to exportInterface

  export-interface " Labor Market.png"

end


to setup

  ca
  reset-ticks

  createWorld
  hire

end



to createWorld


  ask patches [set pcolor white]

  ask (patch-set patches with [pycor = 16]
                 patches with [pxcor = 16] ) [set pcolor black]

  create-firms numberOfFirms [set shape "house"
                              set capitalEndowment 500 + random
500

                              set size 1.5

                              set color red
                              set productivityOfK (0 + random-
float 0.5)
                              set productivityofL (0 + random-
float 0.5)

                              let firmsCreated firms
                              if  [productivityOfK] of
firmsCreated = [productivityOfK] of firms with [who != [who] of
firmsCreated]
```

```
                                and [productivityOfL] of
firmsCreated = [productivityOfL] of firms with [who != [who] of
firmsCreated] [set productivityOfK (0 + random-float 0.5)

set productivityofL (0 + random-float 0.5)]


                                setxy (productivityOfK * 32)
(productivityOfL * 32)

                                set exogenousShock false]


  ask n-of (0.50 * count firms) firms [set size 2.5]

  ask n-of (0.15 * count firms) firms with [size != 2.5] [set
size 3.5]




  ask n-of (0.25 * count firms) firms [set color yellow
                                       set productivityofK 0.5 +
random-float 0.5
                                       set productivityofL 0 +
random-float 0.5

                                       let firmsCreated firms
                                       if  [productivityOfK] of
firmsCreated = [productivityOfK] of firms with [who != [who] of
firmsCreated]
                                       and [productivityOfL] of
firmsCreated = [productivityOfL] of firms with [who != [who] of
firmsCreated] [set productivityOfK (0.5 + random-float 0.5)

set productivityofL (0 + random-float 0.5)]
                                       setxy (productivityOfK *
32) (productivityOfL * 32)]


 ask n-of (0.25 * count firms) firms with [color != yellow] [set
color orange
                                                             set
productivityofK 0 + random-float 0.5
                                                             set
productivityofL 0.5  + random-float 0.5

                                                             let
firmsCreated firms
                                                             if
[productivityOfK] of firmsCreated = [productivityOfK] of firms
with [who != [who] of firmsCreated]
```

```
                                                                    and
[productivityOfL] of firmsCreated = [productivityOfL] of firms
with [who != [who] of firmsCreated] [set productivityOfK (0 +
random-float 0.5)

set productivityofL (0.5 + random-float 0.5)]

setxy (productivityOfK * 32) (productivityOfL * 32)]

 ask n-of (0.25 * count firms) firms with [color != yellow and
color != orange] [set color green

set productivityofK 0.5 + random-float 0.5

set productivityofL 0.5 + random-float 0.5


let firmsCreated firms

if  [productivityOfK] of firmsCreated = [productivityOfK] of
firms with [who != [who] of firmsCreated]

and [productivityOfL] of firmsCreated = [productivityOfL] of
firms with [who != [who] of firmsCreated] [set productivityOfK
(0 + random-float 0.5)

set productivityofL (0 + random-float 0.5)]

setxy (productivityOfK * 32) (productivityOfL * 32)]



 create-population sizeOfPopulation [set shape "person"
                                     set size 1.5
                                     setxy random-xcor random-
ycor
                                     set employed false
                                     set personalEndowment 13 +
random 27
                                     set underPovertyLine false

                                     set wage 0

                                     set skills 0
                                     set color grey

                                     ;set rehired false
                                     ]

 ask n-of (count population / 3) population [set color cyan
                                             set skills 1]
```

```
 ask n-of (count population / 3) population with [color != cyan]
[set color blue

set skills 2]


 ask firms [if size = 1.5 [set numberOfHirings (capitalEndowment
* 0.01) * (1 - productivityOfL)]
            if size = 2.5 [set numberOfHirings (20 +
capitalEndowment * 0.09) * (1 - productivityOfL)]
            if size = 3.5 [set numberOfHirings (150 +
capitalEndowment * 0.1) * (1 - productivityOfL)]
           ]

ask firms [ifelse productivityOfK < 0.5 [set probabilityOfShock
0 + random-float 0.5]
                                        [set probabilityOfShock
0 + random-float 1]
          ]


set price 0

end



to hire


ask firms with [color = green]

[if numberOfHirings < count population with [not employed and
color = grey]

              [let myGreyOfGreen n-of (numberOfHirings * 0.20)
population with [not employed and color = grey]

               if myGreyOfGreen != nobody

               [create-links-with myGreyOfGreen

               ask myGreyOfGreen[set employed true
                                 set wage 1
                                 set myFirm myself
                                 set xcor ([xcor] of myFirm - 2)
                                 set ycor ([ycor] of myFirm -
2)]
               ]
               ]
```

```
if numberOfHirings < count population with [not employed and
color = cyan]

                [let myCyanOfGreen n-of (numberOfHirings * 0.15)
population with [not employed and color = cyan]

                 if myCyanOfGreen != nobody

                 [create-links-with myCyanOfGreen

                 ask myCyanOfGreen[set employed true
                                   set wage 2
                                   set myFirm myself
                                   set xcor ([xcor] of myFirm)
                                   set ycor ([ycor] of myFirm -
2)]
                 ]
                 ]

if numberOfHirings < count population with [not employed and
color = blue]

                  [let myBlueOfGreen n-of (numberOfHirings *
0.65) population with [not employed and color = blue]

                   if myBlueOfGreen != nobody

                   [create-links-with myBlueOfGreen

                   ask myBlueOfGreen[set employed true
                                     set wage 3
                                     set myFirm myself
                                     set xcor ([xcor] of myFirm
+ 2)
                                     set ycor ([ycor] of myFirm
- 2)]
                  ]
                  ]
]



 ask firms with [color = orange]

[if numberOfHirings < count population with [not employed and
color = grey]

              [let myGreyOfOrange n-of (numberOfHirings * 0.50)
population with [not employed and color = grey]

               if myGreyOfOrange != nobody
```

```
                [create-links-with myGreyOfOrange

                ask myGreyOfOrange[set employed true
                                   set wage 1
                                   set myFirm myself
                                   set xcor ([xcor] of myFirm -
2)
                                   set ycor ([ycor] of myFirm -
2)]
                ]
                ]


if numberOfHirings < count population with [not employed and
color = cyan]

                 [let myCyanOfOrange n-of (numberOfHirings *
0.30) population with [not employed and color = cyan]

                  if myCyanOfOrange != nobody

                  [create-links-with myCyanOfOrange

                  ask myCyanOfOrange[set employed true
                                     set wage 2
                                     set myFirm myself
                                     set xcor ([xcor] of myFirm)
                                     set ycor ([ycor] of myFirm -
2)]
                  ]
                  ]

if numberOfHirings < count population with [not employed and
color = blue]

                   [let myBlueOfOrange n-of (numberOfHirings *
0.20) population with [not employed and color = blue]

                    if myBlueOfOrange != nobody

                    [create-links-with myBlueOfOrange

                    ask myBlueOfOrange[set employed true
                                       set wage 3
                                       set myFirm myself
                                       set xcor ([xcor] of myFirm
+ 2)
                                       set ycor ([ycor] of myFirm
- 2)]
                    ]
                    ]
]
```

```
 ask firms with [color = yellow]

[if numberOfHirings < count population with [not employed and
color = grey]

              [let myGreyOfYellow n-of (numberOfHirings * 0.25)
population with [not employed and color = grey]

               if myGreyOfYellow != nobody

               [create-links-with myGreyOfYellow

               ask myGreyOfYellow [set employed true
                                   set wage 1
                                   set myFirm myself
                                   set xcor ([xcor] of myFirm -
2)
                                   set ycor ([ycor] of myFirm -
2)]
               ]
               ]


if numberOfHirings < count population with [not employed and
color = cyan]

                [let myCyanOfYellow n-of (numberOfHirings *
0.15) population with [not employed and color = cyan]

                 if myCyanOfYellow != nobody

                 [create-links-with myCyanOfYellow

                 ask myCyanOfYellow[set employed true
                                    set wage 2
                                    set myFirm myself
                                    set xcor ([xcor] of myFirm)
                                    set ycor ([ycor] of myFirm -
2)]
                 ]
                 ]

if numberOfHirings < count population with [not employed and
color = blue]

                  [let myBlueOfYellow n-of (numberOfHirings *
0.60) population with [not employed and color = blue]

                   if myBlueOfYellow != nobody

                   [create-links-with myBlueOfYellow
```

```
                    ask myBlueOfYellow[set employed true
                                       set wage 3
                                       set myFirm myself
                                       set xcor ([xcor] of myFirm
+ 2)
                                       set ycor ([ycor] of myFirm
- 2)]
                   ]
                   ]
]


ask firms with [color = red]

[if numberOfHirings < count population with [not employed and
color = grey]

               [let myGreyOfRed n-of (numberOfHirings * 0.50)
population with [not employed and color = grey]

                if myGreyOfRed != nobody

                [create-links-with myGreyOfRed

                ask myGreyOfRed[set employed true
                                set wage 1
                                set myFirm myself
                                set xcor ([xcor] of myFirm - 2)
                                set ycor ([ycor] of myFirm - 2)]
                ]
                ]

if numberOfHirings < count population with [not employed and
color = cyan]

                 [let myCyanOfRed n-of (numberOfHirings * 0.40)
population with [not employed and color = cyan]

                  if myCyanOfRed != nobody

                  [create-links-with myCyanOfRed

                  ask myCyanOfRed [set employed true
                                   set wage 2
                                   set myFirm myself
                                   set xcor ([xcor] of myFirm)
                                   set ycor ([ycor] of myFirm -
2)]
                  ]
                  ]

if numberOfHirings < count population with [not employed and
color = blue]
```

```
                  [let myBlueOfRed n-of (numberOfHirings * 0.10)
population with [not employed and color = blue]

                   if myBlueOfRed != nobody

                   [create-links-with myBlueOfRed

                   ask myBlueOfRed[set employed true
                                   set wage 3
                                   set myFirm myself
                                   set xcor ([xcor] of myFirm +
2)
                                   set ycor ([ycor] of myFirm -
2)]
                   ]
                   ]
]



 ask population [if count my-links = 0 [set employed false
                                        set wage 0]
                ]

 ask firms with [count my-links < 1] [die]

 ask population with [not employed and color = grey] [setxy 1 1]
 ask population with [not employed and color = cyan] [setxy 3 1]
 ask population with [not employed and color = blue] [setxy 5 1]

 ask population [if (count population-here) != 0 [set label
(count population-here)]
                                                  set label-
color black]


end



to go

  tick

  produce&consume

  if stop-ticks? [if ticks >= numberOfTicks [stop]]
  if count population with [underPovertyLine] = count population
or count firms = 0 [stop]

end
```

```
to produce&consume


  fire
  rehire


  if reactionToShock = "fire" [technologyShock]


  ask population [ifelse not employed [set myConsumption
myBenefit + random-normal 0.6 0.3]

                                       [set myConsumption wage +
random-normal 0.6 0.3]


                   ifelse employed [set yearIncome (wage -
myConsumption)
                                    set personalEndowment
(personalEndowment + yearIncome)]

                                   [set yearIncome (myBenefit -
myConsumption)
                                    set personalEndowment
(personalEndowment + yearIncome)]


                   if personalEndowment < 0 [set underPovertyLine
true]

                   if ticks > (ShockWhen? + 5) and
reactionToShock = "fire"

                                [if basic-income?

                                                  [ifelse employed
[set myConsumption (myBasicIncome + wage - random-normal 1 0.5)]

[set myConsumption (myBasicIncome - random-normal 0.5 0.25)]

                                                   set yearIncome
(wage + myBasicIncome - myConsumption)

                                                   set
personalEndowment (personalEndowment + yearIncome)]
                                                                  ]
                   ]

  set TotalConsumption sum [myConsumption] of population
```

```
  ask firms [if size = 1.5 [set myProduction 80 + random-normal
20 10]
             if size = 2.5 [set myProduction 140 + random-normal
40 20]
             if size = 3.5 [set myProduction 300 + random-normal
100 50]

             set fixedCosts (productivityOfK * 10)

             let myEmployee population with [myFirm = myself]
             set costOfLabor sum [wage] of myEmployee
             ]


  if reactionToShock = "implementProduction" [technologyShock]

  set priceT-2 priceT-1
  set priceT-1 price

  if priceT-2 != 0 [ask firms [if priceT-1 > priceT-2 [set
myProduction (myProduction + myProduction * random-normal 0.1
0.2)]
                               if priceT-1 < priceT-2 [set
myProduction (myProduction - myProduction * random-normal 0.1
0.2)]
                               ]


                    ask population [if priceT-1 > priceT-2 [set
myConsumption (myConsumption - myConsumption * random-normal 0.1
0.2)]
                                    if priceT-1 < priceT-2 [set
myConsumption (myConsumption + myConsumption * random-normal 0.1
0.2)]
                                    ]
                    ]


  set TotalProduction sum [myProduction] of firms

  if count population != 0  and count firms != 0 [set price
(TotalConsumption / TotalProduction)]


  ask firms [set profits (myProduction * price) - costOfLabor -
fixedCosts - contributionForBenefit

             set capitalEndowment (capitalEndowment + profits)

             if capitalEndowment <= 0 [ask my-links [die]
```

```
                                        die]
            ]


 ask population [if count my-links = 0 [set employed false
                                        set wage 0]
                ]

 ask population with [not employed and color = grey] [setxy 1 1]
 ask population with [not employed and color = cyan] [setxy 3 1]
 ask population with [not employed and color = blue] [setxy 5 1]

 ask population [if (count population-here) != 0 [set label
(count population-here)]
                                                    set label-
color black]




 if unemploymentBenefit? [ask population with [not employed]
[set myBenefit 0.6]
                                                                ]

 if basic-income? and ticks > (shockWhen? + 15) [ask population
[set myBenefit 0]
                                                        ]

 if unemploymentBenefit? [ask firms [set contributionForBenefit
(sum[myBenefit] of population / count firms)]
                           ]

end




to fire

    ask firms with [productivityOfL < 0.5]

          [if profits < 0 or capitalEndowment < 150

              [ifelse productivityOfK > 0.5 [ask n-of (0.2 *
count my-links with [[color] of end1 = grey or [color] of end2 =
grey])

my-links with [[color] of end1 = grey or [color] of end2 = grey]
[die]
```

```
                                                ask n-of (0.2 *
count my-links with [[color] of end1 = cyan or [color] of end2 =
cyan])

my-links with [[color] of end1 = cyan or [color] of end2 = cyan]
[die]
                                              ]

                                              [ask n-of (0.1 *
count my-links with [[color] of end1 = cyan or [color] of end2 =
cyan

or [color] of end1 = grey or [color] of end2 = grey])

my-links with [[color] of end1 = cyan or [color] of end2 = cyan

or [color] of end1 = grey or [color] of end2 = grey] [die]

                                                ask n-of (0.1 *
count my-links with [[color] of end1 = blue or [color] of end2 =
blue])

my-links with [[color] of end1 = blue or [color] of end2 = blue]
[die]
                                                ]
          ]
         ]


    ask firms with [productivityOfL > 0.5]

          [if profits < 0 or capitalEndowment < 150

              [ifelse productivityOfK > 0.5 [ask n-of (0.1 *
count my-links with [[color] of end1 = grey or [color] of end2 =
grey])

my-links with [[color] of end1 = grey or [color] of end2 = grey]
[die]

                                                ask n-of (0.1 *
count my-links with [[color] of end1 = cyan or [color] of end2 =
cyan])

my-links with [[color] of end1 = cyan or [color] of end2 = cyan]
[die]
                                              ]

                                              [ask n-of (0.05 *
count my-links with [[color] of end1 = cyan or [color] of end2 =
cyan
```

```
or [color] of end1 = grey or [color] of end2 = grey])

my-links with [[color] of end1 = cyan or [color] of end2 = cyan

or [color] of end1 = grey or [color] of end2 = grey] [die]

                                                ask n-of (0.05 *
count my-links with [[color] of end1 = blue or [color] of end2 =
blue])

my-links with [[color] of end1 = blue or [color] of end2 = blue]
[die]
                                                ]
          ]
         ]



 ;show [self] of population with [not employed]
 ;show word"1" population with [not employed]

 ask population [ifelse count my-links > 0 [set employed true]
                                           [set employed false
                                            set wage 0]
                ]

 ;show [self] of population with [not employed]
 ;show word "2" population with [not employed]
 ;ask population with [not employed] [set wage 0]


 ask population with [not employed and color = grey] [setxy 1 1]
 ask population with [not employed and color = cyan] [setxy 3 1]
 ask population with [not employed and color = blue] [setxy 5 1]

 ask population [if (count population-here) != 0 [set label
(count population-here)]
                                                    set label-
color black]

end




to rehire


ask firms with [(profits > mean[profits] of firms) or
(capitalEndowment > 1.5 * mean[capitalEndowment] of firms)
```

```
              ]

          [ifelse productivityOfL > 0.5

                  [if productivityOfK > 0.5 ;and 1 > count
population with [not employed and skills = 2]

                                                [let myNewEmployed n-
of (1) population with [not employed and skills = 2]

                                                if myNewEmployed !=
nobody

                                                [create-links-with
myNewEmployed

                                                ask myNewEmployed[set
employed true
                                                                    set
wage 3
                                                                    set
myFirm myself
                                                                    set
xcor ([xcor] of myFirm - 2)
                                                                    set
ycor ([ycor] of myFirm - 2)

;set rehired true
                                                                    ]
                                                ]


                   if productivityOfK < 0.5  ;and 1 > count
population with [not employed and (skills = 1 or skills = 0)]

                                                [let myNewEmployed2
n-of (1) population with [not employed and (skills = 1 or skills
= 0)]

                                                if myNewEmployed2 !=
nobody

                                                [create-links-with
myNewEmployed2

                                                ask myNewEmployed2
[set employed true

set myFirm myself

set xcor ([xcor] of myFirm )

set ycor ([ycor] of myFirm - 2)
```

```
                                                                    ;
set rehired true
                                                                    ]
                                                ask myNewEmployed2
with [skills = 1] [set wage 2]
                                                ask myNewEmployed2
with [skills = 0] [set wage 1]
                                                ]
                                                ]

            ]
            ]

                [if productivityOfK > 0.5 ;and 2 > count
population with [not employed and skills = 2]

                                               [let myNewEmployed3 n-
of (2) population with [not employed and skills = 2]

                                                if myNewEmployed3 !=
nobody

                                                [create-links-with
myNewEmployed3

                                                 ask
myNewEmployed3[set employed true

set wage 3

set myFirm myself

set xcor ([xcor] of myFirm - 2)

set ycor ([ycor] of myFirm - 2)

;set rehired true

]
                                                ]
                                                ]

                 if productivityOfK < 0.5 ;and 1 > count
population with [not employed and skills = 1]

                                               [let myNewEmployed4 n-
of (1) population with [not employed and skills = 1]

                                                if myNewEmployed4 !=
nobody

                                                [create-links-with
myNewEmployed4
```

```
                                                ask myNewEmployed4
[set employed true

set wage 2

set myFirm myself

set xcor ([xcor] of myFirm )

set ycor ([ycor] of myFirm - 2)

;set rehired true

]
                                                ]
                                                ]

                  if productivityOfK < 0.5 ;and 1 > count
population with [not employed and skills = 0]

                                               [let myNewEmployed5 n-
of (1) population with [not employed and skills = 0]

                                                if myNewEmployed5 !=
nobody

                                                [create-links-with
myNewEmployed5

                                                ask myNewEmployed5
[set employed true

set wage 1

set myFirm myself

set xcor ([xcor] of myFirm - 2)

set ycor ([ycor] of myFirm - 2)
                                                                    ;
set rehired true
                                                                    ]
                                                ]
                                                ]

            ]
            ]


end
```

```
to technologyShock


  if ticks > ShockWhen?

        [ask firms [if probabilityOfShock > (1 -
pervasivenessOfShock) and not exogenousShock [set exogenousShock
true]
                    ]
                    ]

  if ticks = ShockWhen?

         [ask firms with [exogenousShock] [set productivityOfK
productivityOfK + sizeOfShock]
         ]


  if ticks > ShockWhen?

        [ask firms with [exogenousShock] [if reactionToShock =
"implementProduction"

                                                          [set
myProduction myProduction * (1 + sizeOfShock * 100)]

                                              if reactionToShock =
"fire"

                                                          [ask n-of
(sizeOfShock * 0.8 * count my-links with [[color] of end1 = grey
or [color] of end2 = grey])

my-links with [[color] of end1 = grey or [color] of end2 = grey]
[die]

                                                           ask n-of
(sizeOfShock * 0.9 * count my-links with [[color] of end1 = cyan
or [color] of end2 = cyan])

my-links with [[color] of end1 = cyan or [color] of end2 = cyan]
[die]

                                                          ask n-of
(sizeOfShock * 0.4 * count my-links with [[color] of end1 = blue
or [color] of end2 = blue])

my-links with [[color] of end1 = blue or [color] of end2 = blue]
[die]
```

```
                                                                  if ticks
> (ShockWhen? + 5) [if basic-income? [ask population [set
myBasicIncome LevelOfBasicIncome]


if contributionForBasicIncome = "equalForAllFirms"


[ask firms [set taxForIncome (sum[myBasicIncome] of population /
count firms)

set profits (profits - taxForIncome)]

]


if contributionForBasicIncome = "robotTax"


[ask firms [set taxForIncome sum[myBasicIncome] of population *
(productivityOfK / sum[productivityOfK] of firms)

set profits (profits - taxForIncome)]

]


if contributionForBasicIncome = "incentiveToInnovation"


[ask firms [set taxForIncome sum[myBasicIncome] of population *
((1  - productivityOfK) / sum[productivityOfK] of firms)

set profits (profits - taxForIncome)]

]


if contributionForBasicIncome = "profitBased"


[ask firms [set taxForIncome sum[myBasicIncome] of population *
(profits / sum[profits] of firms)

set profits (profits - taxForIncome)]

]


]
                                          ]
```

```
                                                    ]
                                                    ]
                                                    ]

end
```