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Simulating a Basic Income to Cope With the Technological Transition: An Agent-Based Model

Abstract. The "machinery question" has been a hot topic for at least two centuries, with many thinkers discussing the impact of machinery on the interests of the different classes of society. The Covid-19 pandemics, together with the raise of Artificial Intelligence, impressed a further acceleration to the automation of the productive processes, and the consequent disappearance of many traditional jobs is a well-documented fact. Technological unemployment is then outlining a structural change of the labor market, and this should impose a paradigm shift in the way that we think at welfare systems. I propose an agent-based model (ABM) to study the impact of technological shocks automating productive processes, then I simulate how a universal basic income would face the challenge of these structural changes. In the model agents interact both on the good market and on the labor market, with endogenous mechanisms defining their ecology and developing some adaptive behaviors. The model explores alternative scenarios of firms' coping strategies when an exogenous technological shock intervenes. The simulation is thought to discuss the role of innovation in driving paradigm shifts and to analyze whether and how a universal basic income would help face the latter. Results display the feasibility of the measure showing that it provides a larger stability of the model, which guarantees its sustainability in the long run..

Keywords. Agent-based modelling, Universal basic income, Technological transition, Paradigm shift.

1. Introduction

Technological unemployment stands as one of the most compelling challenges of nowadays. The automation of productive processes, boosted by the raise of Artificial Intelligence (AI), is causing a paradigm shift in the way that we think at the role of human labor in society. Moreover, the outbreak of the Covid-19, and its relapse on the economic system, both speeded this process up and pushed millions of people into harsh economic conditions. All this made even more urgent to open a debate on how to update the welfare system supporting individuals toward this transition. This work aims at analyzing the dynamics driving from technological innovation to labor market's structural changes, proposing a universal basic income as a tool to cope with the latter. I build a theoretical agent-based model (ABM) to clarify how these dynamics may unfold under different conditions, simulating the effects of introducing such a policy.

Section 1 recalls the theoretical framework of the debate on technological transition and a proposal about the tools to update welfare systems, also in the light of the economic crisis resulting from the Covid-19 pandemics and of the broader discussion about technological unemployment as a *new normal*. In Section 2, I propose an ABM to simulate an economy where firms and individuals interact both on the goods- and on the labor market. Here endogenous mechanisms defining the agents' ecology take place and agents develop adaptive and learning behaviors. The model is thought to study the effects of technological shocks on the simulated economy and to explore alternative scenarios which may arise from agents' copying strategies. While presenting the possible outcomes that these may lead to, I suggest a universal basic income as a public policy to face the economic transition. Section 3 presents and discusses the results of my model. The simulation aims at verifying the financial feasibility of the proposed policy, but also at testing whether it would be an effective tool to guarantee a larger economic stability during the technological transition.

2. THEORETICAL FRAMEWORK: BETWEEN CRISES, TECHNOLOGICAL ANXIETY AND NEW POSSIBILITIES

2.1 Technological unemployment, the new normal

The Covid-19 recession is only the latest in a long series of crisis impacting the global economy: credit crunch, job-places disruption and drops in incomes, consumptions, and investments levels have become keywords of the modern era, and once again the consequences on the labor market are dramatic (Coates *et al.*, 2020; Fana *et al.*, 2020).

However, the *jobless recovery* phenomenon is not a novelty: starting from the early 1990s all the crises have been followed by periods of output recovery which have not come with a recovery of the employment rate (*e.g.* the 1990-91 crisis, the 2000's Dotcom Bubble, and the Great Recession started in 2007). The Covid-19 crisis is not an exception in this trend: on the contrary, Hodder (2020) highlights the urgence of being retrospective and observing the role played by new technologies in the current crisis. Moreover, Blit (2020) claims that the pandemics accelerated automation and reallocation processes, which may usher in the future of work as more and more jobs have been substituted by machineries. Economists have long tried to explain the search-matching frictions on the labor market, ascribing different causes to the jobless recovery phenomenon: the sectoral reallocation investing many industries (Aaronson *et al.*, 2004); the increasing job-polarization due to the substitution of middle-skilled jobs (Autor and Dorn, 2013); and the so-called labor hoarding theory (Schwartz and Burger, 2016). Alle these theories share the idea that there is some structural change affecting the labor market, and that the so-called technological unemployment is becoming a *new normal*, which also requires a paradigm shift in the economic theory to look for sustainable solutions.

2.2 The "machinery question" today

Debates about technological unemployment, however, are nothing of new in the human history. Mokyr *et al.* (2015) show how 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 "machinery question", discussing the relationship between technological development and (un)employment, has been a hot topic for at least two centuries. First posed by Ricardo, who devoted the chapter 31 of his *Principles* (1821 [2001]) to the topic, it concerns 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". A century later, Keynes (1930 [2010]) in the *Economic Possibilities for our Grandchildren* discusses the acceleration in the technological development experienced between the 18th and the 19th century, defining the consequent technological unemployment of those years as "only a temporary phase of maladjustment".

Predictions of automation making humans redundant have been made before going back to the Industrial Revolution, when textile workers, most famously the Luddites, protested that machines and steam engines would destroy their livelihoods, but also in the 1960s when someone feared at first firms installing computers and robots, or in the 1980s when PCs landed on desks. Analogously, nowadays someone looks at Artificial Intelligence (AI) as a threat to humanity or a "mighty power which has come before we knew how to employ it rightly" (The Economist, 2016). There are many historical examples of how new technology introduced in the productive processes changed them: Bessen (2015) claims how rather than destroying jobs, automation redefines them, changing their nature and the skills required to them – and that it does so in ways that reduce costs and boost demand.

However, a widely note study by Frey and Osborne (2017) examined the probability of computerization for 702 occupations and found that 47% of workers in America had jobs at high risk of potential automation. Moreover, as Autor (2015) warns, this time, many workers will have to switch from routine, unskilled jobs to non-routine, skilled jobs to stay ahead of automation. In previous waves of automation, they could switch from one kind of routine work to another; but now the big data techniques allow companies to train machine-learning systems to perform the jobs of more and more people. The number of jobs lost to more efficient machines is only part of the problem as – as Autor states – automation may prevent the economy from creating enough new jobs. Throughout industry, the trend has been to increase 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.

Even Ford (2016) agrees that the current technological revolution is different from the earlier one as, in contrast to earlier disruptions, which affected specific sectors of the economy, the effects of today's revolution are "general-purpose": according to him, from janitors to surgeons, virtually no jobs will be immune as the labor-saving technology is whittling their numbers.

Hence, there are two basic aspects to be addressed: by one side, this time the transition is likely to be faster, as technologies diffuse more quickly than they did two-hundred years ago; on the other hand, this may cause income inequality to grow further due to the consequent mass unemployment. And without work how will people have enough money to support the mass consumerism on which any remaining jobs might depend? After the Industrial Revolution, governments took a century to respond with new education and welfare systems: nowadays a quicker response is required to allow employers and policymakers to help existing workers acquire new skills and prepare future generations for a workplace stuffed full of AI. Furthermore, the Covid-19 pandemics imposed an acceleration towards the technological transition, but it also pushed the unemployment rates up, with the resulting explosion of poverty that millions of people experienced. For all these reasons, many scholars support the idea of a universal basic income to deal with this transition, and after the pandemics outbreak, many studies push towards this direction (*e.g.* Nettle *et al.*, 2021; Ståhl and MacEachen, 2021; Johnson and Roberto, 2020).

2.3 A basic income to cope with the technological transition

It was still 1858 when Marx wrote his *Fragment on Machines*: in his view, while the development of machinery led to the oppression of workers under capitalism, it could also offer a prospect for future liberation through what he calls the general intellect, *i.e.* the combination of technological expertise and social knowledge. Finally, today, the structural changes of labor market driven by the technological transition, together with the dramatic consequences of the outbreak of the Covid-19 pandemics on the economic scenario, have made more urgent to think at how updating welfare systems, making at the same time possible to modernize the way at we think at human labor in society. Both economic insecurity conditions experienced by the precariat and concerns about AI and automation have led to calls for a stronger safety net to deal with growing social inequalities and to protect people from labor-market disruption and help them switch to new jobs: hence, both labor market scholars and AI commenters support the idea of a universal basic income as a right.

According to Van Parijs (2004), one of the most distinguished supporters of this idea, 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". This 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 (Standing, 2008). 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 tool 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 and the Covid-19 crisis has shed further light on the urgence of the topic. Since the idea took hold, there are many pilots and experiments all around the world projecting the implementation of such a measure (see Banerjee *et al.*, 2019;

Hoynes and Rothstein, 2019; Torry, 2019 for a review), and there is some debate around its feasibility (*e.g.* Colombino, 2018; Martinelli, 2017; Browne and Immervoll, 2017). This work aims at contributing to it with a theoretical agent-based model, testing its feasibility, but also discussing whether it would be an effective tool to guarantee economic stability during the technological transition.

3. The model

3.1 Defining the agents and the starting assumption of the model

I build an agent-based model (ABM)[1] to investigate the linkages between technological innovation and paradigm shifts affecting the structure of the labor market, then I simulate the introduction of a universal basic income as a possible tool to update the welfare system while facing structural changes. As I opt for a concept-driven theoretical model and not for a data-driven one, the parameters applied in the assumptions are arbitrarily chosen, and the model aims at reflecting the dynamics of interaction and at shedding a light on what scenarios could emerge from those, under given conditions.

The model basically relies on two classes of agents – namely individuals and firms – that interact on both the labor and the goods market. Individuals may be employed or unemployed, being all of them assumed to be part of the workforce and displaying different level of skills: the starting population of the model is equally distributed over low-skilled, medium-skilled, and high-skilled individuals. Furthermore, they are provided with a personal endowment, which is randomly assigned at the start of the simulation and is a function of the level of skills if they are employed as the model evolves through its cycles.

Firms are classified according to their main features, being: i) the productivity of capital; ii) the productivity of labor; iii) their capital endowment; iv) their size; and v) the maximum number of workers that they can employ. As far as the productivity of capital and labor are concerned, they are not meant in a traditional manner as

[1] For those who want to explore the model, they can find it at the following repository on GitHub https://github.com/eleonorapriori/basic_income__netlogomodel and play with it using NetLogo 6.1.1.

complements: then, they do not measure how much each of these factors contributes to a unit of product, but rather the efficiency of the investments on capital and labor of each firm compared with that of the other ones. As in Moretti (2013), I define productivity as the amount of output which a worker (or a machine) generates for each worked hour. Each of these two parameters take values between zero and one, and I classify firms according to a semiotic map representing the productivity of K on the abscissa axis and the productivity of L along the ordinate axis. As a result, an equal number of firms is distributed over four clock faces in the graphical interface of the simulation:

- the bottom-left sided quarter represents an area with low productivity of both K and L;
- the bottom-right sided quarter represents an area with low productivity of capital and high productivity of labor;
- the top-left sided quarter represents the opposite situation, *i.e.* an area with high productivity of K and low productivity of L;
- the top-right sided quarter represents an area with high productivity of both K and L.

This distribution allows to reflect four situations occurring in the global labor market: i) areas with low levels of technological development and low levels of employment rates; ii) areas with low levels of technological development and high levels of employment rates; iii) areas with high levels of technological development and low levels of employment rates; and iv) areas with high levels of technological development and high levels of employment rates.

Capital endowment then is a proxy of firms' savings: at the start of the simulation it assumes random values, then it evolves over time depending on the results which firms earn on the market. Firms are also classified according to their size distinguishing between small-sized firms, middle-sized firms, and big firms. The size of the firms, combined with the capital endowment *CE* and the productivity of labor *L*, determines their capacity in terms of job-places, *i.e.* the maximum number of workers *NW* they can employ. Then the equation defining the firms' capacity of creating job places is given by:

$$NW = (\alpha + \beta CE) * (1 - L)$$

where the parameters α and β depend on the firm's size. Hence, the maximum number of workers is an endogenous variable, which depends positively on the capital endowment and negatively on the productivity of labor, as the more productive the workers are, the lower is the number of individuals that firms will hire.

Once that the number of workers that each firm can employ is set, the model computes which workers each firm needs according to their level of skills. To do so, I assume that all the workers are employed in job positions reflecting their level of skills and that firms' labor demand depends on their productivity mix between capital and labor as follows:

- firms with low levels of productivity of both K and L distribute their workers in a 50% of low-skilled workers, a 40% of middle-skilled workers and a 10% of high skilled workers since they mainly require low-skilled and middle-skilled workers due to the low level of technological development;
- firms with low productivity of K and high productivity of L require the 50% of low-skilled workers, the 30% of middle-skilled workers and the 20% of high skilled workers;
- firms with high productivity of K and low productivity of L distribute their workers in a 25% of low-skilled workers, a 15% of middle-skilled workers and a 60% of high skilled workers since the labor-force demand shifts from low-skilled to high-skilled workers to deal with the increased technological level of the tools used by the firm;
- firms with high productivity of K and high productivity of L employ 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.

As the model considers search-matching frictions, it may be the case that firms do not fill all their job places, with some workers remaining unemployed due to an informational asymmetry, preventing demand and supply to meet each other. According to these rules, firms employ only the unemployed workers following a random process, then workers cannot choose the firm where to work, but only accept the first offer they get. Once that the hiring process is done, employees perceive a wage accordingly to their level of skills; unemployed individuals do not receive a wage but only an unemployment benefit and firms with no workers are ruled out from the market.

3.2 The baseline dynamics: the goods- and the labor market

Upon this framework, I build the model over 100 subsequent cycles representing each one year of the simulation. In each cycle individuals and firms interact on the goods market and firms update their labor demand according to the results they perform on the latter.

Individuals are provided with a consumption function extracting random values from a normal distribution, whereas firms' production decisions are defined setting a minimum produced quantity according to their size, plus a random value extracted from a normal distribution to provide heterogeneity to the model. Then, firms' cost function is given by the sum of the wages of its workers and by a fixed parameter multiplying their productivity of capital, which defines the firms' fixed costs. In this way, the model computes the price level as the relation between the total quantity of goods demanded and produced (assuming the market selling a unique good), and the price is applied to the exchanges on the market. Hence, individuals' personal endowment is updated adding the annual wage (or an unemployment benefit lower than the minimum wage if they do not work, which is built by equally taxing all the firms operating on the market) and subtracting their consumption quantity multiplied by the price level. Analogously, firms update their capital endowment according to the profit/loss performed on the market. Furthermore, agents observe prices in the two previous periods, and adjust their production and consumption choices according to them (*i.e.,* consumers demand smaller quantities and firms produce more if prices grow over time, and vice versa).

Similarly, firms adapt their choices on the labor market according to their results on the goods market and decide whether to fire some of their employees or hire some new. Then, if they perform some loss or if their capital endowment becomes lower than a given threshold, they fire a share of their workers, selecting which ones according to their productive mix. Specifically, the level of productivity of L determines the number of workers to be fired: low-labor productivity firms will fire higher amounts of workers rather than high-labor productivity ones due to efficiency reasons. Instead, the level of productivity of K determines which kind of workers to fire, as firms with higher levels of productivity of K will prefer to fire low- and middle-skilled workers and keep those with higher level of skills, since they enhance the technological endowment of the firm, whereas firms with low productivity of K are more in need of low labor. With a specular logic, firms that perform profits above average or whose capital endowment is greater than an arbitrary threshold will demand more labor to keep on growing. Again, the productivity of L determines the quantity of demanded labor, whereas that of K impacts on the quality of demand. Hence, firms with lower productivity of L will require higher numbers of new workers to compete with their high productivity of labor rivals, which being more efficient can demand lower numbers of new employees. Firms with higher levels of productivity of K will invest on hiring high-skilled workers, whereas those with lower productivities of K will ask for low- and middle-skilled work.

3.3 A policy to manage the technological transition

Once that the baseline of the model is set, I introduce a technological shock affecting the system at a given time. This represents the impact of innovation on the model and is assumed to be exogenous and to affect firms with different probabilities, reflecting their heterogeneity in the aptitude at embracing changes. Then, if the aptitude of a firm in exploiting innovation is higher than a given threshold, the shock invests the firm. When the technological shock hits a firm, this enlarges its productivity of capital by a given size, which is exogenously defined with a parameter. Now, firms may react to the shock adopting one of two opposite behaviors: they can either implement the production of goods keeping or choose to replace workers with machineries. To do so, firms would fire a consistent share of their workers as the increase in productivity of K allows them to keep the production levels stable by significantly reducing their cost function cutting the cost of labor. I explore which scenarios will arise by each of these cases in the *Results* section.

However, under the latter hypothesis, I test different universal basic income proposals to face the technological unemployment scenario that emerges. A basic income provision being equal to the maximum wage is distributed to all the individuals in the model some cycles after that the technological shock hits the economic system. As the agent-based model I represent is a closed system, where all the economic flows come from the interaction between the agents and no external resources are introduced, the basic income proposal is financed through firms' taxation. Different criteria of taxation may be selected, and here I investigate four scenarios: i) a taxation equally divided among all the firms; ii) a redistributive model where firms are taxed according to the profits they gain; iii) 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); iv) a taxation based on stimulating firms in investing even more in technologies, with higher contributions for firms displaying lower productivities of capital, being the opposite principle of the "robot tax". However, the model does not highlight crucial differences among different financing criteria.

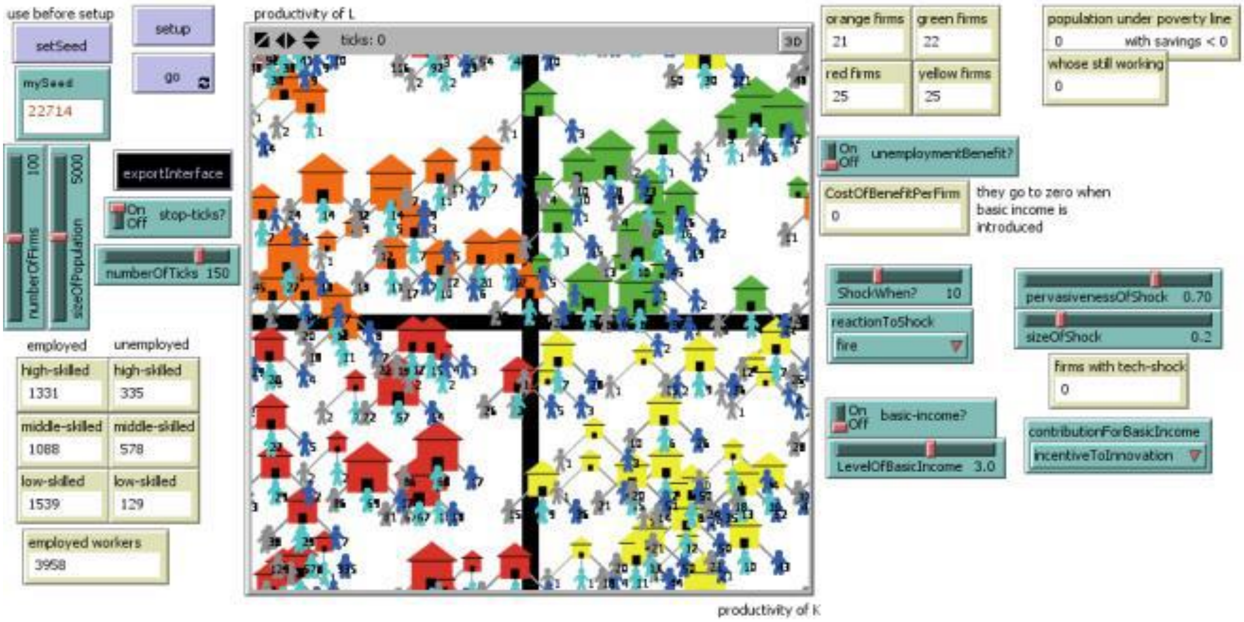
4. Results

4.1 Calibration of the model

In this section I present the results emerging by running the simulation for 100 subsequent cycles (*i.e.* one-hundred years), and I explore the different scenarios arising under different input conditions of the model.

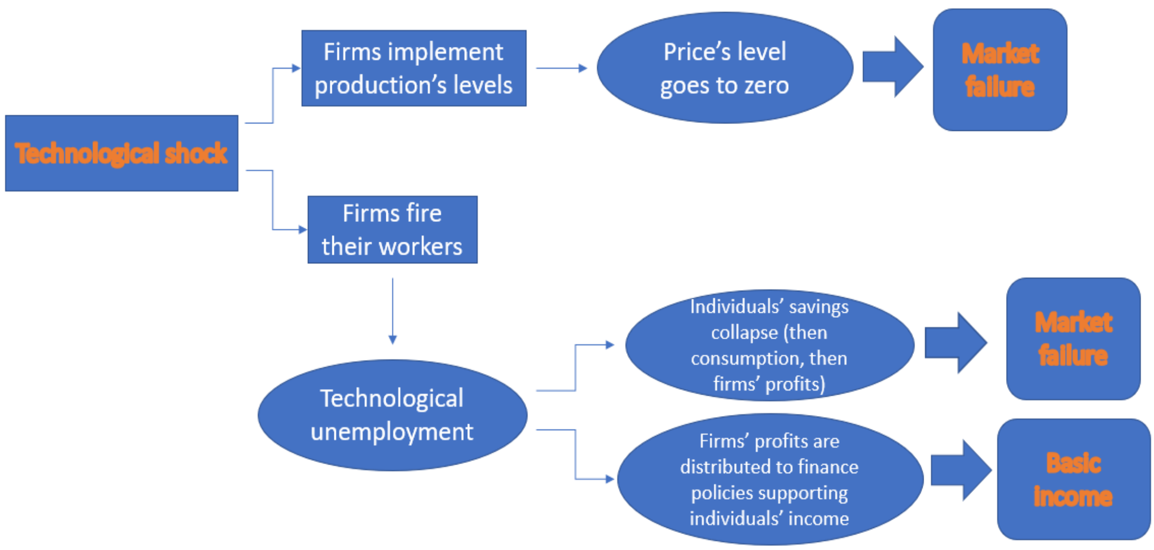
Before focusing on them, let me recall some items on the calibration of the model, being them equal for all the scenarios. Population is split according to their level of skills in three groups of equal size and the same holds for the four classes of firms; the population size is 5000, and the number of firms is 100. As this parametrization choice is arbitrary, one can explore different starting settings by modifying the parameters of the model, which is available at: https://github.com/eleonorapriori/basic_income__netlogomodel. According to the starting setting I defined above, one can easily observe that one agent out of five is unemployed in the model, as firms absorb 3958 workers over a population of 5000. Furthermore, the rules defined while modelling the process of matching between demand and supply on the labor market leads to a strong job-polarization scenario, where firms are more incline to employ low-skilled workers (the 92% are employed) and high-skilled workers (the 80% are employed) rather than middle-skilled ones (where only the 65% have a job). This scenario reflects the tendency of the job-market to employ either low labor or highly specialized workers, whereas middle-skilled job-places are progressively disappearing as they are those with higher probability of being substituted by machineries. Moreover, it is interesting to notice that firms with high productivity of labor are more likely to be ruled out from the market because they do not employ workers, meaning that they find it harder to find the match with the workers they require.

FIGURE 1 • THE GRAPHIC INTERFACE OF THE MODEL AFTER THE INITIAL SETUP OF THE MODEL.



Once that I discussed the starting setting of the model, let me now introduce the scenarios that I focus on. In any case, the model considers that after a given number of cycles a technological shock affects the market, and this implies a structural change in the traditional trends that emerge from the events occurring at any cycle on both the goods- and the labor market. Now, two different scenarios may emerge depending on how firms react to this shock. They can react either by implementing their production levels; or by firing most of their workers. Under this second hypothesis, there are two further possible scenarios: no policy measure to face the situation is implemented; otherwise, a basic income measure is introduced. Figure 2 sums up the flow chart of the outcome scenarios which arise under the different hypotheses of the model.

FIGURE 2 • FLOW CHART OF THE POSSIBLE OUTCOME SCENARIOS OF THE MODEL

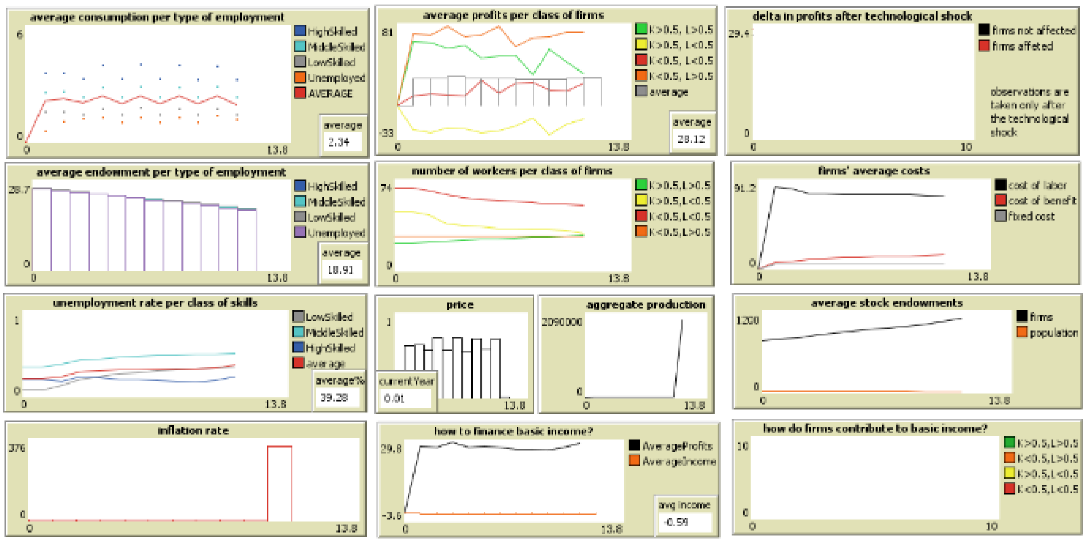


The model aims at investigating the effects of a technological shock that affects the market by augmenting firms' productivity of capital under different conditions. As far as concerns with the calibration of the model, I set the pervasiveness of the technological shock at the 75%, meaning that it affects three out of four firms with high productivity of capital, and the half of those with low productivity of K. 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, the results – of a limited number of firms with no significant impact on the global outcomes of the model. Moreover, the model is robust to different values of the size of the shock, meaning that different values of the parameter affect the intensity of the observed results, but the general outcome is always the same. For the results described hereafter, I assume that the size of the shock, *i.e.* the increment in firms' productivity of K, is of 0.2.

4.2 Can a technological innovation lead to market failure? Two unexpected scenarios

Figure 3 shows the general outcome when firms implement the production to react to the shock.

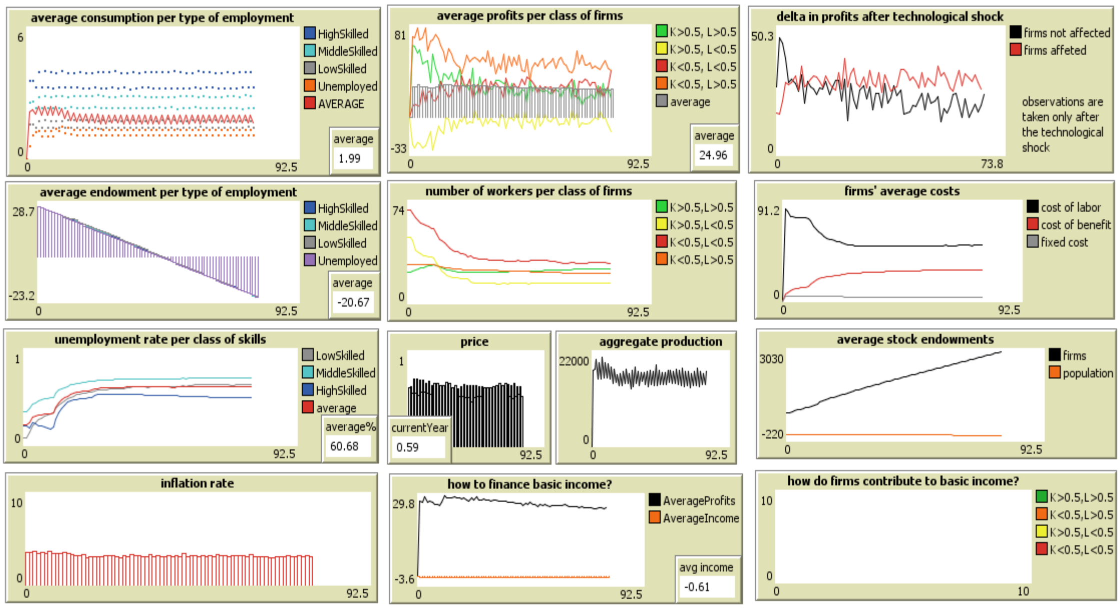
FIGURE 3 • GENERAL OUTCOMES WHEN FIRMS REACT IMPLEMENTING THE PRODUCTION'S LEVELS



Under this scenario, firms implement the quantity of the goods that they produce (and hence supply) as they experience an increase in the productivity of capital and keep the number of workers that they employ stable. This hypothesis drives to an unexpected outcome as the huge rise experienced by the production level yields a supply excess, which pushes the price level to zero. In fact, if the consumption levels (*i.e.* the demand for goods) keeps constant and the supply of goods that firms produce suddenly increases, the price level collapses as its formation mechanism is given by the ratio between the total quantity of goods produced in the system and the total quantity of goods demanded. To put it with the math, when the denominator of this fraction tends to infinite, the result goes to zero, and this clearly emerges by observing the details of aggregate production and of price in Figure 3. This result recalls the famous contribution of Robbins (1932), who defined economics as the science studying the relationship between ends and scarce means which have alternative uses. This specification of my model drives to the disappearance of the notion of scarcity itself in economics, and hence it determines a market failure as prices become meaningless since they do not measure anymore some relationship between production and value coming from the interaction between the agents. When prices become irrelevant, also profits and incomes are meaningless because individuals can catch the goods on the market for free. All of this shows that such a specification of the model drives to highly instable outcomes, which turn out to be unsustainable in the long run: for this reason, the model cannot be run for all the 100 cycles.

After observing that this scenario turned into an unsustainable market failure, let me introduce the next one, whose general outcomes are summed up in Figure 4.

FIGURE 4 • GENERAL OUTCOME WHEN FIRMS REACT TO THE SHOCK FIRING THEIR WORKERS AND NO POLICY IS IMPLEMENTED



In the case that firms opt for firing a vast majority of their workers to react to the shock, a technological unemployment scenario emerges: the 60% of the population in the model are not employed under these conditions. This represents a long-run change in the structure of the environment that I simulate: since the model is a closed system where no external resources are introduced, when a permanent high unemployment rate arises, this rapidly turns into a drop in the average consumption as the agents do not perceive an income to be reinvested on the goods market, and this in turns drives to an economic crisis scenario due to the collapse in firms' profits. When workers switch from employed to unemployed, they change their budget constraints to face the loss of their wages. Since their consumption functions allow for expenditures higher than the in-flows that they gain from working or from perceiving an unemployment benefit, they continue purchasing goods on the market, even if lowering their consumption. Looking at firms' aggregate production, it is possible to observe a drop, which is due to the reduction in the consumption level. All this implies a twofold effect: the first one is the collapse in firms' profits; the second one is that since individuals purchase more than their budget constraint, they reduce their personal endowment cycle by cycle until it gets negative. Hence, also under these conditions the emerging outcome is an unsustainable scenario: all the individuals end under the poverty line after just eighty cycles and their savings assumes negative values, meaning that they should get into debt to buy their consumption goods. Then, also this hypothesis drives to a market failure as it yields a scenario where the agents can no longer keep the cycles of production and consumption self-sustaining due to the structural change on the labor market that the technological shock provoked.

4.3 Introducing basic income

Hence, when a technological unemployment scenario emerges, this drives to the unsustainability of the simulated model as it triggers an economic crisis which propagates through the consumption-production cycle. To prevent this from happening, I simulate what would be the effects of introducing a public policy managing with the paradigm shift: the model proposes a universal basic income supporting all the individuals in facing this transition. The role of this measure is to provide all the population with an income to support their consumption, hence stimulating the demand on the goods market and allowing firms to keep their production's level.

FIGURE 5 • GENERAL OUTCOME WHEN A UNIVERSAL BASIC INCOME IS INTRODUCED TO FACE TECHNOLOGICAL UNEMPLOYMENT

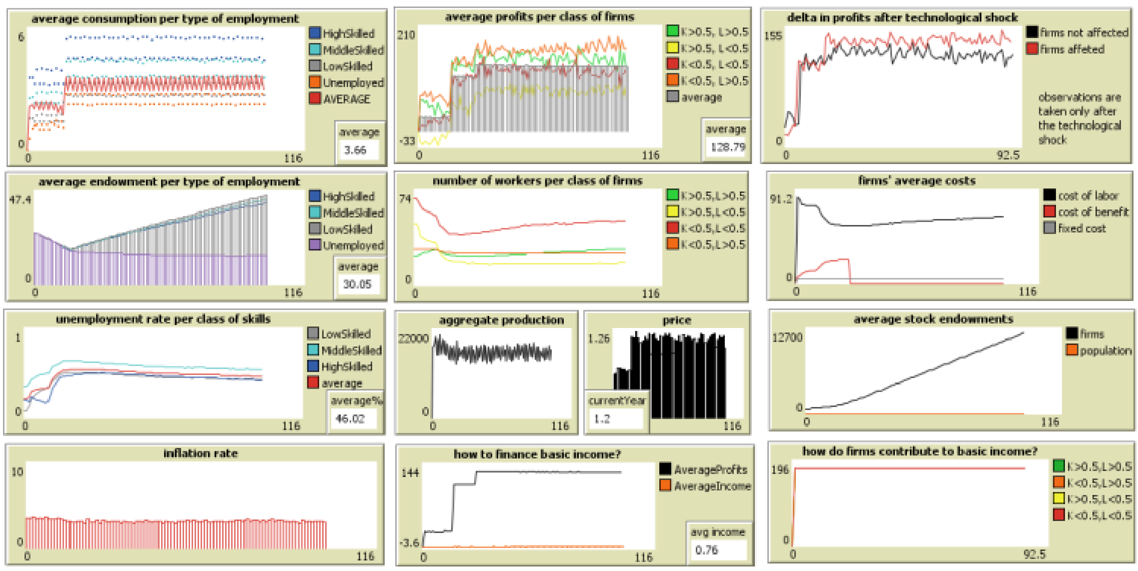


Figure 5 reports the general outcome observed when a universal basic income policy is introduced. The simulation aims at studying different aspects of the measure: i) to show its feasibility displaying that it led to a stable macro-economic pattern; ii) to verify its impact on individuals' savings, and then their consumption trend; iii) to analyze the effects on the labor market; iv) to observe whether it affects firms' profits and production levels; v) to discuss how these interact with prices, showing whether there is some effects on the inflation rate.

The first aim is satisfied, as the model achieves a stable long-run macroeconomic pattern where the dynamics of interaction between the agents self-sustain the model itself, meaning that the economy is sustainable and the economic flows driving the economic cycles are in balance.

The introduction of the basic income policy brings stability to the model, but also to the agents themselves: individuals' endowment levels decrease cycle by cycle until cycle 15, which is the moment individuals start to perceive their basic income. Hereafter, they increase their savings if they work (and therefore perceive a further wage plus the basic income) or keep them constant around the same level of endowment if they do not, and only the 8.2% of the individuals lie under the poverty line: a great result if compared with the previous scenario, where the whole population ended under the poverty line (and even in shorter times). Clearly this implies positive consequences for the consumption levels, boosting a virtuous circle since higher consumption levels sustain higher firms' profits.

As far as the dynamics of the labor market are concerned, there is a sensitive drop in the unemployment rate, which reaches the 47% with respect to the 60% of the previous scenario. This happens because the market is more efficient and then the number of firms disappearing is lower. Moreover, it is suggested in the literature that individuals perceiving income supporting measures tend to invest this amount to train and enter the productive process again obtaining higher-qualified job positions: the model does not account for this hypothesis, but it should be considered in a further development. However, observing the distribution of job-places in the simulation, it again displays a high level of job-polarization, but high-skilled workers turn out to be those with higher probabilities to be employed. This can easily be explained by considering the increment in firms' levels of innovation (*i.e.* productivity of capital), which pushes the demand for highly-qualified workers up, whereas middle-skilled workers are again those suffering more from the job places disruption. Low-skilled workers instead are still required on the labor market, since there are no incentives to invest in machines substituting their tasks as they work at low cost. Workers are distributed over the four types of firms according to patterns noticeable: firms with high productivity of capital do not decrease the number of their employees, rather they experience a slight constant increase. Firms with low productivity of capital experience a significant drop in the number of workers they employ, but those with also low productivity of labor are still the firms with the highest number of employees, whereas those with high productivity of labor end the simulation with the smallest number of workers.

The overall effect of the basic income on firms' profits is positive as supporting consumption levels it supports firms' supply, and then their profits. Let me look at the increment in firms' profits observing how they are distributed for each typology of firms. Firms with low productivity of capital and high productivity of labor are those with the highest profits as their cost function is the slimmest one, even if it is also interesting to notice how the distance with the firms with high productivity of both K and L is thinner after the shock, displaying that the latter have gained some comparative advantages from the technological shock. Moreover, it is shown the delta between the firms affected by the technological shock and those which did not receive it: this clearly displays the comparative advantages that the shock produces as it allows to reduce the costs of production. However, it seems clear that the productivity of capital and labor are the determinants of the profits' level as they enter the cost function equation.

The technological shock yields a slight reduction in the aggregate production level, which is due to several firms quitting the market as they remain with no workers: this together with the boost in the consumption levels coming from the income-supporting measure determines a huge increase in price's level. However, looking at the consumption levels expressed in terms of units of goods purchased it is possible to observe that its value keeps constant over time, meaning that some inflation occurred, and it is reasonable to reconduct it to the measure, but that this should not worry as the real consumption level keeps constant and satisfies all the agents yielding to a stable pattern of the model.

To conclude, my model provides different proposals on the ways to distribute taxation among firms to finance the public policy. Being the model a closed system, the only way to achieve the financial affordability to implement the measure is to raise money by taxing firms' profits. To do so, I identify four possible criteria: a) by dividing the total amount equally among all the firms; b) by dividing the total amount according to the levels of profits (*i.e.* asking the firms with more profits to contribute more); c) by applying a "robot tax" (*i.e.* taxing the firms with the highest levels of productivity of capital); d) by incentivizing firms to invest in innovation and technology (*i.e.* taxing firms displaying lower levels of productivity of capital).

It is interesting to notice that when the tax levy is equally distributed among all the firms, there are no firms quitting the market after the introduction of the basic income measure. As far as the profits-based taxation case, there is a high variability depending on the fact that firms' profits levels hugely vary from one cycle to the other one. While applying the robot tax and the incentive to innovation, the tax levy keeps a value constant over time since I simulate only one technological shock, and after its occurrence, the productivity of capital – being the parameter upon which these measures are built – keeps a constant over time.

As I yet mentioned before, firms experience a huge increase in their profits' levels due to the introduction of the basic income. Clearly, average values of profits do not change in the different financing hypotheses, what changes is the distribution across different typology of firms, even if also the latter seems to be restrained. In each of the four cases, firms with high productivity of labor and low productivity of capital are those performing highest profits, and those with high productivity of capital and low productivity of labor are those more in trouble; and this depends on how the productivity of K and L impacts on the firms' cost function determining their profits.

Hence, switching from one policy to the other does not affect considerably firms' results, but the measure has an important redistributive effect, shifting financial flows from firms to population. Moreover, it seems to bring large benefits both for population and firms, since it provides stability and robustness to the whole economic system by sustaining the demand for goods. Broadly speaking, the impact of universal basic income on the economy of the model seems to be pretty positive: simulated trends show 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, the stability of the economic pushed down the unemployment.

5. Conclusions

Moving from the Covid-19 pandemic crisis, I analyze some recurring patterns in the recessions over the latest twenty years. I focus on the impact of technological innovation on the labor market, discussing whether the technological unemployment observed in these trends could be considered as a structural change. After presenting the outlines of the historical debate on the so-called "machinery question", I suggest that the current technological revolution may represent a *new normal*, which hence requires an update of the welfare system to cope with the economic transition. Arguing in favor of a universal basic income proposal to do so, my contribution presents a theoretical agent-based model to discuss both its feasibility and the benefits it would yield. The model simulates a simple economy where individuals and firms interact both on the goods- and on the labor market, developing adapting behaviors and with some endogenous mechanisms defining the features of their ecology: among this there is the price formation mechanism, turning out to be crucial in determining the system' dynamics. The model is thought to study the effects of a technological shock on the system, exploring alternative outcome scenarios which may arise from agents' choices and testing the impact of introducing basic income as a public policy, also comparing different criteria to finance the measure. Results show that with no public intervention technological shocks may lead the model to a market failure in the case of both firms implementing a coping strategy of hyper-production and under a technological unemployment hypothesis of firms' reaction. On the contrary, a redistribution scheme obtained taxing firms' profits and providing individuals with a basic income would prevent this outcome, guaranteeing a larger stability of the model during the technological transition and supporting the long-run sustainability of the system.

6. References

Aaronson D., Rissman E.R., Sullivan D.G. *et al.* (2004), *Can Sectoral Reallocation Explain the Jobless Recovery?*, «Economic Perspectives-Federal Reserve Bank of Chicago», 28, pp. 36-49

Autor D.H. (2015), *Why Are There Still So Many Jobs? The History and Future of Workplace Automation*, «Journal of Economic Perspectives», 29, 3, pp. 3-30, doi:10.1257/jep.29.3.3

Autor D.H., Dorn D. (2013), *The Growth of Low-skilled Service Jobs and the Polarization of the US Labor Market*, «American Economic Review», 103, 5, pp. 1553-1597, http://dx.doi.org/10.1257/aer.103.5.1553

Banerjee A., Niheaus P., Suri T. (2019), *Universal Basic Income in the Developing World*, «Annual Review of Economics», 11, pp. 959-983, doi:10.1146/annurev-economics-080218-030229

Bessen J.E. (2015), *How Computer Automation Affects Occupations: Technology, Jobs, and Skills*, «Boston University School of Law, Law and Economics», Research Paper, n. 15-49.

Blit J. (2020), *Automation and Reallocation: Will Covid-19 Usher in the Future of Work?* «Canadian Public Policy», 46, S2, pp. S192-S202, https://doi.org/10.3138/cpp.2020-065

Browne J., Immervoll H. (2017), *Mechanics of Replacing Benefit Systems with a Basic Income: Comparative Results from a Microsimulation Approach*, «The Journal of Economic Inequality», 15, 3, pp. 25-344, doi:10.1007/s10888-017-9366-6

Coates B., Cowgill M., Chen T., Mackey W. (2020), *Shutdown: estimating the COVID-19 employment shock*, Grattan Institute, Working Paper n. 2020-03

Colombino U. (2019), *Is Unconditional Basic Income a Viable Alternative to Other Social Welfare Measures?*, «IZA World of Labour», 128, doi:10.15185/izawol.128.v2

Fana M., Torrejon Perez S., Fernandèz-Macìas E. (2020), *Employment Impact Of Covid-19 Crisis: From Short Term Effects To Long Terms Prospects*, «Journal of Industrial and Business Economics», 47, pp. 391-410

Ford M. (2016), *Rise of the Robots: Technology and Threat to a Jobless Future*, New York, Basic Books.

Frey C.B., Osborn M.A. (2017), *The future of Employment: how susceptible are jobs to computerization?*, «Technological Forecasting and Social Change», 114, pp. 254-280, doi.org/10.1016/j.techfore.2016.08.019

Hodder A. (2020), *Technology, Work and Employment in the Era of COVID-19: Reflecting on Legacies of Research*, «New Technology, Work and Employment», 35, 3

Hoynes H.W., Rothstein J. (2019), *Basic Income in the US and Advanced Countries*, «Annual Review of Economics», 11, pp. 929-958, doi:10.1146/annurev-economics-080218-030237

Johnson A.F., Roberto K.J. (2020), *The COVID-19 Pandemic: Time for a Universal Basic Income?*, «Public Administration and Development», 14, doi: 10.1002/pad.1891

Keynes J.M. [1930] (2010), *Economic Possibilities for Our Grandchildren*, in *Essays in Persuasion*, London, Palgrave Macmillan, https://doi.org/10.1007/978-1-349-59072-8_25

Martinelli L. (2017), *Assessing the case for a Universal Basic Income in the UK*, (IPR Policy Brief), Institute for Policy Research, University of Bath, http://www.bath.ac.uk/publications/assessing-the-case-for-a-universal-basic-income-in-the-uk/

Marx K. [1858] (1973), *Fragment on machines*, in *Grundrisse. Foundations of the Critique of Political Economy*, New York, Vintage Books (6th ed.)

Mokyr J., Vickers C., Ziebarth N.L. (2015), *The History of Technological Anxiety and the Future of Economic Growth: Is This Time Different?*, «Journal of Economic Perspectives», 29, 3, pp. 31-50

Moretti E. (2013), *The New Geography of Jobs*, New York, Mariner Books

Nettle D., Johnson E., Johnson M. *et al.* (2021), *Why Has the COVID-19 Pandemic Increased Support for Universal Basic Income?*, «Humanities and Social Sciences Communications» 8, 79, https://doi.org/10.1057/s41599-021-00760-7

Ricardo D. [1821] (2001), *On Machinery*, in *On the Principles of Political Economy and Taxation*, Kitchener, Batoche Books

Schwartz J.S., Burger J.D. (2016), *Jobless Recoveries: Stagnation or Structural Change?*, http://dx.doi.org/10.2139/ssrn.2793153

Ståhl C., MacEachen E. (2021), *Universal Basic Income as a Policy Response to COVID-19 and Precarious Employment: Potential Impacts on Rehabilitation and Return-to-Work*, «The Journal of Occupational Rehabilitation», 31, pp. 3-6, https://doi.org/10.1007/s10926-020-09923-w

Standing G. (2008), *How Cash Transfer Promote the Case for Basic Income*, «Basic Income Studies», 3, 1

«The Economist» (2016), *March of the Machines*, June 25th

Torry M. (2019), *The Palgrave International Handbook of Basic Income. Exploring the Basic Income Guarantee*, Cham, Palgrave Macmillan, doi:10.1007/978-3-030-23614-4

Van Parijs P. (2004), *Basic Income: A Simple and Powerful Idea for the Twenty-First Century*, «Politics & Society», 32, 1, pp. 7-39