The influence of productivity gains, their distribution, and market structure on economic growth in a Sraffian Supermultiplier model. Short-, medium-, long-term trends and secular tendencies

An analysis performed through a multisectoral macroeconomic SFC-AB model

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PhD Thesis
XXXIV cycle

UNIVERSITà POLITECNICA DELLE MARCHE
DIPARTIMENTO DI SCIENZE ECONOMICHE E SOCIALI

September 2022

Abstract
The purpose of this work is to investigate the properties of the Sraffian supermultiplier model in which technological change and autonomous demand, coming from the public sector, jointly affect macroeconomic dynamics. The growth rate of the economy is determined by the path of productivity growth, which frees up the labour force to be used in the production of alternative goods, and by the public sector, which, if unwilling to accept high unemployment, must increase its expenditures in order to generate the necessary demand for achieving macroeconomic growth.

Given the assumption that the technological change is affected by the sales level (due to the possibilities it opens in terms of labor division) -at all layers (macro, meso and micro), in contrast to the majority of supermultiplier models, the long-run growth rate of our model is also affected by the income distribution (both functional and personal) that shapes the level of total demand and its composition across sectors, and by the market structure that determines the production allocation among firms.

For the purpose of our research, we have developed a multi-sectoral macroeconomic Agent based - Stock Flow consistent model (AB-SFC). The model is grounded on a theoretical framework representing a monetary economy of production (e.g., Graziani, Lavoie) where the principle of effective demand determines the level of output, while innovation is characterized by a typical Schumpeterian process of creation and destruction. The functional income distribution is determined as in the classical theory and it is the resultant of the struggle between capitalists and working class. In particular, the markup fixed by firms on normal unit-cost of production determines the normal rate of profit. Money is endogenous and it is injected into the system by banks which grant loans to firms to finance investments or wages anticipation, and by government expenditure financed by issuing public bonds.

In the second chapter, a short-term perspective is taken and the impact of annual macroeconomic performance on the long-term trajectory of the economy is analysed. First, we demonstrate that process innovation is a necessary but insufficient condition for economic growth (and a potential source of economic instability) and that, to achieve macroeconomic growth, a hands-on public sector is required (that increase its debt every time an increase in productivity occurs and stabilises the economy). Then, we investigate how different appropriations of the productivity gains (and, consequently, different distribution configurations) affect the future trend of productivity (and, consequently, the long-run growth rate of the economy) via changes in the aggregate volume level and their allocation between sectors.

In the third chapter, the focus moves to the extremely long-term dynamics of the capitalist system and the connection between process innovation, market concentration, and income inequality. We start exploring which can be the secular trends that come with economic growth and the structural changes forces, which are naturally behind it. Specifically, we show how the reduction of the employment, at the sectoral level, which logically comes with increasing level of labor productivity and consumers preference for variety can have repercussions in terms of market structure and personal distribution.

Then, the economic growth consequences of the potential combination of market structure and income inequality, which may occur in economies experiencing growth and structural changes, are then analysed.

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1 Introduction, literature review and contribution

Economic growth is one of the most relevant areas of economics. It aims to explain how mankind has witnessed, throughout capitalism's history, a remarkable growth in consumption levels, both in terms of consumption quantity and quality. A bunch of historical data exists that demonstrates just how narrow the typical consumption level was only a couple of centuries ago.

The problem of economic development remains a major one for humanity (Acemoglu, 2012). Already Adam Smith was himself questioning the capabilities of the capitalistic system to bring prosperity and economic growth, especially for the poorest classes. At that time, the difference between rich and the poor countries was very little (Angus, 2001), but since then, the gaps have increased reaching levels never seen before. Whereas some countries have experienced impressive growth rate for extended periods, others are still far behind from the level reached by the most advanced economies. Moreover, over the last three decades, most of the advanced economies have witnessed a number of structural changes and income inequality appears to be increased while economic growth has slowed (Syverson, 2019).

Despite the great relevance and importance of these issues, there are still many unknowns and major challenges to be addressed. A more holistic approach seems to be needed. As Kuznets emphasized, economic development is not just about growth of aggregate output; it also encompasses all the structural transformations of an economy that range from the composition of the consumption bundle to employment dynamics, as well as the population demographic and its entire social and institutional framework. For this reason, even though there have been numerous studies and the topic has attracted great attention, this research field continues to be an area of interest.

Any explanation of the way the capitalist system has developed and conquered almost all the world cannot escape from making explicit reference to those forces that allowed an enormous increase in the quality and quantity of the goods produced over time.

This study is not an historical analysis of the possible factors behind such progress, but rather we look at one of the possible determinants, and we study its main factors and repercussions these have in the macro variables. Specifically, we investigate how the different market structures and the different personal and functional distributions, affecting the GDP level and the production allocation among sectors and firms, may determine productivity dynamics and therefore economic growth.

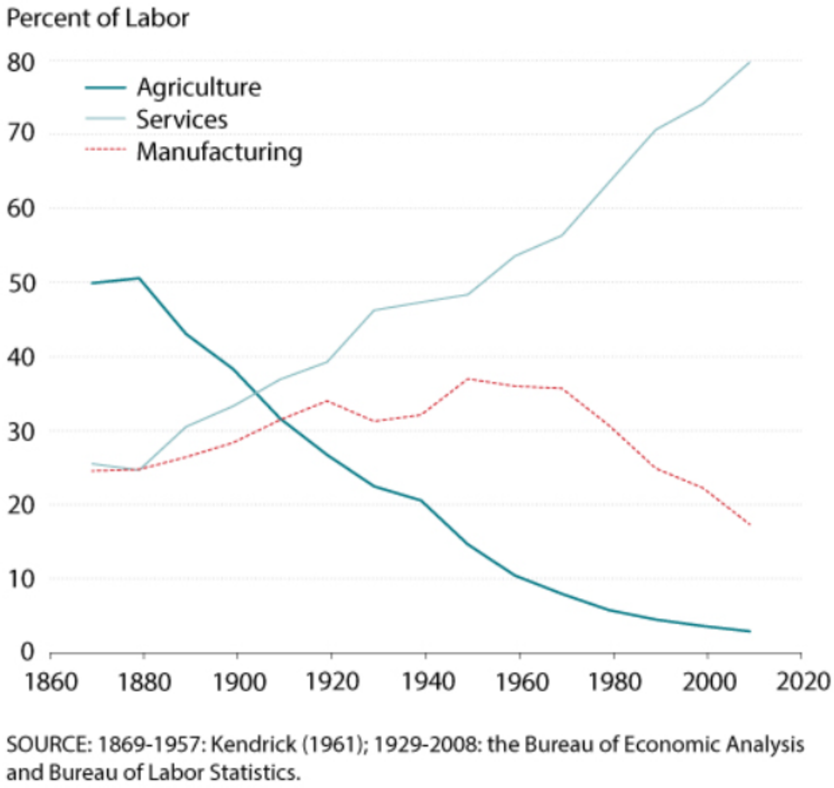
1.1 Current debate

In the history of the capitalist system, advanced economies have observed some structural changes that have implied a sectoral shift of the share of output (employment) from "old" sectors to new "sectors", such that the share of the agriculture sector, in almost all the advanced economies, has drastically diminished in favor of the service sector (Alvarez-Cuadrado et al., 2018). Figure 1 presents the labor share in the US economy.

According to Henry (2014), the US economy has experienced a general trend in the reduction in the consumption share for "basic good" across all the income categories. The consumers in the highest income quantile have experienced a decline from 33.8% to 27.7.8%, while those at the lowest quantile have seen their share decreasing from 63.5% to 54.5%. In contrast, there has been a significant increase in the consumption share of "luxury" goods. This increase has been uneven among the various socioeconomic classes and has primarily affected the highest income earners.

These sectoral transformations that encompass complex interplays between technical change, productivity trends and employment dynamics are at the center of the policy debate.

Figure 1: Labor share in United States



In fact, there is still a different understanding of whether innovation is beneficial or not for employment and for the economic growth overall (Calvino and Virgillito, 2018).

The vibrant debate about the role of technology in shaping future labor markets and overall economic well-being is age-old and encompasses both demand side concerns regarding the possible satiation of consumers' needs (Keynes, 1978) and more supply side theories that shed light on the fear about job displacement.

The *future of work* debate started with a seminal work by Chris Freeman (Freeman and Soete, 1987) that looked in more detail at the different effects of technical change on employment. But, even as early as 1821, Ricardo questioned weather innovation was beneficial or detrimental for employment and both Karl Marx and even Adam Smith investigated the effects of the technological progress on the distribution of income and on the long-run economic growth.

The debate is still open and is particularly interesting nowadays that stagnation theories (Summers, 2015) are back in the limelight. Moreover, since the end of the 70's and onset of the 80's, the aggregate wage share seems to have drastically decreased and there is an ongoing discussion on the divergence between wages and productivity. More recently, after the COVID 19 pandemic, US wages are seen to be slightly increasing and researchers are wondering whether this is due to past productivity improvements not yet shared or whether the working-class is gaining ground against the capitalist class and if the prices will sooner or later react.

There is also a vivid debate about the inequality level and its nexus with economic growth. In fact, the Kuznets curve has been criticized by Piketty (2014) and appears to be no longer valid. The trend reversed from the 1980s in the most advanced countries.

Nowadays, there are numerous survey-based studies on the impact of process innovation, both at sectoral level and firm level. At sectoral level, technological change seems to be seen as having a negative effect on employment level (Piva and Vivarelli, 2017). On the contrary, firm-level studies have found process innovation to have a positive effect (Calvino and Virgillito, 2018). Such apparently conflicting evidence can be explained by their different starting points. Indeed, a firm gaining market share might well increase its labor demand because of higher sales at the expense of the share of its competitors, leaving the overall sectoral output invariant and reducing the total employment level in the industry (Dosi and Mohnen, 2019).

1.2 Growth theory, a literature review

Since the emergence of the field of economics, the studies have focused primarily on the potential determinants of economic growth, with classical economics mainly concerned with the generation and distribution of the surplus product. With the Marginalist Revolution this approach practically disappeared from the agenda of the economic profession. Only with the effort of Harrod and Domar, who extended the Keynes's principle of effective demand to the long-run, did the focus return to economic growth.

Roy Harrod and Evsey Domar both concluded that any equilibrium growth path should satisfy the condition $s^*v = n + m$, that is that the product of the fraction of aggregate output saved and the reciprocal of the capital–output ratio should equal the sum of the rate of growth of the working population and the rate of growth of labor productivity. If this were not so, smooth growth compatible with full employment could not possibly persist. At that time, it seemed that the only solution was to make endogenous one or more of these parameters so that the economy could always reach a stable growth path.

While the classical tradition, founding its theory on the acceptance of Say's Law (according to which supply creates its own demand, because all savings are automatically invested in capital accumulation), by assumption, avoids the instability problem related to the demand side, the economists after Keynes had to deal with that. N. Kaldor and L. Passinetti, for instance, in order to solve the instability problem highlighted by Harrod and Domar, introduced the functional distribution of income between profits and wages into their models, such that the endogenous nature of the savings rate led to the path of sustainable development.

The earliest neoclassical growth model chose capital intensity as the primary adjustable parameter. This gave enough flexibility to make steady-state growth something other than an anomaly, through the possibility of price-guided adjustments. It was explicitly only meant to hold in the long run, without considering any impact that the business-cycle could have had in the long-run steady-state. However, the neoclassical theory of factor–income distribution was unable to explain the per capital growth, which was captured by factors exogenous to the model (Solow's residuals).

Instead, assumptions about the division of production among social classes not based on economic elements and the possibility of full reproducibility of the means of production, with the constant returns to scale technologies, allowed the classical economists to construct a theory of growth able to ensure the possibility of persistent (endogenous) growth.

Lastly, in response to the unsatisfactory "Old growth theory" which could not explain the per capital growth, the "New growth theory" was born and, since then, the Endogenous growth models have become the workhorse of the mainstream growth theory.

Following the classification proposed by Salvadori (2003), the economic growth models can be grouped according to the tendency of the rate of profit to fall to zero or not and therefore the possibility for perpetual growth.

- Constant returns to capital models are those models that assume constant return to scale technologies and are similar to the Ricardian model which obtains a stationary state only because of the scarcity of the land available. If land were not needed as an input or if it were available in abundance, then the marginal productivity of labor would be constant, whatever the amount of labor and capital. As a consequence, the rate of profit, as well as the growth rate, would also be constant.

- Backstop technology models assume the possibility that the limits given by the scarcity of any input can be overcome by the technological progress that makes the production possible without those inputs that are available in limited quantities. In this way, with a continuous substitution between labor and the limited inputs with new machinery and new production processes, the marginal productivity of labor would be continuously decreasing, but bounded from below. In this case the profit rate and thus the growth rate would be falling, but they could never fall below certain positive levels. The system would grow indefinitely at a rate of growth that asymptotically approaches the product of the given saving rate times the value of the achieved (bounded) profit rate.
- Increasing returns to capital models assume increasing returns technologies. In line with Adam Smith, some post-Keynesian economists (such as Kaldor (1957)) and the proponents of the endogenous growth models (EGM) are the main sponsors. Profit and growth rates increase when additional factors are engaged and/or progressive productivity is assumed. If a uniform rate of profit has to be maintained, it must be assumed that the increasing returns are external to the firm and dependent on the market size of the economy, as a whole. In any case, the sum of profits and wages equals the product of the given amount of labor (and capital) multiplied by the corresponding level of output per unit of the factors.

1.2.1 Classical theories

The authors that usually go under the umbrella of the Classical economics were mainly concerned with the generation and distribution of the surplus product and focused mainly on the analysis of the supply-side. According to a circular flow view of the production, the surplus product corresponds to the production left after the wage goods and what is necessary for the replacement of the means of production have been deducted from the annual output. This surplus can then be consumed or accumulated. The capitalist economy described by the Classical economists is based upon the classes structure and while the capitalists anticipate the wages, which in turn are entirely consumed by the working class, and invest the profits, the rentiers consume all the rents. The economy system is seen in motion, as a sequence of long-run positions where the rate of profits, the rents and prices might change according to the technologies available, which are adopted. The overall level and the composition of output and the real wage rate depend upon the conditions of the labor market. The real wage rate determines the rate of profits, and thus the rate of growth, through the saving-investment channel. Indeed, classical economists, in line with neoclassical economists, accept the idea that savings can be equalized to investments through the capital market.

We can consider two kinds of models in the classical framework; the Ricardian model and the Smithian model. While in the first one the scarcity of natural resources implies the tendency of the economy toward a stationary state, the second model highlights the progressive nature of the economic growth. The Marxian models share with the latter the possibility of the infinite accumulation. However, Marx assumed a tendency of the system toward declining profit rates because of the increase in the composition of the organic capital.

Both models are commonly interpreted as being characterized by the assumptions that capital and labor are employed in fixed proportions. While the amount of land is constant, labor supply is constant only in the short run, whereas in the long run it is infinitely elastic at the natural wage rate w. This means that the supply of labor can be increased (or decreased) indefinitely at wage rate w. However, the Malthusian law regulates the rate of increase of the population; a wage rate higher than the natural one, which maintains constant population, yields a population increase.

Below, we report some of the more important growth theories developed by the Classical economists.

1.2.1.1 Adam Smith

The renowned Scottish economist believed the main driver of economic growth to be the productivity dynamics. Productivity that comes from the divisibility of labor which, in turn, is determined by the market size is what allows the poorer classes to become less poor and the richer classes to become richer. This is possible because of the assumed increased returns of the factors that are involved in the production process, since new technical knowledge is treated, as in main endogenous growth models, as a public good. Moreover, any limits due to the scarcity of the natural resources are set aside or taken to be compensated by the increase in productivity and therefore there is no upper limit to labor productivity. In fact, as other classical economists believed, the amount of work force cannot constitute a limit to economic growth. Indeed, the additional work force required in the process of accumulation is generated endogenously. Labor power is considered as a commodity, the quantity of which is regulated by the effectual demand for it. Within such a setting, there is no limit to growth. Adam Smith explained economic growth thoroughly as an endogenous phenomenon where the growth rate depended on the saving and investment decisions, since economic growth depended on the division of labor that in turn was related to the market size which was based on the level of capital accumulation. Also, creativity and inventiveness of the agents were considered of primary importance, framed within a given social and historical condition and institutional settings. People specialized in observing and analyzing the manner of production (”the philosophers”) were responsible for its improvement in terms of efficiency.

Smith introduced the concepts of induced and embodied technical progress. He also introduced the idea of learning by doing, learning by using, workers skills improvement and time saving through doing the same task, instead of task fragmentation among many workers. Labor productivity was also the result of the invention of specific machinery.
All this led to the idea of increasing returns. Such increases were external to firms, so that economic growth was compatible with the classical hypothesis of a uniform rate of profit. Indeed, a larger market generates a larger division of labor among firms so that a larger productivity of labor is experienced for all firms and capitalists have not the power to exploit any advantageous position.

However, labor productivity that comes from labor division might come at the expense of an ever-increasing social alienation.

1.2.1.2 David Ricardo

Similar to Adam Smith, Ricardo argues that the growth rate is endogenous to the economic system but, in contrast to Smith, he believes that the profit rate may fall to zero. This decline is related to the possible diminishing returns in agriculture and the exhaustion of certain natural resources.

Indeed, given the diminishing returns on land (which is due to the scarcity of land of equal quality) and the fact that wages are constant, there has to be an increasing amount of capital employed on it. Therefore, over time, there has to be a decreased rate of production.

In fact, like Smith, Ricardo believed that savings and investments would largely come from profits, whereas wages and rents played a negligible role. As for most of the classical economists, the pace at which capital accumulates also regulates the pace at which labor grows.

The renown Ricardian theory, that goes under the ”scarcity principle” name, means that certain prices might rise to very high levels over many decades. Once both population and output begin to grow steadily, land tends to become increasingly scarce relative to other goods. The law of supply and demand then implies that the price of land will rise continuously, as will the rents paid to landlords. The landlords will therefore claim a growing share of national income, and the share available to the rest of the population decreases.

Even though the author believed this to be a natural course of events leading to a stationary state, he considered the possibility that an increase in technology could offset, at least partially, problems related to the scarcity of the natural resources. If this were the case, then limits to the economic growth would be relaxed.

1.2.1.3 Karl Marx

In the reproduction schemes, Marx studied the conditions under which the system is capable of reproducing itself in an upward spiraling level. According to him, the expansion of the economy at a persistent growth rate is a possibility and the growth rate depends on the proportion of the surplus value that comes back into the productive system. Indeed, the Marx's reproduction schemes show how demand for capital comes from capital itself, directly or indirectly and reflects the Marx's idea that capital accumulation is an element immanent in the capitalist process of production. This possibility, though, does not prevent the system from suffering a number of crises that might come from the exhaustion of the Industrial Reserve Army or the Law of the Tendential fall of the rate of profit or the crisis of realization.

According to Marx, the "Accumulate, accumulate!" strategy is too simplistic. Indeed, with high capital accumulation, the probability of crisis increases while the firm's ability to survive a crisis is weakened because of the dependency from the financial market. Under these conditions, even a super competitive environment can make the accumulate strategy not a viable and convenient one.

The crisis in the production sphere is linked to erosion of the reserve army that happens in motion. At the beginning, the accumulation process (capital widening) is satisfactory because the competition leads to increases in productive capacity while the markets are growing and no significant change in the technical composition of capital occurs. Then, however, erosion of the reserve army gives workers the power to ask for higher real wages. Following the workers increased bargaining power, the capitalists are forced to invest in new machineries that embody labor-saving technologies. The capital deepening mode, therefore, in contrast to the capital widening mode, implies a fratricidal form of competition between capitals because it brings cost advantages to the leading accumulators and threatens the survival of all the incumbents. The capital deepening mode, therefore, might destroy rather than preserve the value of the preexisting stock of capital. Now, if the losses in value of the preexisting capital stock are taken into account, negative profit rates may occur and an "invest or die" situation emerges. For this reason, the accumulation process is a contradictory process.

The lack of coordination and the intensification of the level of competition can facilitate collusion among firms such as oligopolistic structures, trade associations, and conglomerate enterprises that enable firms to reduce uncertainty and generate greater profits. However, this might lead to excessive remuneration to the top manager and risk-averse strategies that widen the gap between the technologies adopted in the market and those at the leading edge. Thus, the higher the competition the higher the incentive to collaborate, but the longer the collusion lasts the greater the incentive for some firm to undermine the process.

Realization crises, instead, are caused by the firm's inability to sell all the goods produced. This situation slows the accumulation process because of the uncertainty of the expected rate of capacity utilization and thus of the expected rate of profit. According to Marx, realization crises are problems of disproportionality between the way income is distributed between classes in the sphere of production and the way income is allocated across the different markets. Another approach regarding realization crisis is the one that is often erroneously labeled as 'underconsumptionist' (Bellofiore, 2011). This is the idea that the decreasing share of consumption in the national income cannot always be counterbalanced by a rising net investment demand because of the profitability of the new machines that depend on future sales which, in turn, would be less and less stable. In any case, such types of crises arise from a lack of coordination typical of the capitalist system.

Even though an endless growth was theoretically possible, in reality Marx foresaw an end to the capitalism production system, beyond the crisis related to the exhaustion of the Industrial Reserve Army or the crisis of realization. According to him, the capitalist production system is characterized by a tendency of the rate of profit to fall, as a result of a rise in the organic composition of capital. Such a reduction would then affect the engine of accumulation. Another reason, similar to this one, is that there would be a workers union or revolution because of the indefinite increase of the capital share of the national income. Moreover, even though Marx thought of the technological progress as an immanent force that springs from competition (among capitals and between capital and labor), he neglected the possibility of a durable technological progress and, thus, a steadily increasing productivity because it would serve, to some extent, as a counterweight to the process of accumulation and concentration of private capital.

1.2.1.4 Malthus

Thomas Robert Malthus is mostly known because of the ideas he published in 1798 in his essay "An Essay on the Principle of Population". In this study, he presents what is now known as the Malthusian Law of Population, according to which the population grows in a geometric progression while food production grows in an arithmetic progression, resulting in food scarcity and famine until birth rates decline. Moreover, the theory claims that growing population rates contribute to a rising supply of labor and to lower wages because of the market forces guided by the differences between demand and supply. In essence, Malthus feared that continued population growth lends itself to poverty.

The increase in population that is caused by a temporary increase in the real gross domestic product of a country (like in all the classical Economics) makes resources ever more scarce and the higher demand and limited resources will, in turn, cause a decline and the end of economic growth.

So, while for Ricardo the primary threat to the economic system was the long-term evolution of land prices and land rents, for Malthus it was overpopulation. They both underestimated the impact an efficient technical progress could play on the smooth running of an economy.

1.2.1.5 Von Neuman

The most sophisticated linear model of endogenous growth was elaborated by John Von Neumann in 1945. Von Neumann studied a multisector version of the classical Smithian–Marxian model. From the formal point of view, this model is a multisector linear model with only labor as the non-produced means of production; there are therefore multiple goods produced with constant returns–to–scale technologies.

The real wage rate, that covers the subsistence level, is given and paid at the beginning of each production period. The wages are, as such, part of the capital advanced that has to be reintegrated at the end of the production period and all the surplus reinvested.

In von Neumann's model there is no problem of resource scarcity and the rate of growth is determined endogenously. While all primary factors are available at whichever amount at zero price, labor is assumed to be available at the required amount at a given real wage rate.

1.2.2 Keynesian growth theories

The first economists that tried to adapt the Keynesian scheme to the long-term economic growth were Harrod and Domar. Harrod (1972) was the first to question the way an economic system can reach a position of long-run steady growth and, consequently, his work is conventionally seen as the beginning of modern growth theory. For him, the steady-state growth was nothing other than the adaptation to the dynamic case of the notion of static equilibrium.

Changes in investment levels determine changes in output (through the multiplier) and, at the same time, increase the capital stock and, therefore, increase the productive capacity of the economy and the potential output. Harrod's main novel proposal is represented by the so called "marriage of the acceleration principle and the multiplier theory" (Harrod, 1939), from which the "warranted rate" can be derived. A unique rate of growth exists (warranted growth rate) $g^k = su/v$, which is compatible with the optimal rate of utilization of capital, and therefore does not induce further changes[1]. However, this equilibrium growth rate has two disturbing properties. It does not guarantee full labor employment and it is not stable. A rate of accumulation higher (lower) than g^k will manifest itself as a level of capital utilization higher (lower) than u_n. Therefore any deviation from equilibrium will be amplified in a self-reinforcing explosive or implosive pattern (Harrodian instability).

In the Harrod-Domar model, if the actual growth rate, the warranted growth rate and the natural growth rate (sum of population growth and labor productivity grow) are equal, both capital and labor are used fully and the growth path is stable. Harrod called such situation "the golden age".

Therefore, full employment is the exception rather than the norm: the economy needs to expand at its natural rate to keep a steady employment rate, but nothing ensures this will happen because the determinants of the warranted and natural rate are unrelated. Moreover, there are no self-correcting mechanisms capable of dampening deviations of the actual rate from the warranted rate. Equilibrium requires equalization of savings, which are dependent on households, and investments, which are instead in the hands of the capitalists. Hence, this is difficult to fulfill. The savings rate is exogenous, and the same applies to any growth of population which depends on its natural dynamics. In addition, since the model also assumes a constant ratio of capital to labor, with no possibility of substitution of factors of production, there is no mechanism to balance the three growth rates.

The first models that attempted to answer the questions rising from the Harrod-Domar model were proposed by Robinson (1965), Kaldor (1957, 1961) and Pasinetti (1962). These models (post-Keynesian models) were characterized by full capacity utilization of plants, flexible income shares and a functional relationship between the rate of capital accumulation and the rate of profits. Since output is rigid and only capitalists save (not in the model developed by Pasinetti, where the workers also save and receive interest on their savings), the required level of saving (following an exogenous increase in the investment level) is determined through changes in the normal distribution (in favor of the capitalists) that result from the increase in prices (because of higher investments) and wage rigidity. In these models the economic growth depends on the accumulation rate that ultimately depends on the profit reached by the capitalists.

The seminal work of Nicholas Kaldor, borne as a direct answer to both the contemporary Keynesians growth theory (Harrod) and the Neo-classical theory, sparks the development of the Post-Keynesian growth literature where long-run growth is seen as a self-reinforcing process driven by the interplay and co-evolution of effective demand and technological dynamics.

[1] From I=S, $g^k = I/K = S/K = S/Y * Y_n/K_n * Y/Y_N$. Given an average propensity to save (S/Y) equal to the marginal one (s), Y_n/K_n being equal to the inverse of the normal capital-output ratio v and Y/Yn defining the actual degree of capacity utilization

Kaldor (1954, 1961) states that investment, technical progress and population growth are the cause of growth. The driving force of growth is technical progress, and the observed increases in savings, investments and in the population growth were consequences. In this, he follows the Keynesian approach in conceiving the expansion of the economy as driven by psychological and social factors like 'human attitude to risk-taking and money-making'. He maintains, following the fundamental Schumpeterian intuition, that a satisfactory growth theory cannot be constructed without a business cycle theory. He distinguished two growth-regimes of the capitalist economies: the stagnant growth path of the early stages of capitalism and the self-sustained growth path of a mature stage of capitalism. The differences between the two relied on the capitalist availability of the financial resources to start the accumulation process.

Later on, Kaldor (1966, 1972) proposed the (linear) relationship, today known as the Kaldor-Verdoorn Law, between the productivity growth rate and the growth rate of output. This relation results from the efficiency gains that derive from the resources generated in the past invested in renewing the production capacities and from a macro-level division of labor that allows for macro-level efficiency gains. The expansion of aggregate demand drives increases in production capacities and future productivity growths.

A second group of theories (labeled Neo- Kaleckian models) was inspired by the works of Kalecki (1971) and Steindl (1976). They assume that firms underuse their productive capacity and apply mark-up procedures in determining prices. In the so-called Neo- Kaleckian model of growth and distribution, which is nowadays, perhaps, the most influential non-Neoclassical growth model, the saving level is achieved through variation in the output level and in the utilization capacity (in the short run). Thus, in the long-term, then, the productive capacity adjusts to higher levels. While the actual profit increases, the functional distribution is untouched. The functional distribution only determines the rate of growth according to different regimes (profit-led or wage-led). Capital accumulation depends on the investment function and is driven by profitability (through the rate of profits) and by effective demand (through the degree of capital utilization). The long run is shaped by the sequence of the short run and this model allows for less than full utilization of both capital and labor. In fact, because factor demands are inelastic to factor prices, there is no market based equilibrating mechanism toward full utilization of all factors of production.

However, the alternative growth models have also shown some drawbacks; in the post-Keynesian models the functional distribution is the adjusting (endogenous) variable, determined by the economic growth (differently from the classical assumption) that depends on the accumulation rate, whereas, in the Neo- Kaleckian models, there are serious problems related to the Harrodian instability since the degree of capacity utilization reached in the steady state is different from the normal one. Moreover, all these alternative demand-led models see the engine of growth in an exogenous increase in the investment level; this seems unsatisfactory.

Another model which shares the Keynesian tradition, and attempts to respond to the unsatisfactory aspects of the post-Keynesian models, is the Sraffian-Supermultiplier model. As originally presented in Serrano (1995), its main purpose is to determine output according to the principle of effective demand, through an integration of the traditional Keynesian multiplier and an investment function based on the accelerator principle.

The Sraffian Supermultiplier model treats investments as fully induced by higher autonomous demand, and therefore growth is shaped by the independent evolution of the demand components, such as exports, public spending or credit-financed consumption. The higher savings required by an increase in the rate of accumulation are generated through increases in the output level that are made possible by short-run rises in the degree of utilization of the existing stock of capital. In the long-run equilibrium of the model, capacity adjusts to demand and a normal utilization of the productive capacity is restored. Coherently with the Classical and Sraffian tradition, income distribution is exogenously determined by social and historical factors and not the result of capital accumulation.

To conclude, the growth models that have a Keynesian structure are characterized by the influence of the different components of the aggregate demand and by a theoretical framework which does not assume full employment as a given but as a possible scenario that might be reached, or not. What differentiates a Keynesian theory of growth from another framework is the idea that growth comes from demand and, for this reason, investments and the active role of the state play a key role. Moreover, while the majority of growth theories conceive saving as wholly transformed into investment through the capital market and the price adjustments, Keynesian theory conceives investment as the source of the savings and, for this reason, is intrinsically connected with the theory of the business cycle. Short term dynamics affect, as in the Kalesky view, long term dynamics.

1.2.3 Neoclassical framework

The neoclassical growth theory also arose as a reaction to the Harrod-Domar models of the 1940s and 1950s, which stated the difficulty for the system to reach its steady growth path given the possibility of the economic system having a long period of labor shortage and a long period of unemployment. The solution to such instability has been to make endogenous one of the parameters that the authors kept independent (sv = n + m), those of capital output ratio, savings propensities, growth rate of the population and labor productivity. Within the neoclassical framework, most studies have treated as endogenous the capital intensity of production and the rate of saving and investment. However, most neoclassical growth theories have treated the technological progress as exogenous and, until the 1980s with the pioneering works of Lucas (1989) and Romer (1986), there were no formal theorizing about the rate of endogenous technological progress.

The neoclassical models presuppose Say's Law and, therefore, omit any considerations about the role of aggregate demand in the growth process. Since the economic growth is determined by supply factors alone, its main concern is the allocation of scarce resources over competing needs. Technical progress is not even considered or treated as an exogenous variable. Generally, the Neoclassical Growth Model claims that the level of capital accumulation is the main determinant of economic growth. Moreover, the supply side of the economy is often described by an aggregate production function which has constant return to scale and implies the possibility of full substitutability between the inputs of production, which are usually labor and capital. Income distribution is determined by the relative scarcity of the productive factors and the economy modeled is composed of a representative agent only, who earns a salary as worker and receives interest income as the owner of capital assets.

The neoclassical models of economic growth begins with the model of Robert Solow (Solow, 1999) which proposed a long term economic growth model in response to the results of the Harrod - Domar's model (Solow, 1956). In his work, he demonstrated the insignificance of land, capital and labor in terms of per capita growth, which had to be explained by other factors ("residuals"). His aim was different from the Keynesian growth theory; his major objective was to construct a theory of general full-employment growth, and show the tendency of the economy to convergence towards a sustainable growth path. He conjectured that the growth theory should explain the potential growth of economies, without paying attention to the business cycle and its possible effects on the long-run trend of the economy. For this reason, Solow assumes that prices are flexible so that all the markets are cleared. The equilibrium of the capital market implies that in case investments are different from savings the price adjustment yields the equalisation between the two, until the steady state is reached. The equilibrium of the labor market, instead, yields that there is always full employment of labor so that the economy is in a steady state.

The problems identified by the Harrod–Domar model were solved by introducing the assumption of perfect substitution of factors of production, which in turn removed the assumption of a constant ratio of capital-output and the convergence process towards the steady state was ensured by the assumption of decreasing productivity of capital.

According to the Solow model, permanent per capita growth is only achievable through factors external to those taken into consideration (residuals). Indeed, the shifts in saving could cause only level effects in the long-run, that is in the absolute value of real income per capita while only the growth rate of technology and the growth rate of the population sets the long-run growth rate of the economy, and only the former can affect the growth rate of output per worker. Such a model will have therefore a tendency to converge to a steady state, with zero per capita growth.

Before the endogenous growth model was presented, the neoclassical growth theory was dominated by the Solow growth model and its optimal growth counterparts, such as the Ramsey model where the saving rate was determined endogenously according to an inter temporal maximization.

In the 1960s, the Cambridge capital controversy warned about the possibility of deducting an aggregate production function with decreasing real marginal product of capital from an economic system characterized by heterogeneous capital goods (Garegnani, 1970). Such a critique, which undermined the foundations of the neoclassical theory of growth and distribution, pushed many non-neoclassical economists to look at the process of technical change as opposed to capital/labor substitution, in order to embed in the growth models a different distribution theory, not reliant on the marginalist theory.

In contrast to the Solow growth model, a new family of models that appeared in the economic field during the 80's, referred to as "New growth theory", attempted to capture and make endogenous those factors at the bottom of a permanent economic growth. The endogenous growth models were firstly formalized in the 1980s with the pioneering works of Lucas (1989) and Romer (1986) which made the rate of technological progress endogenous . In these models, the long-run growth in income per capita depends on the investment decisions, that are in turn affected by the savings behavior and the policy decisions. In this perspective, the main novelty of these models is to justify a production function characterized by non-decreasing returns to scale with respect to the accumulated factors. This result is accomplished either by removing the scarcity of natural resources or by introducing technical progress.

The simplest endogenous growth model is the so-called AK model (Rebelo, 1991) that simply avoids the diminishing return to capital. Indeed, instead of the usual parametrized Cobb–Douglas production function, it makes use of the typical features of the Ramsey model with the assumption that the production function is linear with respect to the physical capital (that is as a special case of a Cobb–Douglas function with constant returns to scale) and there are not problems related to scarce resources. Given these assumptions, a constant positive rate of growth of the per capita consumption can be obtained. As in all the neoclassical models, and unlike the Keynesian models, production is allocated between consumption and savings according to the household utility function and, as usual, savings always equalize the investment level through the capital market. In the simple AK model per capita variables grow at a fixed rate, regardless of the level of capital.

The aim of the endogenous growth theory is therefore, firstly, to overcome the shortcomings of the Solow and Ramsey models which were unable to explain sustained growth. It adopts Ramsey's model as a reference, and the saving level is the outcome of the decision of a maximising agent which solves an intertemporal optimization problem. In order to overcome the diminishing marginal productivity of capital, the assumption of imperfect competition is adopted which makes investment in R&D activities reasonable for better technologies or, more in general, for better products and this shows a substantial break away from previous growth models founded in the neoclassical framework. The possibility of profits indeed is necessary to incentivise the invention sector to continue its activity. Such models endogenise the production of new ideas and introduce the Schumpeterian idea that technical progress is linked with imperfect competition. However, differently from the Schumpeterian models, the production and introduction of new ideas in these models is conceived as a smooth process, while for Schumpeter the introduction of new invention causes turbulent dynamics and is linked, as in Kaldor's view, to business cycle. Generally the non-decreasing returns to scale comes from non-rival and completely non-excludable goods (e.g. externalities, knowledge accumulation, learning by doing, business organization).

One strand of study uses human capital accumulation to sustain growth (e.g., Lucas Jr (1988), Jones and Manuelli (1990) and Rebelo (1991)), another strand perpetuates growth through the accumulation of knowledge, either through learning by doing (e.g., Romer (1986), Stokey (1988) and Young (1991)) or through R&D (Romer (1990), Grossman and Helpman (1991b) and Aghion et al. (2005)).

The inventions are either embodied in vertical intermediate product innovation (Grossman and Helpman, 1991a), or in new types of capital goods (Rivera-Batiz and Romer, 1991), or in an increase in product variety (Grossman and Helpman, 1991b), or in new instruction for mixing raw materials (e.g., Romer (1990), Arrow (1971) and Lucas (1989)). There are also models that reason on competitive frameworks. In such a framework, the state might play a role as institution defending property rights, supporting the development of science and technology, or a favorable investment climate. Table 1 shows a summary of the main EGM.

Kurz and Salvadori (Kurz and Salvadori, 2003) relate the new growth theory to the theories proposed by the classical economist. Indeed, they show how the main factors and the causal mechanisms at work that allow economic growth are very similar, and for such, new growth theory owes much to the Classical tradition.

1.2.4 Evolutionary economics

From the discussion so far, it is difficult to consider economic growth without thinking about the dynamics and the factors that determine the innovation process and, more generally, technological change.

The first economists already considered the dynamics and consequences of increases in efficiency (productivity); some brilliant economists even came up with a flawed theory related to the development of the capitalist system based on the innovation theories that they had in mind. Wrong interpretations about the role of technological change and its power have indeed led to wrong predictions about the dynamics of the capitalist system, particularly those of Mathus and Ricardo. Technological change enabled the increase in population to be managed without experiencing a huge lack of resources (and thus a decrease in the population). Similarly, even if land rents remained high for an extended period, the relative value of the land reduced, as the share of agriculture in national income decreased. Therefore, theories on economic growth can hardly be separated from a theory on technological change and evolutionary economics are surely those that focus more on the technological change.

Evolutionary economics, an approach that goes back at least to Malthus and Marx and scholars like Veblen, von Hayek and, certainly, Schumpeter, has seen a strong revival in economics since the pioneer work of Nelson and Winter (1982). Although there are authors that distinguish between "old" and "new" evolutionary economics (e.g. Hodgson (1993), the core of such line of thought relies on the idea that innovation is the main factor behind long-run economic development. The advantage of evolutionary economics is that it can account and analyze the properties of dynamical systems which displays various forms of non-linearities typical of evolutionary processes.

The evolutionary approach to growth draws attention to three aspects that are neglected in both neo-classical and endogenous growth models. First, technological advancement ought

Table 1: Endogenous growth models, a review

Source of growth	**Vector of innovation**	**Source of innovation**	**Authors**
Knowledge spillover. The stock of knowledge arises from previous design projects	New types of capital goods	R&D incentivized by monopoly rents	Rivera-Batiz and Romer (1991)
Products follow a stochastic progression up the quality ladder and enjoy a limited run at the leading edge of technology. Entrants learn the state of knowledge	Ongoing product improvements (intermediate and final good)	R&D incentivized by monopoly rents	Grossman and Helpman (1991b), Aghion and Howitt (1990) on technology obsolescence (intermediate goods)
Technological spillovers through reduction in the cost of product development	Expand product variety	R&D incentivized by monopoly rents	Grossman and Helpman (1991a)
Knowledge diffusion. Stock of human capital determines the rate of growth. Increase in productivity thanks to non-rival and partially excludable good	New instructions for mixing raw materials	R&D incentivized by monopoly rents	Romer (1990)
		Competitive framework. Increase in knowledge arises as an induced effect of physical/ human capital accumulation. Learning by doing	Arrow (1971) and Lucas (1989)
Obstacles of technology diffusion from mismatch between knowledge and technologies or technology standardization			Acemoglu et al. (2012), Acemoglu and Zilibotti (2001)

to be conceptualized as a disequilibrium process involving high ex–ante uncertainty, path dependency and long–lasting adjustment processes. Secondly, growth theory should be based on a more realistic theory of the firm that stresses also firm capabilities, rather than just investment in human capital and R&D. Thirdly, it must take into account the institutional framework that presumably contributes strongly to an explanation of country differences in economic growth.

However, it is not easy to incorporate features from the empirical and theoretical literature specialized on innovation and knowledge accumulation into a comprehensive macroeconomic model. Aistleitner et al. (2020) point out that "*in fact, despite the literature clearly shows that the process of acquisition and diffusion of new technological capabilities is an important determinant for growth and development on the national and regional level, as well as for the business success on the firm level, in the macroeconomic modelling framework little attention is given to the precise mechanisms according to which such a capability accumulation takes place.*"

The agent based modeling (ABM) emerged as a good methodology to build the required bridge between the macro and the micro/industrial economic aspects regarding innovation and technical change.
Indeed, the ABM modeling is more inclined to replicate a respectable number of stylized facts on the micro, meso and macro level (Dawid and Delli Gatti, 2018). It starts from (relatively) simple behavioral rules that lead to complex macro-dynamics and allows demand side and supply side elements to be combined. Taking into account heterogeneity and agent interaction, this methodology is ideal because of the possibility it gives in allowing for the path dependency nature of the economy and analyzing endogenous business fluctuations and (large) crises. With such architecture, it is possible to account for innovation, unlike most DSGE, and for demand fluctuations unlike all the endogenous growth models, allowing the nature of capitalism that is in continuous evolution, through cycles and crises, to be taken into account. In the ABM models, even though process innovation comes in different ways, the result shapes the long-run growth path, according to different institutional frameworks.

In the macro-evolutionary ABMs, technical progress is usually driven by stochastic innovations introduced in the economy by firms producing new capital goods (e.g Dosi et al. (2010), Caiani et al. (2016) and Dawid et al. (2019)). In the work of Dosi et al. (2010), the corporate sector is typically composed of consumption good firms and capital good firms whereby the former buy capital-embodied innovations produced by the latter based on their relative price, which is inversely proportional to the associated labor productivity. This means that, quite oddly, the most efficient machines are also the cheapest ones, meaning everyone can easily access them.

However, a number of studies stress the role of technological knowledge and capability accumulation in the success of innovative activities carried out by (capital good) firms. Dawid et al. (2019) conceive technological knowledge as necessary for firms in the consumer industry to employ the machines at the leading edge of technology. In their version of the EURACE model, technological knowledge is embedded in the skill level of workers. Turco and Terranova (2021), instead, have an explicit process of knowledge accumulation in the consumer industry, which evolves over time by means of a firm's own R&D investment.

1.2.5 Structural change theories

Innovation is often related to structural change. As Pasinetti (2006) stated *"The evolution of modern economic systems...shows that, as time goes by, the permanent changes in the absolute levels of basic macro-economic magnitudes...are invariably associated with changes in their composition"*.

Indeed, if we consider the satiation of needs, the innovation process and thus the increase in labor productivity implies shifts in the allocation of working hours and increases in consumption bundles. Structural change models, in contrast to other models, emphasize more the structural transformations the capitalist economies experience over time. A special emphasis is given to a sectoral view of the economy, paying attention to the shift in time in the employment structure and in the composition of production and of consumption bundles.

A number of studies connect economic growth with structural change and different factors have been highlighted as a source of non-balanced growth. Some of these studies focus more on the demand side and see unbalanced growth coming from non-homothetic preferences (Engel's Law), or hierarchies of needs (Foellmi and Zweimüller (2002), Buera and Kaboski (2012)). Others studies, instead, stress the supply side and see the different productivity growth rates across the economic sectors as the source of unbalanced growth. Such disparities may emerge from differences in factor proportions and capital deepening (Acemoglu and Guerrieri, 2008) or from different TFP growth rates (Ngai and Pissarides, 2007).
Demand and supply side sources of non balanced growth have been combined together in the work of some authors that, acknowledging the importance of innovation and the tendency of the economic system to change its fundamental and structure over time, have investigated which are the effects of such dynamics in terms of economic stability and business cycle. Pasinetti (2006) stressed how market saturation together with different productivity growth rates in the economic sectors might make the system unstable. Indeed, different sector productivity growth rates affect the sectoral labour coefficients differently. Stability requires an equal shift in employment, consumption and production and *"when there is technological progress, therefore, an increase in consumption is not a possibility, it becomes a necessity"*.

Linkages between innovation and instability have also been studied in the work of Perez (2003). The author analyses the real and financial instability and highlights how business cycles might emerge from technological revolution that, combined together with financial capital, first gives rise to a financial bubble, followed by collapse and finally the golden age.

Table 2: Endogenous growth and development models with structural change consistent with the "Kaldor facts"

Source non-balanced growth	Features	Authors
Demand-side: non-homothetic preferences (Engel's Law) [2]	From agricultural to manufactured goods	Laitner (2000)
	Hierarchy of needs or qualities	Foellmi and Zweimüller (2002), Buera and Kaboski (2012)
	Health care superior good	Hall and Jones (2007)
Supply-side: different productivity growth across sectors	Transition towards service economy (little progress)	Baumol (1967)
	Different TFP growth rates (Identical CDp functions)	Ngai and Pissarides (2007)
	Differences in factor proportions and capital deepening	Acemoglu and Guerrieri (2008)

Table 3: Instability structural change models

Source of instability	Features	Authors
Saturation and different productivity growth	Different sector effects of technical change on labor coefficients. Stability requires an equal shift in employment, consumption and productivity	Pasinetti (2006)
Real and financial instability	Technological revolution-financial bubble-collapse -golden age (structural change)	Perez (2003)

1.3 Contribution and thesis structure

In almost all the growth models in the economic discipline, growth rates depend on the rate of surplus the economy produces and injects back into the economy. At their core is the idea that what is saved from the current consumption is used for investment purposes, allowing increasing production levels in the future.

All the classics and the neoclassic economists, focusing on Say's law and idea that the actual output tends to adjust to the potential output rather than the other way round, have a special focus on the supply side. In the Solow's model the output growth is driven by the exogenous growth of population and by technical progress while in the more contemporaneous Endogenous Growth Theory capital accumulation and output growth is affected by the pattern of technical progress which depends on the system's propensity to save, determined in the utility-maximizing process. Thanks to the perfect substitutability among factors and the adaptation of investment to full-capacity savings, the long-run pattern of the economy tends to the full utilization of the resources.

In contrast, alternative approaches (post-Keynesian and Neo-Kaleckian, among others) state that the aggregate demand, both in the short- and in the long-run, determines the actual output and, through this, drives the potential output. Investment generates the necessary amount of savings and there is no automatic mechanism warranting that the equilibrium level of output is consistent with the full employment of resources.

However, the majority of such alternative approaches, in accordance with the Keynesian theory, have shown that the long-run growth is sensitive to investment decisions. What is different with respect to the neoclassical theories and classical theories are the different factors that foster the level of investments; saving behaviour and market structure in the former and income distribution, the state of the labor market, and investors' behaviour in alternative theories.

In the first post-Keynesian theories (e.g., Robinson (1962)), where output is like implicitly assumed constant and only the capitalists save, the required level of saving (following an exogenous increase in the investment level) is determined through changes in the normal distribution (in favor of the capitalists) that result from the increase in prices (because of higher investment demand) and the wage rigidity.

In the so-called Neo-Kaleckian model of growth and distribution (Rowthorn, 1981), which is nowadays, perhaps, the most influential non-Neoclassical growth model, the saving level is achieved through variation in the output level and in the utilization capacity (in the short-term). Thus, in the long-term the productive capacity adjusts to higher levels. While the actual profit increases, the functional distribution remains untouched. The functional distribution only determines the rate of growth according to different regimes (profit-led or wage-led).

However, also the alternative growth models have shown some drawbacks. In the post-Keynesian models the functional distribution is the adjusting (endogenous) variable, determined by the economic growth (in contrast to the classical assumption), whereas the Neo-Kaleckian models have to face the difficulties connected with a steady state degree of capacity utilization that differs from the normal one (Harrodian instability). Moreover, the demand-led models see in an exogenous increase in the investment levels the engine of growth, and this also appears unsatisfactory. In a monetary economy, higher capacity-generating investments can only emerge once higher monetary demand has emerged; otherwise increase in productive capacity are not stimulated. Also if they were, lower utilization rate and lower investments would follow, unless these were self-feeding investments which create stable demand for their own capacity[3]. In any way, if this were so, the economy would be easily affected by Harrodian instability; every increase (decrease) in the autonomous demand would trigger a positive (negative) spiral and the utilization rate would never manage to adjust to the normal levels.

Also higher investments that substitute old machineries cannot be the engine of growth because of the lower investments in the old equipment that have to follow. In any case, higher net investments are always constrained by the amount of work available in each period. Therefore, the investments cannot explain persistent growth rates, but, if at all, can influence the macro trend through the business cycle. There is a need for an alternative discourse regarding investments that increase labour productivity and hence enable economic growth. However, these investments allow growth to materialize but the ultimate drivers of the economic growth lie in the factors affecting the research and development activities and, in general, the technological change that is behind the new capital goods.
The Sraffian Supermultiplier model (Serrano, 1995), treating investments as fully induced by autonomous demand, seems a solution to the problems faced by the post-keynesian and Neo-Kaleckian models. Growth is shaped by the independent evolution of demand components like exports, public spending or credit-financed consumption and this allows the Harrodian instability to be properly handled. The higher savings required by an increase in the rate of accumulation are generated through increases in the output level that are made possible by short-run rises in the degree of utilization of the existing stock of capital. In the long-run equilibrium of the model, capacity adjusts to demand and a normal utilization of the productive capacity is restored. Normal distribution is not affected and the Keynesian Hypothesis is preserved.
In this study, we propose to explore the characteristics of the Sraffian-Supermultiplier model where technological change and autonomous demand, coming from the public sector, determine the macroeconomic dynamics. The growth rate of the economy is determined by the productivity growth path that, on one hand, frees up labor to be employed in the production of alternative goods, and from the other hand, creates the increases in income required for economic growth. The increases in real incomes materialize once the technology-induced displacement of employees occurs and the incomes lost by those workers who lose their job[4] are redistribute (through the different compensation mechanisms - markup increase, price reduction or wage increase) to those still involved in the production. While the consumption pro-capite increases, the economy does not grow, as a whole, and the unemployment rate soars. At this point, the public sector, which is forced to increase its expenditure, if not willing to accept high unemployment rates, generates the necessary demand for achieving spread (macroeconomic) growth, with the workers thrown out of the labor market being moved into new sectors, producing different and better goods.
Therefore, the macroeconomic growth is driven by the interplay of the technological change

[3]possible only under very peculiar parameters that have to deal with consumption propensities lower than 1 and timing issues related to the multisectoral composition of the economy

[4]because of the mechanisms behind the Engel's Law the productivity growth rates might be higher than the output growth rate.

that frees up labor and the public sector that increases its debt every time a process innovation occurs.
The technological change (the productivity gains), however, as has been widely acknowledge in literature (starting from A. Smith, and then revitalized by more contemporaneous authors such as Kaldor, Verdoorn, Marshall, Young and Arrow), depends on the sale levels because of the possibilities these open in terms of labor division[5]. The link market size-productivity exists both at the macro and the meso level. And also at the micro level.

Thus, within this framework, in contrast to the majority of the Supermultiplier models, the long-run growth rate of the economy is also affected by the income distribution (both functional and personal) which shapes the level of the total demand (because of the different consumption propensities) and its composition across sectors, and by the market structure that defines the production organization at firm level (allocating the output between firms).

The firsts mechanisms are what we will call the macro channel and the composition (meso) channel and the latter is the micro channel.

In this theoretical growth model in mind, to an increase in the demand level not only follows the physical accumulation but also the knowledge accumulation (R&D activities are proportionally to the firm output levels). While the former allows the growth materialization the latter will pave the way for higher future growth, that, by the way, cannot feed a vicious spiral growth because of the multisectoral structure of the economy and the consumers preference for variety.

For the purpose of our research, we have developed a multi-sectoral macroeconomic Agent based - Stock Flow consistent model (AB-SFC). The model is grounded on a theoretical framework representing a monetary economy of production (e.g. Graziani, Lavoie) where the principle of effective demand determines the level of output, while innovation is characterized by a typical Schumpeterian process of creation and destruction. The functional income distribution is determined as in the classical theory and it is the resultant of the struggle between capitalist and workers class. In particular, the markup fixed by firms over normal unit-cost of production determines the normal rate of profit. Money is endogenous and it is injected into the system when banks grant loans to firm to finance investments or wages anticipation and Government expenditure is financed by issuing public bonds.

The thesis is structured as follows:

- The first chapter provides a short review of the economic growth and structural change theories. After an excursus in the history of economic though, the contribution of our work is presented.

- The second chapter studies how the short-run affects the long-run path of the economy through the innovation process, whose gains over time depend on historical previous cumulated efforts whose destinations and intensities are shaped according to the ongoing economic dynamics. More precisely, the way the productivity gains appropriation affects the future trend of productivity (and therefore the long run growth rate of the economy), through changes in the aggregate volumes level and their allocation between sectors, is investigated.
  Firstly we show how process innovation represents a necessary but not sufficient element for economic growth and also a possible source of economic instability (because

[5]the multitude of the activities per-worker can be progressively and infinitely reduced the higher are the production volumes per unit of production. This reduction entails all the benefits related to the activity repetition (standardization) such as experience curve, mechanization and time saving in task shifting. Higher production volumes are associated to higher productivity gains also because of the increasing efforts in research activities that would result, and the non-linear dynamics embedded in the research and development process (that, for instance, comes from the rationalization of activities and the elimination of the repetitions).

of the technology-induced displacement of employees it incurs). We show how, in order to achieve a macroeconomic growth, a public state with an hands-on approach it is needed that increases its debt every times an increase in productivity occurs. Otherwise, only a few people can increase their consumption levels, at the expense of other workers that are removed from the labor market and lose access to the goods market. Then, based on Smith's heritage that the market size affects productivity growth, we analyze how different short-run appropriations of productivity gains, impacting differently on the GDP and shaping its composition (through distribution), outline the future productivity trajectories. Productivity increases that are translated into rising markups negatively affect short-run macroeconomic performances (mainly because of the different consumption propensities) and lead to future lower productivity growth and slower economic growth. On the contrary, productivity gains followed by reduction in prices pave the way toward future high productivity (and economic) growth due to increasing values of the monetary stocks that boost the economy. This is the macro channel through which income distribution influences the long-term economic growth. We further show how the different distributive scenarios impact differently the long-term economic growth also through the meso level. Dispersion of the production across sectors that comes with a more unequal income distribution (because of the consumer preference for variety) hampers the imitation dynamics and through this the economic growth. The macro and meso channel work in coordination.

- The third chapter focuses on the very long-term dynamics of the capitalist system and examines the connection between process innovation, market concentration, and economic growth. We investigate how the employment reduction at sectoral level, which comes logically from rising labor productivity and consumers' preference for variety, can affect market concentration and the distribution of income among the economic agents. Particularly, we show that anytime sectoral employment declines, in absence of rising markups or higher market concentration, the personal distribution shifts toward the workers. Such result, that translates Marx's idea of the tendency of the technical progress to drive the profit rate to fall into a tendency of the technical progress to move the personal income distribution towards the workers, can only be counterbalanced by an increase in the markups or in the market concentration.
  Then, given the different combinations of concentration-inequality highlighted, we study their implications in terms of economic growth. While the degree of market concentration affects the productivity trend shaping the way the production is organized at micro level, the level of inequality, because of the preference for the variety (Engel's curve), affects the production composition. The meso and the micro channels affect differently the productivity path. Market structures more inclined to market concentration show higher increase in labor productivity but the resulting inequality produces higher production dispersion.
  At this extent, we have taken the an SFC-ABM multisectoral model developed in the second chapter and we have made some amendments to properly tackle the issues related to inequality and market structure. Particularly, we have implemented a more complex firm structure in which diverse labor skills are necessary to operate the business and each sort of worker is compensated differently based on the type of job. In addition, we have modified the manner in which the innovation process influences our artificial economy during the simulation periods.

Figure 2 presents a summary of the covered subjects and depicts the versions of the model used throughout the entire study to address the various topics.

Figure 2: A systemic approach to productivity and growth. Topics and versions of the model adopted

	Main theme	Time Horizon	Topic	Different Scenarios	Version of the model	Labor productivity change	Chapter	Section n°
1)	Productivity and employment displacement. Conditions to achieve growth	Short-run	The elite tendency behind the process innovation and the difficulty to reach macroeconomic growth	Distributive scenarios (price, wage, markup channels)	SFC one-sector economy	One-shot shock	2	2.6
2)	Productivity gains distribution and economic growth	Short-run toward the long-run	How the macro level affects the future labor productivity (macro effect)	Distributive scenarios (price, wage, markup channels)	SFC-ABM one-sector economy	Ongoing stochastic process	2	2.7
3)	Productivity gains distribution and economic growth	Short-run toward the long-run	How the meso level affects the future labor productivity (composition effect)	Distributive scenarios (price, wage, markup channels)	SFC-ABM multi-sector economy	Ongoing stochastic process	2	2.8
4)	The consequences of growth on income distribution and market concentration and their feedback loops on future growth	Secular trends when structural changes occur	How the Micro and Meso level combine to shape the future labor productivity	Market Structure scenarios (Concentration vs Competition)	SFC-ABM multi-sector economy with multi layers firm organization structure	Ongoing stochastic process with exponential productivity functions	3	3.6

2 Productivity gains distribution and economic growth. How the short-run affects the long-run trend of the economy

2.1 Chapter structure

The objective of the present thesis is to study the macroeconomic effects of the innovation process in a multi-sectoral economy where the productivity trends diverge among firms, with the households which buy goods according to a hierarchical ranking of needs that reproduces the dynamics depicted in the Engel's Law. More in particular, modeling an ongoing process that makes always available new products and services[6] which consumers are always willing to buy (according to a hierarchical ranking)[7], we examine the effects of the innovation process on employment levels, distribution, market concentration and economic growth[8].

In this chapter, we explore how the short-run dynamics can persistently affect the long-run of the economy. Given the path-dependency nature of the innovation process, where outcomes are the results of the cumulated efforts whose destinations and intensities are historically shaped, according to the ongoing economic dynamics, the current production determines the locus and the frequency of the future gains in production efficiency, and therefore the economic growth pace.

More precisely, we study how the alternative allocations of the current productivity gains among the economic agents affect the future productivity path, through changes in the aggregate volume levels and in their composition (macro and meso channels).
For the purpose of our research, we have developed a multi-sectoral macroeconomic Agent based - Stock Flow consistent (AB-SFC). The model is grounded on a theoretical framework representing a monetary economy of production (e.g. Graziani, Lavoie) where the principle of effective demand determines the level of output, while innovation is characterized by a typical Schumpeterian process of creation and destruction. The functional income distribution is determined as in the classical theory and results from the struggle between capitalist and workers. In particular, the markup fixed by firms over normal unit-cost of production determines the normal rate of profit. Money is endogenous and is injected into the system when banks grant loans to firm to finance investments or wages anticipation and Government expenditure is financed by issuing public bonds.

The AB macro modeling is suitable for our purpose because it allows to take into consideration all the mentioned micro-economic dynamics, such as needs, preferences, competition and technological change and combine these together with macro roles and the micro-macro feedback. Indeed, AB models start from simple behavioral rules that lead to complex macro-dynamics and takes into account heterogeneity and interaction. This feature allows to analyses the emerging proprieties of the economy, in terms of growth and distribution.

The model shares with the post- Keynesian literature, among other elements mentioned above, the importance given to the interlinkages between stocks and flows and the endogenous money theory. In particular, the model is based on Stock-Flow consistent structure which integrates the financial and real side of the economy and take into explicit consideration both flow and stock variables and the related macro-accounting consistency constraints. Each financial stock is associated with its own flow, meaning that the former is continuously fueled by (and, in turn, fuels) the latter. This is coherent with the 'quadruple accounting'

[6]We leave aside all the analysis regarding the determinants and the macroeconomic implications of product innovation

[7]We also skip the study of those scenarios where consumption propensities decrease over time, because of the progressively satiation of needs

[8]For sake of simplicity, also all the possible problems linked to labor mobility and skills development are left aside

principle, according to which any economic transaction requires at least four recorded entries for the accounting matrices to balance out.

This means that the model is far from any Walrasian equilibrium were prices and quantities are a way to clear the market. It shares evolutionary roots, but tries to explore feedback between factors influencing aggregate demand and those driving technological change and their combined effects on the macro variables. With such architecture, it is possible to account for innovation, unlike most DSGE, and for demand fluctuations unlike all the endogenous growth models. In line with the Classical economist (such as Adam Smith, for instance) and differently from main neoclassical growth model (principally the Solow model) the model we have developed explains economic growth thoroughly as an endogenous phenomenon which is determined by the interplay between the multiplier and the acceleration mechanism together with the endogenous stochastic innovation process.

The chapter is structured as follows:

- Section 2.4 presents a review of the specialized existing literature and section 2.5 a description of the model adopted.
- Section 2.6 presents some analysis concerning the short-run dynamics generated by the innovation process and the required conditions for achieving macroeconomic growth. In this context, an aggregate version of the model (SFC) is adopted, with one firm and one sector only (still with a multiplicity of households). The increase in productivity comes as a one-shot shock.
- Leveraging on the Adam Smith's argument (higher market size higher productivity), section 2.7 and 2.8 examine how the different allocations of the productivity gains (to workers, consumers or to capitalists) impact the economic long-run growth rate through the macro and the meso channel. The micro channel, instead, will be handled in the third chapter.
  In particular:
  - Section 2.7 is about the "macro effect" that refers to the possibility for the different distributive scenarios to affects the productivity trajectory of the economy and therefore the long-run growth of the economy through the determination over time of the macro dimensions. More aggregate production and therefore employment levels will positively affect the future increases in labor productivity. In this section, we adopt the disaggregated version of the model (because we are currently dealing with innovation and the micro level cannot be ignored) but we limit our artificial economy to one sector economy so that all the increases in income that follow the increases in productivity are spent in the same good (increasing the quantities). Moreover, the innovation process is modeled as an endogenous stochastic process that depends on the R&D levels.
  - Section 2.8 focuses on the "composition effect". This makes reference to the impacts the different allocations of the productivity gains have on future process innovations through the determination of the composition of the macro consumption bundle. More precisely, we explore how the different consumption structure, implying a different production structure and different allocation of the working hours across the business sectors, affect the productivity trends and therefore the output growth. We are not referring to the firm number or to different distributions of the firm sizes, that will be object of the third chapter, but to the different allocation of the companies across sectors (while the distribution of the firm size and the number of firm remains invariant).

For the object of this we finally use the disaggregated multisectoral version of the model (AB-SFC).

2.2 Process innovation

The study comes from the idea that any attempts to interpret the evolution and the future dynamics of the capitalist system cannot be done without first studying the innovation process, its factors and its economic impacts. Schumpeter refers to the process of innovation within capitalist economies as follows:

"The fundamental impulse that sets and keeps the capitalist engine in motion comes from the new consumers' goods, the new methods of production or transportation, the new markets[....]. This process incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of Creative Destruction is the essential fact about capitalism." Schumpeter (1934).

The economic literature ultimately reduces innovation (technical change) to two things: either producing new commodities and services, or producing the existing ones with fewer inputs. Broadly, product innovation is aimed at creating more appealing goods for the customers, while process innovation is more about the internal-cost minimization process. A key objective of product innovation may be the differentiation of goods through novelties that pertain to function, aesthetics, customer experience, whereas process innovation may have more to do with the improvements of the operational efficiency, continuously reducing the number of working hours per output produced. Utterback and Abernathy (1975) defines the process innovation as the development of the entire production process, which is "the system of process equipment, workforce, task specifications, material inputs, work and information flows, etc. that are employed to produce a product or service".

In this study, although there might be some overlaps between the two, we will focus on the latter only, leaving the analysis about creation and satisfaction of the new needs to future studies.

With process innovation are meant all those gains in terms of labor productivity that come from the rationalization of the activities or the reduction of the inputs embedded on them and that result in fewer inputs per unit of output.

In a world where the working hours are invariant, and fully utilized, the main factor behind economic growth is related to the productivity dynamics. An increase in working hours, that is linked to an increase in population or to higher employment rates (differently from an increase in the average working hours per person), cannot directly explain the growth of GDP per capita. It only implies an higher level of production, which has to be shared among more people.

The dynamics of the productivity are at the bottom of the increase in the consumption bundle both in quantitative and qualitative terms. The productivity gains, in any possible ways are allocated (to the consumers, to the workers or to the capitalists), lead to an increase in the income levels to be consumed in better quality goods or in new types of goods. These movements are at the roots of the structural changes that the advanced economies have experienced in the recent decades. Obviously, for these to occur, it is both needed that always new products are available in the market and that the labor skills change over time, according to the production necessities. Additionally, it is necessary that consumption propensities do not decrease as consumption bundles increase.

So, process innovation is not only important, at macro level, because of the possibilities it opens in terms of economic growth but also because of the distributive and the stability issues that are naturally connected with it; the gains in labor productivity have to be allocated in any way to the different agents (capitalists, workers or consumers) and higher efficiencies in the production lines might lead to technology-induced labor displacement and the reshuffle of the production structures (because of the Engel's Law) with all the difficulties related to labor mobility that this incurs.

Even if treated and retained differently, the change in labor productivity has always been an hot topic in the history of the economic though. Mostly because it is an empirically relevant fact that helps explaining the growing consumption bundles but also because it is a logical force that emerge intrinsically in the capitalist mode of production where single firms look for cost-saving techniques as competitive weapons against competitors or ways to squeeze the labor force and increase their profit rates. Indeed, all the machinery employed in the production process are properly designed to increase the power of the labor force and all the efforts of the upstream sector are addressed to discover and develop new capital equipment that are always more productive, while answering to the always changing needs of the downstream sector. The public sector, also, has really good reasons for adopting an hands on approach that pushes the increases in productivity so to acquire advantages against other countries.

If there are, as briefly mentioned above, really good micro behaviors that explain some incentives to bring higher efficiency, the concept of productivity is even more profound in the capitalist system. Indeed, the division of labor has always represented the workhorse of such system of production (Smith et al., 1776). Namely, a production system that brings together billions of people where neither one produces more than an atom of what it is necessary for its survival. In the productivity, rests the possibility for profitability. Indeed, given the productivity levels achieved by the system, is very tough for individuals to escape from the wage labor. The labor force accepts to be "exploited" in change of higher prosperity (Smith et al., 1776).

The literature shows a bunch of studies on process innovation, both from a micro and macro perspective. From the micro perspective, most of the works have focused on understanding the potential sources of the innovation and have traced it back to the accumulation of technological capabilities that are seen as essential for the business success of firms (Aharonson and Schilling, 2016), labor division (Smith, 1851), firm efforts in research and development activities, value chains fragmentation and globalization that both enhance competitive pressure and create new opportunities in business for corporate firms (e.g. De Loecker (2007) for Slovenia and Serti and Tomasi (2008) for Italy).

The approach that is among the most common to study macroeconomic growth and development is the endogenous growth theory. Such models have their roots in the neoclassical framework and find the source of economic growth in the technological progress. Increasing returns to scale come from non-rival and completely non-excludable goods (e.g. externalities) and take different forms, such as new types of capital goods, ongoing product improvements (intermediate and final good), new instructions for mixing raw materials and product variety expansion. Even though the mechanisms are several, innovation mainly comes from decision of firms to invest in R&D with the perspective of gaining market shares (e.g. Rivera-Batiz and Romer (1991), Grossman and Helpman (1991b). Nonetheless, there are also works (e.g.Arrow (1971) and Lucas (1989)) that study innovation spreading in a competitive framework through increases in knowledge that arise as an induced effect of physical or human capital accumulation. Some of the building blocks of the endogenous growth model are also present in more applied models such as DSGE models that introduce innovation and avoid treating it as an exogenous factor.

From the evolutionary literature, there are more comprehensive analyses that try to put together and study the interlinkages between micro, meso and macro level (Dawid and Delli Gatti, 2018). Such models, as pioneered by Nelson and Winter (1982), are driven by a Schumpeterian core with endogenous innovation. Also in this case, the way innovation appears is multifaceted and there are several factors that drive innovation. Dosi et al. (2010) in their K+S model, represent innovation as result of R&D expenditure that are a percentage of sales. Such expenditure is addressed to produce a more productive capital good so that consumption-good firms may produce with lower labor per unit of final goods. The innovation success and its spread in the market depends on a stochastic process that mimic both imitation and innovation dynamics. The same applies in the model developed by Caiani et al. (2019)[9], representative of the "Benchmark" model, as well as in Ciarli et al. (2019). In the latter study, R&D is based on anticipated pay-off, and innovation comes from new capital goods that embody a higher technology. These authors, in contrast to the others, stress the structural changes that may emerge in the economy given demand and supply-side factors that determine unbalanced growth.

2.3 Evidence and age-old debates

Within the economic discipline, the effects of the technological progress on the employment level, the long-run economic growth rate and on the distribution of income among social classes has always been a topic of debate.

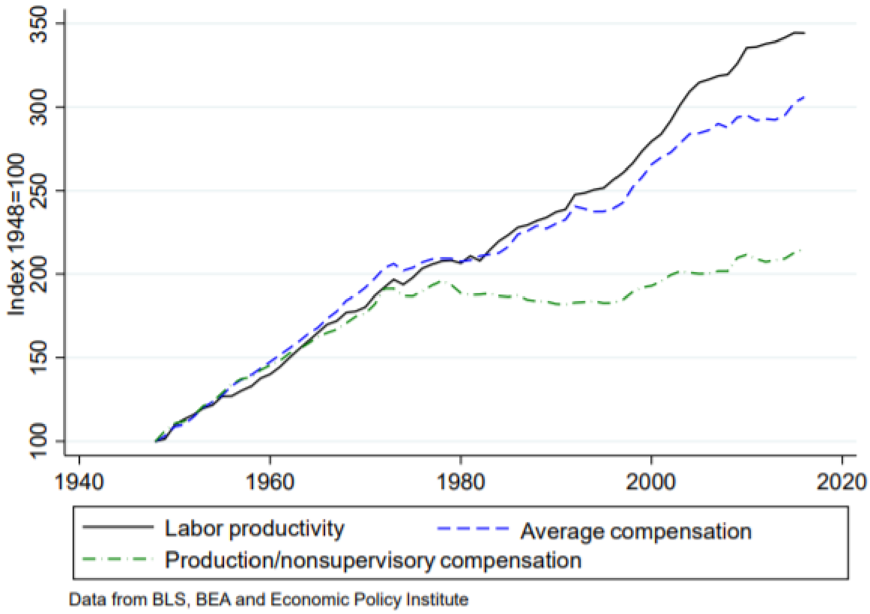
When classical political economy was born at the end of the nineteenth century, the issue of distribution was already prominent. Ricardo described it as one of the principal problems that the discipline should have dealt with it. Increasing evidence suggests a persistent decline of the aggregate wage share over the recent decades (OECD (2015), IMF (2017)). Moderate growth of real wages has been recorded in comparison with the pace of labor productivity growth. The wage indexation has generally fallen and moved to the firm-level (Schwellnus et al., 2017), implying that raising productivity is no longer enough to raise real wages. Confirmatory evidence for the US is reported by Stansbury and Summers (2018b). Giovannoni (2014) shows that in the US, excluding the top 1% wage earners, the income share going to wages has decreased from 75% in 1980 to the 60% in 2010; indeed, real wages have been slowing down more than the the productivity dynamics since the early 1970s, causing the labor share to decline (e.g Autor et al. (2020), Barkai (2020) and Benmelech et al. (2020)).

Figure 3 shows the growth in labor productivity, average compensation, and average production since 1948 in the US economy.

While stability of the labor share of GDP throughout much of the twentieth century was one of the famous Kaldor "stylized facts" of growth (Kaldor, 1957), a number of researches have documented a decline in the share of GDP going toward labor in many nations, over recent decades (e.g., Blanchard et al. (1997), Karabarbounis and Neiman (2014), Piketty et al. (2014)). The macro-level stability of labor's share was always, for Keynes, "something of a miracle," and indeed it covered a lot of instability at the industry level (Elsby et al., 2013). Even though there is an ongoing controversy over the degree to which the fall in the labor share of GDP is due to measurement issues such as the treatment of capital depreciation (e.g. Bernanke and Gürkaynak (2001) and Bridgman (2018)), or housing (Shleifer et al., 2015), or self-employment (Elsby et al., 2013), or intangible capital, there is a general consensus that the fall is real and significant.

[9]in this paper, in contrast to Dosi et al. (2019), the R&D expenses are paid to skilled workers whose incomes and expenditures affect the macroeconomic results, respecting in such way the stock flow consistency of the model.

Figure 3: Productivity and wage



Source Stansbury and Summers (2018a)

The decoupling between productivity and wage dynamics has been mainly explained by the interplay between excessive labor-saving techniques and the declining labor share (Alvarez-Cuadrado et al., 2018), weaker workers' bargaining power also given by an increasing flexibility of labor markets (Mergulhão and Pereira, 2021) and the slowdown of aggregate demand. A Post-Keynesian 'demand-based' explanation is strictly related to the globalization and financialization (Lavoie and Stockhammer, 2013). The Phillips curve seems not playing its role any more and the working class has lose its bargaining power. To some extents, it might be explained both from the different role the state plays in the economy, without the communist threat (E. Brancaccio), and from the capital centralization without concentration (Bellofiore, 2011) that contributed, among other issues, to a full under-employment. Karabarbounis and Neiman (2014) hypothesize that the cost of capital relative to labor has fallen, driven by a rapid decline in the quality-adjusted equipment prices which could have lowered the labor share if the capital-labor elasticity of substitution is greater than 1.2. While Elsby et al. (2013) argue for the importance of trade and international outsourcing, Piketty (2014) stresses the role of social norms and labor market institutions, such as unions and the real value of the minimum wage. In contrast, Autor et al. (2020) points to the fact that the decline in the labor share is based on the rise of superstar firms. Such a rise in superstar firms would have occurred because of greater product market competition (e.g., through globalization) or improved search technologies that allowed price comparisons in a framework where a single firm which has scale advantages can easily gain big market shares.

The vibrant debate about the role of technology in shaping the future labor markets and overall economic well-being is age-old and encompasses both demand side concerns regarding the possible satiation of consumers needs (Keynes, 1978) and more supply side theories that shed light on the fear of job displacement. The *future of work* debate started with a seminal work by Chris Freeman (Freeman and Soete, 1987) that deepened the different effects of technical change on employment. Evidence suggests that product innovation as such does not lead to job destruction but possibly to a polarization of jobs. The effects of process innovation are instead more controversial. Nowadays there are a collection of survey-based studies on the impact of process innovation, both at sectoral level and firm level. At sectoral level, there seem to be a negative effect of technological change on employment level (Piva and Vivarelli, 2017). On the contrary, firm-level studies are found to report positive effects of process innovation (Calvino and Virgillito, 2018). Such apparently conflicting evidence is easily explainable by their different starting points. Indeed, a firm gaining market share, might well increase its labor demand because of higher sales, at the expense of the share of its competitors, leaving the overall sectoral output invariant and reducing the total employment level in the industry (Dosi and Mohnen, 2019). The evidence also suggests that another power driver of employment dynamics in the Western economies has been exerted by globalization and offshoring to competition from emerging economies like China.

Bessen (2019) shows that sectoral employment (in textile, motor vehicle, and iron and steel production) follows an "inverted U" pattern; rising during an initial stage of innovation, then ultimately peaking and declining in later stages of maturity. The author goes on to interpret the empirical results through a model where, in the initial stage of product or productivity innovation, the price decline makes formerly unavailable or prohibitively expensive goods affordable for mass consumption. This leads to positive demand responses. But, once high priority consumption demands are satisfied (e.g., clothing, cookware, and motor transportation become cheap and abundant), further process innovations yield only a modest further increase in demand.

At a more aggregate level, the empirical evidence shows that the unemployment rate has fluctuated but its average rate has remained about the same for a century and a half, effectively absorbing major sectoral shifts, such as a rapid increase in women's labor market participation and migrant workers. However, at the same time, the hours worked annually decreased substantially in OECD countries, effectively countering an increase in unemployment otherwise observed.

2.4 Literature review

In this section, we revise a sample of literature that is similar to our study, both in the topic of interest and in the methodology. Specifically, we refer to the evolutionary literature that focuses on the interplay between technological change and economic growth, paying attention to the dynamics linked to structural change and distribution. The work of Dosi et al. (2021b) is a reference point. Building on the previous works (e.g.Dosi et al. (2010)) where capital-good firms invest in R&D and produce heterogeneous machine-tools whose stochastic productivity evolves over time, they add that new consumption goods and industries emerge when new machines are discovered and, in this manner, the technological labor displacement is off-set by the creation of new labor-intensive sectors.

Nowadays, many of the AB macroeconomic growth models that have some sort of endogenous technical change (that results in productivity increases) have a multisectoral framework, where the number of new sectors emerge endogenously (e.g. Ciarli et al. (2019), Saviotti and Pyka (2004), Lorentz et al. (2019) and Gabardo et al. (2020)).

Saviotti and Pyka (2004) is recognized as the very first attempt to focus on structural change rooted in the creation of product variety, even though they do not make explicit reference to how much varieties are related to the individual behaviors.

Lorentz et al. (2019) reproduce the Kaldorian cumulative causation mechanism as an emergent property of the model and show that the two-regimes of endogenous growth discussed by Kaldor can be related. The take-off phase of the capitalist economy which is characterized by economic stagnation (because of the lack of a profit margin that does not encourage investments and the productivity), is followed by a post take-off phase where the level of the demand is such that the capital deepening and the increase in productivity are possible and, at that point, the Kaldor Verdoorn law comes into play. Moreover, they show that the heterogeneity in consumption behavior shapes the type of growth regime emerging from the endogenous structural changes, leading to an extensive growth regime or an intensive one. The more homogeneous is the demand, the more intensive is the growth dynamics and the larger are the productivity gains. Conversely, the more heterogeneous is consumption, the more the extensive growth patterns dominate. By increasing income and employment, the economy expands more quickly despite slower productivity growth.

The Eurace family of ABMs has been used recently to study the impact of new digital technologies on productivity and employment by Bertani et al. (2020). They show how technological unemployment come out in the long run with a high pace of intangible digital investments. Dawid and Hepp (2021) have recently adopted the Eurace model to study the relationship between technological regimes, inequality and concentration.

A working paper recently published by Rolim et al. (2021) studies the interaction between workers' bargaining power and productivity growth. Such work, like ours, stresses the social class conflict that arises in the distribution of productivity gains and looks at the repercussions in terms of economic growth according to the various distribution outcomes. In particular, they show that unemployment rates and output levels crucially depend on the share of productivity gains that are released to consumers. The more productivity gains are released, the lower the unemployment rate and the higher the output level.

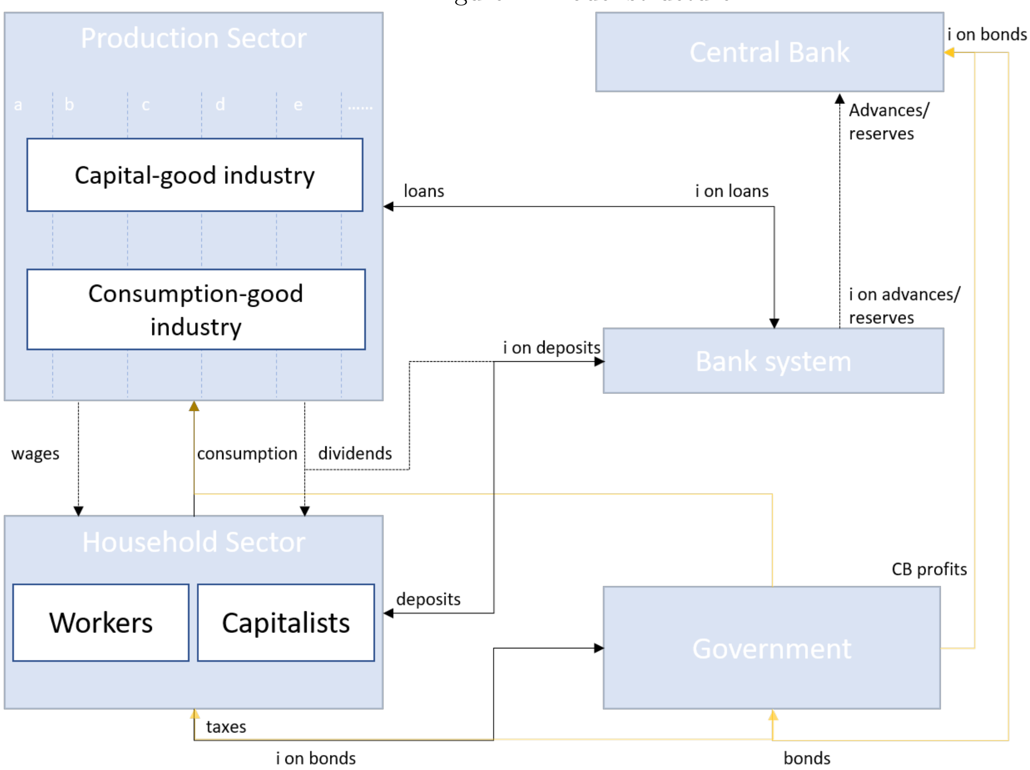
Closer to the core question of this chapter is the work of Ciarli et al. (2019) which studies the relation between income distribution and growth, mediated by structural changes on the demand and supply sides. Regime one, similar to Fordism, is assumed to be relatively less unequal, more competitive and to have more homogeneous consumers than regime two, which is similar to post-Fordism. Higher output and productivity and lower unemployment are reached under the Fordist regime, compared to regime two. The authors also found that concentration of production hampers the output growth, suggesting the relevance of competition norms. Also the work of Turco and Terranova (2021) is close to ours. Revisiting Sylos Labini's theory of oligopoly and technical progress (concentration is driven by technical change that generates technological discontinuities), they construct a model where the differences in knowledge accumulation among heterogeneous firms prevent equal access to capital-embodied innovations resulting in concentration and higher mark-ups. This shift in the income distribution then turns in lower aggregate demand and lower growth because of the differences in the consumption propensities among social classes.

Within such a framework, our contribution to the literature is found on the special focus we put on the interrelationship between productivity appropriation (income distribution) and economic growth that occurs through the determination of both the production (consumption) size and its composition. The mechanism that allows income distribution to affect the growth rate is the dependence of labor productivity on production volumes. Higher production volumes are associated with higher productivity gains because of the possibilities the production size offers in terms of labor division and because of higher resulting research activities, whose outcomes, incidentally, may also display a non-linearly (concavity) with respect the production dimension (due to, for instance, rationalization of activities or elimination of repetitions). Also empirically, there is proof that sales levels shape the productivity dynamics more than worker skills. Dosi et al. (2021a), studying the dynamics of productivity in the italian business companies in the period 2010-2014, find a weak relationship between workers' training activities and labor productivity and suggest that the accumulation of knowledge happens at firm level, in the organizational structure, rather than at individual level.

2.5 The model

We have developed a multi-sectoral macroeconomic agent-based Stock flow consistent model that describes a monetary economy of production. It is a demand-led model where a Keynesian engine together with typical Schumpeterian forces, interpolated with satiation in the consumption preferences of the different goods, allows to study the economic growth, paying attention to the different implications of supply and demand side sources of non-balanced growth.
As shown in figure 4, the economy reproduced is composed of firms, consumers, workers and the public sector.

Figure 4: Model structure



There are two productive sectors. The sector that produces capital goods by mean of labor only, and the sector that produces final products by means of machine tools and labor. The vintages of machinery at the disposal of the consumption-goods industry change over time because new capital goods that embody different technologies appear on the market. Innovations are clearly endogenous to our economy. Indeed, these are the uncertain outcome of the search efforts of the industry producing capital goods.
In line with Kalecky's idea the propensities of capitalist to consume and their *animal spirits* take on significant importance in shaping their own possibility of making profits. Indeed, monetary profits arise only at the end of the production period, once the products have been sold.
There are different final products that are characterized by imperfect substitutability and the ranking order of the basic goods (those purchased by the workers only) is equal across workers. In other word, they all satisfy the basic needs with the same order of preferences. Only after the satiation of a primary need the excess disposable income directed toward to new products that will enlarge the consumption basket.
Both the multiplier and accelerator machine are at play. Every time the actual capital falls below the target level, an order for new capital goods is placed and the producer will start producing it. If needed, a bank loan is provided. The capital sector, however, works only

once orders have been received and payment has been settled.
The banking sector, in line with the theory of endogenous money, together with the state, provides money and creates purchasing power that allows and influences the cycle of production and consumption. If bankruptcy occurs, the bank system forecloses the capital assets in the balance sheet of the bankrupted firm and puts them up for sale in order to minimize the write-off on the non-performing loans.
The public sector, however, taxing company profits, workers wages and capital incomes and allocating its exogenous expenditures according to the production capacity of the consumption-goods industry sectors, represents the autonomous demand of the model.
The equations of the model are shown in annex B.

2.5.1 The multisectoral framework

We implicitly assume that process innovation is coupled with product innovation[10] (which always makes new products and services available, which consumers are always willing to buy, according to a hierarchical ranking) so that the delta incomes generated by the increase in productivity, given the saturation levels on the *more basic* goods, can always be spent on new goods. Therefore, new sectors endogenously emerge whenever the higher real incomes overcome the saturation levels and the monetary demand for the new goods is generated. Companies in emerging markets are not equipped with any machineries and wait for demand to come before ordering capital goods, paying wages, and beginning production. Clearly, we are neglecting all the potential temporaneous macroeconomic repercussions that may emerge when considering the dynamics of trial and error, which are characteristic to the process of product innovation, in the absence of increasing monetary demand.

However, has to be noted that:

- For businesses to launch a new product, there is always a need for spare labour supply. Either a growing population or a rise in productivity must therefore be assumed[11]
- Assuming that the there is labor surplus and the impacted workers were already spending as a result of government subsidies, the impact of these dynamics may be limited. In this situation, the public debt to GDP ratio would be significantly impacted, while consumption and output levels would be affected only by the discrepancy between wages and subsidies.
- In a multisectoral economy, it is also unlikely that what is put into the system, as an attempt to offer a new product, will return as a demand for personal items, even when considering the higher profits generated by the increased employment levels. Therefore, the enduring impacts of these dynamics are questionable.
- Furthermore, in a demand-driven model in which the autonomous component serves as a gravitational force, it is difficult to conceive sustainable trajectories that remain above the gravitational levels.

For these reasons, and for the sake of simplicity, we have left asides all the dynamics behind product innovation.

[10] We leave all the analysis on the determinants of the product innovation and their macroeconomic implications together with the possibility of decreasing consumption propensities to future researches. Also, for sake of simplicity, all the possible problems linked to labor mobility and skills development are not considered here.

[11] In our model we are able to simultaneously coordinate the demand and supply sides of the economy because the gains in worker productivity are at the core of our long-term view.

2.5.2 The household sector

Once workers get their wages and interests on deposit/ government bills and capitalists receive profits and interests on financial investments (bill/ deposit), they decide how much to spend and define their optimal consumption bundle. The amount allocated to consumption ($C_{t,w}$ and $C_{t,c}$) is a function of the disposable income (YD) and the accumulated wealth (V). Both the consumption propensities on YD (α_1) and V (α_2) are given exogenously and the tax rate (θ) is fixed.

$$YD_{w,t} = (Wages + r_b * Bill_{t-1} + r_d * Deposit_{t-1}) * (1 - \theta) \tag{1}$$

$$YD_{c,t} = (Profits_{t-1} + r_b * Bill_{t-1} + r_d * Deposit_{t-1}) * (1 - \theta) \tag{2}$$

$$C_{w,t} = \alpha_{1w} * YD_{w,t} + \alpha_{2w} * V_{w,t-1} \tag{3}$$

$$C_{c,t} = \alpha_{1c} * YD_{c,t} + \alpha_{2c} * V_{c,t-1} \tag{4}$$

Consumption equations of this kind imply that, in the case of invariant disposable income, once the optimal income/wealth ratio is reached, consumers start spending whatever they earn so that the *stock norm* is respected (Godley and Lavoie, 2016). The consumers purchase the basic goods according to a determined hierarchical structure. Only once a satiation level is reached (that means that a certain quantity threshold is exceeded), the further increase in disposable income can be allocated to the consumption of new goods (Gabardo et al. (2020)). The real satiation levels are imposed exogenously and are time invariant.
In contrast to Dosi et al. (2021b), we do not distinguish between basic and luxury goods. The consumption bundle increases endogenously and all the consumption goods (and also the capital goods) are perfectly divisible.

Each consumer compares all the firms by means of price. In particular, consumers observe the prices charged by a random subset of firms in each sector. The subset size is the same among consumers and is time variant because the number of firms in each sector may change over the simulation periods. Once the subset has been defined, individuals sort the possible suppliers by price, from the cheapest to the most expensive. Finally, the households scroll through the list, from top to the bottom, and buy the desired products from as many companies as necessary, until the individual demand is completely matched. This procedure is repeated for each basic goods the workers want to acquire. Once the level of consumption is defined and also its allocation, yearly savings are determined and the new level of wealth is recorded. At this point, the agents decide how to better allocate their wealth. The quantity of bills to hold is determined according to the interest rates and the yd/wealth ratio as shown in equation 5.

$$Bill^d_t = V_{t-1} * (\lambda_0 + \lambda_1 * rb_t - \lambda_2 * (YD_t/V_{t-1}) \tag{5}$$

What is left will be held in deposits. The main point is that households wish to hold a fix proportion (λ_0) of their wealth in form of bills and might positively adjusted it (λ_1) in response to increasing levels of interest rates on bills while they might decrease it for relatively high disposable income levels with respect to accumulated wealth, as a reflection of the transactions demand for money (Godley and Lavoie, 2016).

2.5.3 The consumption-goods industry

According to the circuitist framework, the consumption-good industry decides how much to produce following the sales expectations that are computed as follows:

$$S^e_{i,t} = S^e_{i,t-1} + \beta_1 * (S^d_{i,t-1} - S^e_{i,t-1}) \tag{6}$$

S^d is the previous recorded demand, β is a proxy of production responsivity to demand fluctuations and i stands for the i^{th} final-good firm. This mechanism imposes that expectations are continuously updated to account for past errors, resulting as the cumulative sum of $(S^d_{i,t-1} - S^e_{i,t-1})$, where the more remote are accounted for almost entirely while the more recent are accounted for by a factor that converges to β. It can also be seen, more simply, as an autoregressive process where the expected sales are given by the past sales, in which the recent data are weighted more than the more remote ones. Once expectations are determined, the i^{th} firm is able to set its production level

$$S_{i,t} = min\{S^e_{i,t} * (1+d) - INV_{i,t-1}\ ,\ K^n_{i,t} * ykratio_{i,t}\} \tag{7}$$

where d is the desired level of inventories and INV is the amount of inventories at disposal. Since producing capital takes time, the production is constrained by the level of capital net of depreciation ($K^n_{i,t}$) at disposal in each period. $K^n_{i,t}$ multiplied by $ykratio$ (which determines the number of final goods that can be produced by a unit of capital) sets the maximum amount producible in the year.
Given the dk periods required to produce the capital goods, the consumption-good firm also computes the expected sales growth rate in order to estimate what the sales will be in dk periods in order to decide the investment level. The methodology used to estimate the sales applies also to the expected growth rate $g^e_{i,t}$:

$$g^e_{i,t} = g^e_{i,t-1} + \beta_2 * (g_{i,t-1} - g^e_{i,t-1}) \tag{8}$$

$$S^e_{i,t+dk} = S^e_{i,t} * (1+d) * (1+g^e_{i,t}) \tag{9}$$

With all the information, the future target level of capital is determined

$$K^t_{i,t+dk} = S^e_{i,t+dk}/ykratio_{i,t}/ut \tag{10}$$

where ut is the normal rate of capital utilization. Thus, the investment level will be:

$$K^d_{i,t} = K^t_{t+dk} - K^f_{i,t+dk} \tag{11}$$

This means that, if $K^t_{i,t+dk}$ is higher then the prospective one $K^f_{i,t+dk}$ (taking also into account the depreciation), then an order to the capital sector is made.
We use a typical investment function that exploits the rate of capital utilization and does not take into consideration any financial factors.
Once the level of investments is defined, in order to make their order, the downstream firms have to select their suppliers. The matching mechanism is very similar to that used in the consumption sector between firms and households. The downstream firms select randomly a subset of capital firms and sort them according to the unit costs that the different capital equipment would imply. The unit costs used as selection criteria reflect both the technology level of the equipment that will in turn determine the amount of labor effort per unit of capital and also the price of the machine. The randomly selected sample size also includes the mortgaged capital goods that banks put on sale at a significant discount with respect to the average price in the market.
As far as the price is concerned, a markup pricing strategy is assumed, where a fixed markup is added on top of the production costs for one unit of product.

$$Pc_{i,t} = (1+\mu)\{w_t * (1+r_t)/(ykratio_{i,t} * meanlk_{i,t}) + Pk_{i,t} * (1+r_t)/a/(ykratio_{i,t} * ut)\} \tag{12}$$

The price setting (right hand side) takes into consideration the normal depreciation costs that results from the deterioration of different vintages of capital that have been bought at different times, prices and interest rates. $Pk_{i,t}$ is the price of capital good that depends only on the wages paid and the level of labor productivity in the capital sector (since no capital goods are involved). Interest rates are introduced in the price setting because firms charge consumers all the costs they have to face in order to get the necessary finance to buy the inputs required.

2.5.4 The capital-good industry and the productivity function

While the consumption-goods industry is composed of different firms selling different types of products, those firms being in the capital sector are diverse but all of them produce all the types of machinery needed.
The capital heterogeneity relies only on the different technologies that the machines embody. This in turn implies different associated labor productivity. The technological differences within the capital industry may grow or flatten over time, according to the innovation trajectory. The labor productivity in the production of capital goods is assumed to grow according to the average labor productivity recorded in the consumption industry[12] (Dosi et al., 2019).
In line with the existing literature, the capital sector pays wages to skilled workers for the research activity. R&D expenditures, which are a percentage of past sales, are driven by the desire to discover new capital goods. We are reproducing the dynamics that might emerge in the market where different enterprises compete in terms of quality of their products in order to gain market share or, at least, not lose it.
We model process innovation using the typical innovation function common in the literature (e.g. Dosi et al. (2010) and Caiani et al. (2019)). A Bernoulli distribution is used to model the probability of having or not having innovation. A beta distribution is also employed to define whether innovation is successful or not (this stochastic process gives the productivity improvement/ deterioration). Innovation is considered successful if the technology embodied in the capital good allows the consumption industry to produce with lower labour per unit of capital. The stochastic process mimics those factors which influence search and discovery capabilities (e.g. interdependence among research institutes). The discovery probability is:

$$pinn_{i,t} = 1 - exp(-\tau * \sum_{t=1}^{t=T} RD_{i,t}) \tag{13}$$

In introducing the cumulative R&D we rely on a number of research that demonstrate how the invention process is cumulative and path dependent. Some authors identify worker migration flows as the cause of the cumulative process (e.g., Neffke et al. (2017)), while others (e.g, Alonso and Martín (2019) and Balland et al. (2019)) have stressed the technological relatedness and the importance of the innovation process building on pre-existing capabilities. Moreover we adopt the typical imitation function that reproduce the possible spillover effects that occur among firms belonging to the same business sector. Such dynamics depend on a stochastic process that, exactly as above (equation 13), determines the probability of imitation. Once imitation occurs, the firm can adopt the technology at the frontier. We have also introduced in the model a spillover effect that works even between firms not belonging to the same business sector. In any case, the intensity of the latter force is assumed to be minimal with respect to the imitation effect.
In the present study we assume that the innovation process changes the number of employees per unit of capital ($capital - labor$ ratio), while we leave aside all the considerations that rely on any change in the amount of products per unit of capital ($capital - output$ ratio).

The combined effect of the described functions reproduces the positive relationship between market size and labor productivity. Indeed, while the draws from the Beta distribution, which give the innovation intensities, are time and sales invariant, the probabilities of innovation depend on the levels of cumulated R&D that, in turn, depend on the level of sales.

[12]This simplified specification of capital-goods sector together with the choice of having an innovation process taking place only within the consumption-goods sector are motivated by the aim of the paper, that is the analysis of the role of process innovation in the final-goods sector.

2.5.5 The labor market

The labor market is certainly not Walrasian: real-wages do not clear the market. Real wages are rather the results of market forces such as the workers bargaining power and the productivity allocation.
Workers are employed either in the consumption industry, among the heterogeneous firms producing different basic goods, or in the capital sector, both on production lines or in research labs.
In the consumption-industry the level of employment is a function of the desired production level and the workers productivity

$$N_{i,t} = \sum S_{i,t}/(ykratio_{i,t} * 1/lkratio_{i,t}) \tag{14}$$

The labor productivity $ykratio_{i,t} * 1/lkratio_{i,t}$ ($lkratio_t$ is the number of workers per unit of capital) depends on the technology embodied in the different vintages of the productive machines that determine the number of output per unit of capital and the amount of labor per unit of capital. For this reason, in our model, the $lkratio_{i,t}$ is a weighed average of the different vintages of capital, weighted by the remaining productive capacity of each unit of capital with respect to the total capacity.
The nominal wages, however, are determined at firm level and may be indexed to the firm productivity, according to the different distributive scenarios under analysis. Moreover, there is also a Phillips curve effect that takes into account the bargaining power that might emerge because of higher employment levels.

$$w_{i,t} = w_{i,2} * (1 + ind * deltapr_{i,t} + ph * (-un_{t-1} + un_{t-2}) \tag{15}$$

While in the capital-industry the employment level is determined by the amount of capital to be produced and the industry labor productivity, in the research labs it is determined by the amount of R&D expenditures and the researchers productivity (which is assumed to be equal to that of the workers on the production line, which is indexed to the average productivity of the consumption industry).

The nominal wages in the capital industry, both in research labs or on the productive lines, grow with the corresponding average productivity of the sectors and according to the Phillips curve effect (depending on the scenarios under analysis).

In our model, we assume there are not problems with workers' capabilities; they can move from one sector to another and do not need any skills to be acquired ex ante. In no way we are taking into account the possible frictions and difficulty that might emerge when employment move from one sector to another (Delli Gatti et al., 2012). In addition, we will not examine population dynamics, despite our lengthy discussion of economic growth and productivity increases, which generally demand a substantial amount of time. This is because we want to concentrate solely on per capita increase.

2.5.6 Entry-exit mechanism

Since the firms producing capital goods work only on commission basis, bankruptcy may occur only in the consumption industry. The default appears when a firm does not manage to repay the debt expenses and enters in a Ponzi scheme where new debt is demanded in order to repay the old one. At this point, the firm exits the market and its equipment is foreclosed by the banking system. Since we have assumed that there is a tendency to restore the initial number of firm for each sector, new firms enter into the market according to a stochastic process that also takes into consideration the level of market competition. New firms, as old ones, do not enter into the market with the capitalists' own finance: after having estimated the sales expectation and the necessary level of capital goods, they ask for a bank loan.

2.5.7 Public sector

Public expenditures are anticipated, if necessary, by means of the Central Bank (CB) overdraft line of credit. The state then collects taxes on the earnings. At the end of the period, eventual realized deficits are covered by issuing bonds that are bought by workers and capitalists, according to their preferences. If workers and capitalists purchase less bonds than expected, the CB intervenes as buyer of last resort. We have assumed in our model that the public sector always spends the same in real terms. The invariance of the public expenditure over time and its total independence from the rest of the economy means the state plays an important role. In this approach, there is a constant demand flow that facilitates the stabilisation of the model, which would have been difficult considering the Keynesian multiplier and accelerator mechanisms. Allocation of public consumption between the different final goods depends on the producing sectors capacities. This means that higher is the relative capacity of one sector over the total productive capacity, higher is the amount spent by the state on such a sector. The amount of public deficit/ surplus is anti-cyclical. Because of the invariance of the expenditures, the state collects less taxes when the economy goes down (and goes in deficit) and more when the economy booms (going in surplus).

2.5.8 Banking sector

For the sake of simplicity, the banking sector is modeled as if it were composed of one bank only. It offers loans at the request of businesses for both the acquisition of capital goods and the financing of current operating expenses. Different interest rates are charged and different time spams are set to repay them. Loans on equipment are assumed to be more long-lasting than those issued for current expenses (wages, primarily). In case new loans are required in order to repay previous debts (Ponzi's scheme), the banking sector cuts the credit line and the company defaults and exits from the market. All the outstanding debt becomes non-performing and stays on the bank balance sheet to be partially reduced when the foreclosed equipment is sold. The bank profits are computed as follows:

$$Profit_t = \sum interest_t + rd_t * Reserves_{t-1} - rd_t * Deposits_{t-1} \qquad (16)$$

If both profits and the cash account are positive, then bank owners receive dividends. In case the banking sector run out of money they can always borrow money from the CB. We assume that such advances are to paid in one time period. Converse, if bank liabilities are greater than its assets, the bank lends money to the central bank. Any CB bank profits which are the difference between interest on public bills and interests on reserves are paid back to the state.

The whole outstanding debt of the economy always corresponds to the net savings. Whatever is in the agents bank accounts (workers, capitalist, firm and public sector accounts) has a counterpart in the net outstanding borrowing of the bank sector and net borrowing of the central bank. In the event that CB is forced to buy state bonds, as a buyer of last resort, the whole money in circulation has been issued by both the banking (private money) and public sector. In this case, since we have electronic money only, the banking sector liabilities are greater than assets and reserves appear. Reserves are the counterpart of the public bonds held by the CB. According to the portfolio decisions of workers and capitalists the amount of HPM is greater or lower. Indeed, if the wealth allocation goes more toward money, CB is forced to buy more public bonds. In the alternative scenario, the bond purchase is a way of recycling savings that are in the agents bank account. This suggests that the same level of economic activity is achievable with varying amounts of HPM in circulation (at least, if interests on bonds are assumed equal to zero).

2.5.9 Calibration

Table 4: Benchmark parameters

Description	Symbol	Value
Workers propensities to consume on income	α_{1w}	0.7
Workers propensities to consume on wealth	α_{2w}	0.03
Capitalists propensities to consume on income	α_{1c}	0.7
Capitalists propensities to consume on wealth	α_{2c}	0.03
Fimrs markup	μ	0.2
Bill purchase propensities	λ_0	0.635
Bill purchase propensities function of interests	λ_1	0.4
Bill purchase propensities function of yd/v	λ_2	0.3
Sales expectation correction	β_1	0.4
Sales expectation growth correction	β_2	0.4
Desired level of inventories	d	0.01
Labour productivity in capital sector	pr_{inv}	7
Capital utilization rate	ut	0.8
R&D investment propensity (% over sales)	RD	0.05
Firm search capabilities	τ	0.007
Beta distribution parameters(innovation process)		(3,3)
Products for unit of capital	$ykratio$	2
Units of capital per unit of labour	$klratio$	3.5

2.5.10 The different distributive scenarios under analysis

As recognized by Karl Marx, we also think that the labor productivity trajectory strictly depends on the productive relationships (which define what is to be produced and how) and the level of knowledge in the world. This is a historically determined process that results from multiple combinations of factors, mostly compounded historical ideas, new equipment and mode of production. For this reason, in contrast to the marginalist theory, we do not think there is a proper way to recognize the contribution to productivity gains of each agent employed in the current production. Therefore, we limit our study to looking at different scenarios that reflect the different possible ways of distribution of the productivity gains among the social classes (toward the capitalist class, toward the workers or, more generally, toward all the consumers) that could equally be the results of the relative powers of the workers against the capitalists (in the economy as a whole, in the sector and at firm level) and of the market conditions that shape the possibility for the firms to set their desired level of prices.

The issue regarding allocation of the productivity gains is often referred to as the problem of compensation mechanisms (Freeman and Soete, 1987)

Therefore, in order to understand the effects of technology innovation on the main macroeconomic variables, we run different model simulations under three different scenarios that differ in terms of distribution of the productivity gains between economic agents. In the first scenario (the *wage scenario*) we assume that, when process innovation occurs, the consumption-good industry needs less labor per unit of output and symmetrically there is an increase in the nominal wages while the prices remain unchanged. Most of the evolutionary literature focuses on this mechanism, reproducing the productive forces which were behind the capitalism forces until the eighties and that commonly go under the name the Fordist regime[13] (e.g., Ciarli et al. (2019), Dosi et al. (2021b) or Caiani et al. (2019)). The functional distribution does not change. In our model the wage indexation is at firm level but in reality it can also work at sectoral or economy level. Each of these possibilities can imply different macroeconomic effects at the company and sectoral level, for example, meaning a concentration of redistribution within the working class[14]. At the economy level, however, a unique parametrization level is necessary and would give rise to discrepancies among firms (if the rate of productivity increase differ among sectors), some earning more and others paying more (Baumol's cost disease), with the threat of possible inflationary pressures[15]. Moreover, any sort of wage indexation requires a working class that has enough bargaining power to demand it, assuming that the increases in productivity are known.

In the other scenario, the one we call the *markup scenario*, given the market conditions and the institutional landscape in favor of the capitalist class, companies, leveraging on their market power, take advantage of the improvements in production efficiency and increase their markups. In this instance, unit costs decrease but prices remain unchanged, resulting in a rise in markup. The functional distribution changes in favor of the capitalist class.

Finally, we propose another scenario where the increases in productivity are not entirely appropriated by the capitalist class or the working class, but are shared with the consumers through the price channel (the *price scenario*). Wages and markups remain constant, while prices decrease. In this case, the distribution of the productivity increases among the social classes depends on who the buyers are of the goods produced in the sectors where the innovation has taken place. Once innovation occurs in sectors producing more basic commodities, the poor gain from it, and when it occurs in the luxury sector, the highest-earning individuals do. Therefore, with different productivity trajectories in the various sectors, the productivity improvements can be equally shared among social classes only if their preferences are the same or in the case of shared means of production that embed the technological change. Without considering the possible disparity emerging from the interplay between the locus of the innovation and the different consumption between the social classes, the *price scenario* does not imply any change in the functional distribution.

The price channel, while it might be hampered by firms not willing to start a price war, is a natural result in sectors with positive price elasticity of the demand, such as those capital intensive sectors producing homogeneous goods. Moreover, rather than being the result of actions taken by incumbent firms, the distribution of productivity gains through price decreases may be the result of new firms entering the market with innovative products that incorporate the same or higher productivity and are sold at current prices or lower. When prices are identical, the pricing channel operates implicitly. The proliferation of low-cost businesses increases the operation of the pricing channel, providing customers with an alternative.

The different scenarios might be viewed as all viable options inside the capitalist system. They can also be present simultaneously in different industries or at different times within the same industry.

[13]Usually qualified with relatively lower differences in wages and profit rates, and relatively higher wage elasticity with respect to productivity and inflation

[14]All the workers not employed in the lucky sector/firm are not directly affected

[15]Under certain conditions, and if the inflation works smoothly, this scenario can be closely related to the price channel scenario, as will be seen later.

2.5.11 Different versions of the model

Different versions of the model have been adopted in order to better address the different question we had in mind. These are summarized in the following table.

Table 5: Versions of the model

	Version of the model	Labor productivity change	Topic	Section n
1)	SFC one-sector economy	One-shot shock	Instability and difficulty to reach macroeconomic growth	2.6
2)	SFC-ABM one-sector economy	Ongoing stochastic process depending on cumulated R&D	How the macro level affects the labor productivity (macro effect)	2.7
3)	SFC-ABM multi-sector economy	Ongoing stochastic process depending on cumulated R&D	How the meso level affects the labor productivity (composition effect)	2.8

2.6 The tendency toward the elite embedded in the innovation process and the difficulty to achieve macroeconomic growth

The innovation process is a necessary condition to achieve long-lasting macroeconomic growth; it frees up labor to be employed in the production of different goods. However, it is not a self-sufficient process and is usually interrelated with economic instability.

The embedded instability is not only due to the labor mobility that usually comes with structural changes (Delli Gatti et al., 2012), that soon or later will occur when increasing labor productivity (per output) is associated with consumers preference for variety, but also because of the negative economic spirals that may occur when innovation implies worker displacement[16] and/or higher inequality levels (with the upper social classes that have lower consumption propensities on the income levels).

In addition, if Engle's Law is at play and labour productivity continues to rise, both the availability of constantly new (or better) goods and the consumers' willingness to increase their consumption bundles without decreasing their consumption propensities on income are required to prevent the economy from shrinking (Pasinetti, 2006).

However, even if these conditions are met, there may still be hurdles to economic growth that are tied to the demand side of the economy. In fact, in demand-driven economic systems, even if there is a surplus of labour, macroeconomic growth may not be attained if monetary demand does not increase. Because of adaptive expectations, firms produce more only when they expect to sell more and this expectation only occurs when higher demand is recorded. Accordingly, it is unlikely that the private sector can produce the increased demand required for productivity to propel economic growth. In fact, in order for the gains in efficiency (which may be the engine of economic growth) to be realised, the inputs per unit of output must be reduced, resulting in an increase in the unemployment rate[17]. This means that once the labor productivity increases while a few earn more, there are others that have to quit the market and cannot afford consumption. The total income does not change. It is just redistributed to fewer individuals (those capitalists and workers still involved in the production).

[16]This results when labor productivity growth rates are higher than output growth rate

[17]Things are different when process innovation achieved in a certain business sector goes hand in hand with product innovation in the same sector, so that the reduction of inputs per unit of output is offset by the increase in the number of activities and the final result is a better product at around the same price.

Here below, for clarity, we report the stylized situation that emerges once the increase in labor productivity occurs under the wage scenario.

$$Q_0 = N_0 * w_0/p_0 \tag{17}$$
$$Q_1 = N_1 * w_1/p_1 \tag{18}$$
$$Q_1 = (N_0/(1+pr) * w_0 * (1+pr))/p_1 \tag{19}$$
$$p_1 = p_0 \tag{20}$$
$$Q_1 = Q_0 \tag{21}$$
$$N_0 * w_0 = N_1 * w_1 \tag{22}$$
$$N_0 = N_1 - \Delta N \tag{23}$$
$$w_1 = w_0 - \Delta w \tag{24}$$
$$\Delta N * w_0 = N_1 * \Delta w \tag{25}$$

If there is a perfect alignment between labor saving and wage increase, the real incomes of a few increase, the production levels remain invariant and the unemployment levels increase.

Now, in order to analyse the impacts an increase in productivity has at the macroeconomic level, under the different distributive scenarios, we employ a stock-flow consistent aggregate version of the model. In this Section, to make things very clear, the artificial economy under analysis is limited to one sector only (any gain in real incomes is spent on greater quantities of the same product) and the innovation process[18] emerges as results of a one-shot shock.
The shock occurs in all the scenarios under consideration, once the stationary steady state is already obtained. Figure 5 shows the results.

As can be seen, once the shock hits the economy (at t=350) the employment plummets and never recovers to its pre-shock levels. In contrast, output and consumption levels, at least in the price and markup scenario, gradually return to pre-shock levels after being influenced by the shock. This convergence is possible because of the anti-cyclical nature of the public deficit and because of the dependency of the consumption function on the wealth levels.

Specifically, in a demand-driven model that replicates a monetary economy, a fiscal rule in which both public expenditures (which are, by the way, set in real terms so as not to cause confusing results in the price scenario) and tax rates are constant (therefore taxes are endogenous) yields a stationary steady state where the fiscal accounts are in balance at a certain GDP level (zero public deficit or surplus).

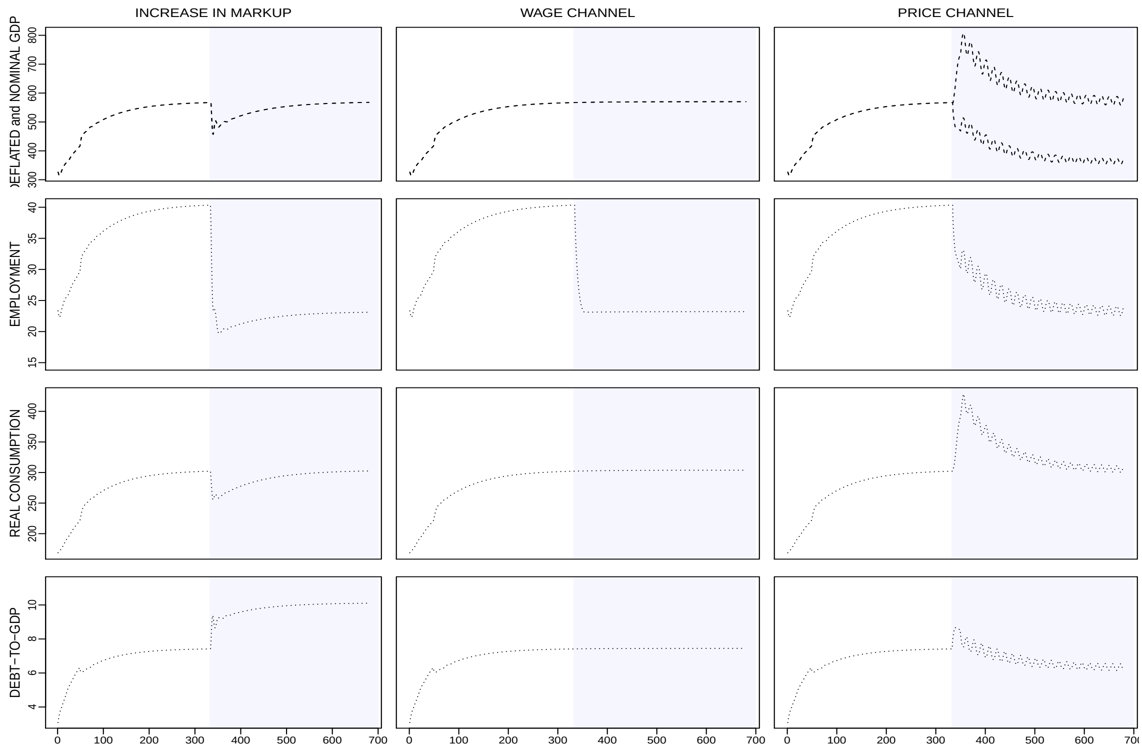
This implies that, if it is assumed that consumer spending is dependent on wealth levels, the state exerts a gravitational force on the economy. Higher monetary injections into the economy from the state (public deficit) increases the stock of private wealth, hence promoting greater production. In contrast, when more money is drained (fiscal surplus), the government slows the economy.

In particular, in the markup scenario, because of the different consumption propensity among the social classes and because of the shift in the functional distribution, the shock boosts the public deficit. The higher net injection into the economy will slowly determine the convergence of the production level towards the pre-shock levels.

In contrast, under the price scenario, a decrease in prices has a beneficial impact on the economy. The value of the stock of wealth rises, and as a result, output increases (because of the stock-norm). However, a public surplus emerges, and the state begins spending less than what it collects (in terms of taxes). Thus the state, withdrawing money from the economy, reduces the expansionary force and restores production levels to pre-shock levels.

[18] To be clear, note that we are working on the productivity of the labor force that is employed in the consumption industry ($capital - to - labor$ ratio) while we are overlooking all consideration related to changes in the amount of products per unit of capital ($capital - to - output$ ratio).

Figure 5: Elite tendency in an aggregated model



Time spam=700 periods. 100% labor productivity shock at t=350

Instead, in the wage scenario, the shock appears to have no effect on the economy, except for the unemployment rate. In fact, the total income remains constant, neither in its distribution across classes is affected. Only the number of workers who benefit from it changes. A few workers increase their consumption, while others leave the market.

The public debt to GDP ratio moves consistently with all this.

In the price scenario, once the shock strikes the economy, private spending rises due to the wealth impact (whose magnitude reflects the earlier price system), allowing for a more gradual decline in the employment rate and fiscal surplus. However, the Debt-to-GDp ratio increases. This is because, while the nominal GDP declines rapidly, the stock of public debt that is tied to earlier economic conditions takes time to adjust to the new system of prices.

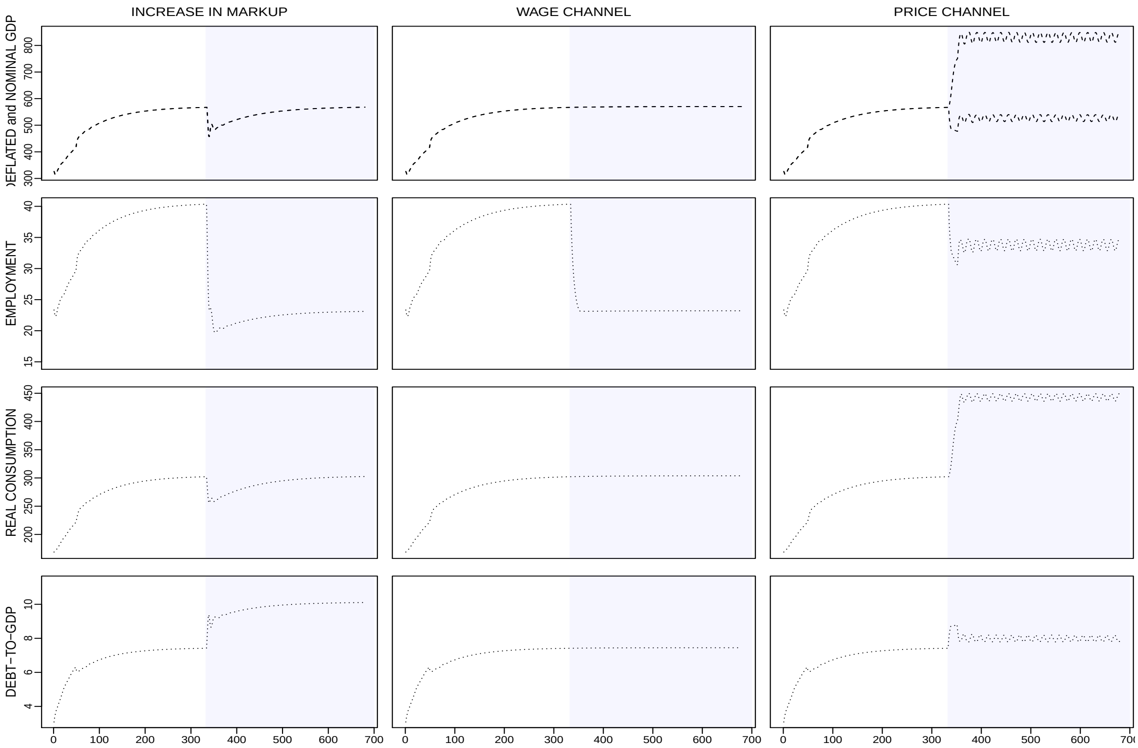
In contrast, under the markup scenario, a stable increase in the public Debt-to-GDP ratio must follow the productivity shock. The shift in functional distribution, which benefits the upper class, which has lower consumption propensities, and the residual nature of profits that emerge only residually (as we will in Figure 8), implies a slowdown in GDP levels and the emergence of transitory public deficits that, by the way, will have a permanent impact on the Debt-to-GDP ratio.

To conclude, in all the scenarios, the new stationary steady state exhibits constant production and consumption levels as well as decreased employment rates[19]. While there are a few individuals who consume more, others are forces to stop consuming.

If we amend the function related to the fiscal rule, for instance, letting the state have a structural fiscal surplus (through, for example, surplus redistribution), the results change. This is shown in Figure 6. In this case, thanks to the higher purchasing power of the monetary stocks, the price channel shows a higher degree of freedom to reach a new stationary steady state where higher production (and a lower unemployment rate) is achieved.

[19]Keeping constant the working hours per person

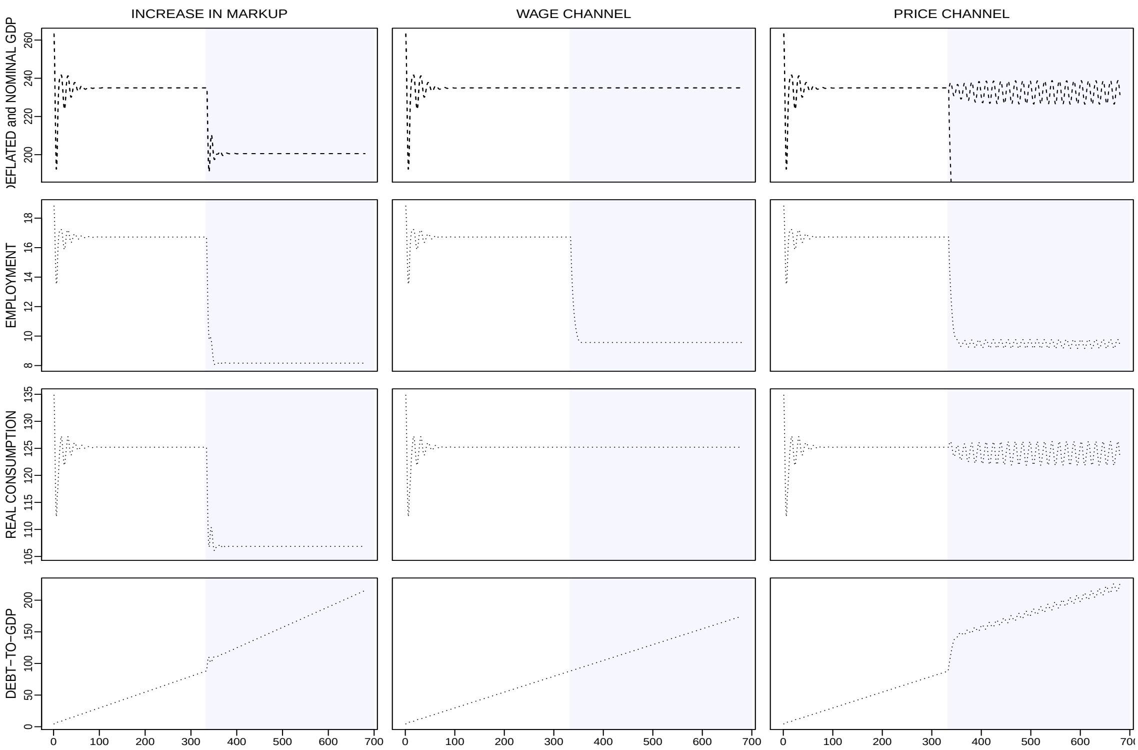
Figure 6: Elite tendency in an aggregated model with redistribution of the fiscal surplus



Time spam=700 periods. 100% labor productivity shock at t=350

In order to show that the higher performances achieved under the price channel are linked to increases in the value of the monetary stocks, Figure 7 shows the simulations where the consumption propensities on the accumulated wealth are set equal to 0.

Figure 7: Elite tendency in an aggregated model, without the consumption propensities on wealth

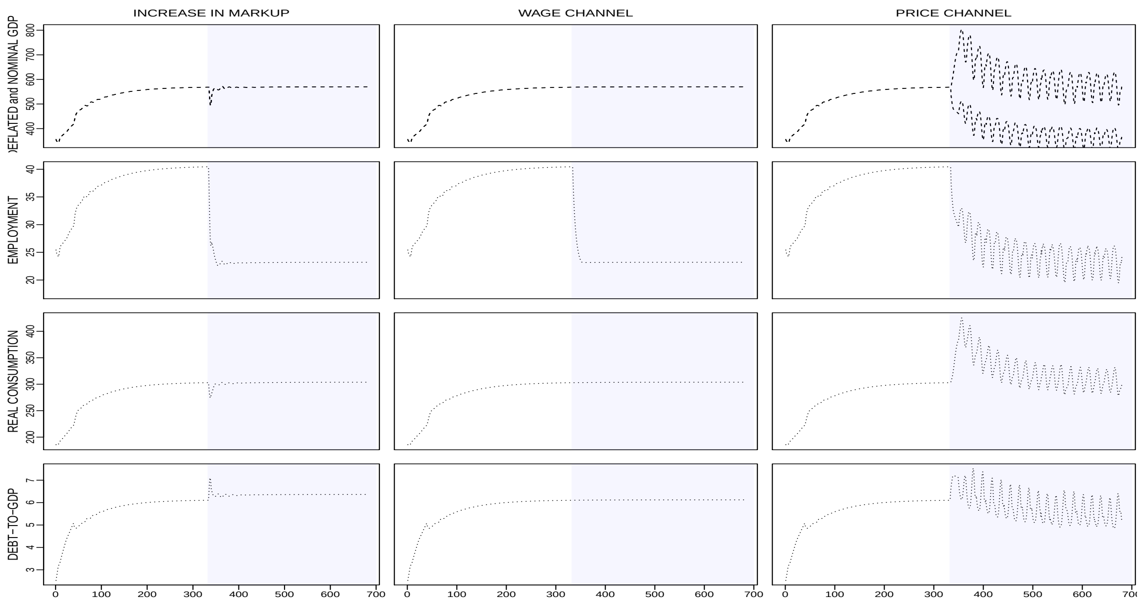


Time spam=700 periods. 100% labor productivity shock at t=350. $\alpha_{2w}=\alpha_{2c}=0$

As can be seen, the price scenario "advantage" has now disappeared. The "passivity" of the accumulated wealth can also be seen from the rising levels of the public debt-to-GDP ratios, which have to deal with the increasing levels of private savings that never re-enter into circulation. For the same reason, the production and consumption levels in the markup scenario in the new stationary steady state are much lower. In this case, even though the state happens to be in structural deficit, injecting more money into circulation is not enough to create the buffer required to allow recovery of the pre-shock production levels, as was the case in the simulations shown in Figure 5. Because of the absence of the stock norm on the consumption function (see equation 4), the average consumption propensity decreases and a new stationary steady state is achieved.
In fact, when the propensities to consume on the accumulated wealth are settled equal to zero, the propensities to consume shape the stationary steady state solutions of the economy.

Now, to show that the decrease in employment and in production that are recorded in the markup scenario are mainly attributable to the different consumption propensities among social classes, Figure 8 shows the simulation obtained in a model where all the social classes have the same consumption propensities.

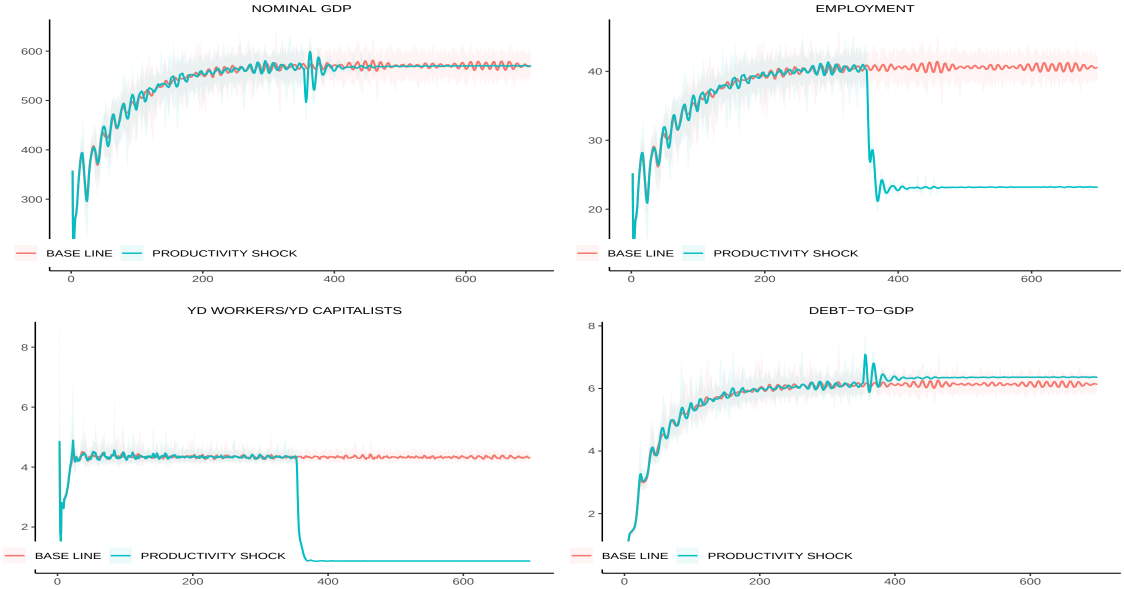
Figure 8: Elite tendency in an aggregated model with same consumption propensities among social classes



Time spam=700 periods. 100% labor productivity shock at t=350. $\alpha_{1w}= \alpha_{1C}= 0.7$, $\alpha_{2w}= \alpha_{2c} =0.03$

As can be seen, the wage scenario and the markup scenario now exhibit identical trajectories. The only minor change regards the public debt to GDP ratio. In attempt to investigate the underlying causes of this disparity, several Montecarlo simulations have been conducted under the markup scenario. The same consumption preferences are assumed across socioeconomic classes, and the productivity shock has been allowed to affect some simulations but not others. The results are shown in Figure 9. The simulations affected by the productivity shock exhibits a major increase in the Debt-to-GDP ratio, despite the fact that the consumption preferences of the various social strata remain unchanged. This growth is attributable to the residual nature of profits. Profits are residual outcomes dependent on overall sales volume. This implies that if the decreased consumption by the working class must be balanced by a greater consumption by the capitalist class, this may not occur due to the timing mismatch, at least if the capitalist class does not foresee the increase in the profit level. Due to Kaleky's theory that capitalists earn what they spend while workers

Figure 9: Comparison of Montecarlo simulations with and without productivity shock. Increases in productivity are appropriated by the capitalist class

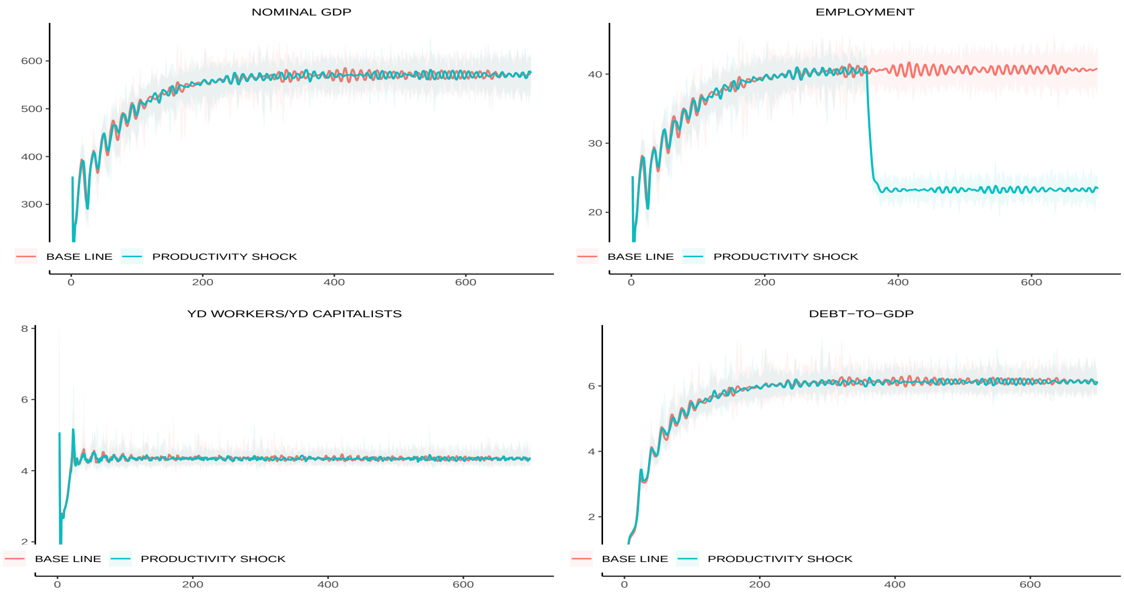


Time spam=700 periods. The sheds enclose all the simulations while the lines represent the average simulation. In blue those simulations hit by the productivity shock. $\alpha_{1w}= \alpha_{1C}= 0.7$, $\alpha_{2w}= \alpha_{2c} =0.03$

spend what they earn, the markup scenario is more likely to result in a recession than the other instances, regardless of consumption propensities.

To illustrate this further, Figure 10 depicts the exact same experiment as Figure 9, but with the productivity gains that are distributed to the working class. In this instance, the Debt-to-GDP ratio remains unchanged.

Figure 10: Comparison between Montecarlo simulations in an economy without the productivity shock and in an economy where the productivity increase is recognized by the working class



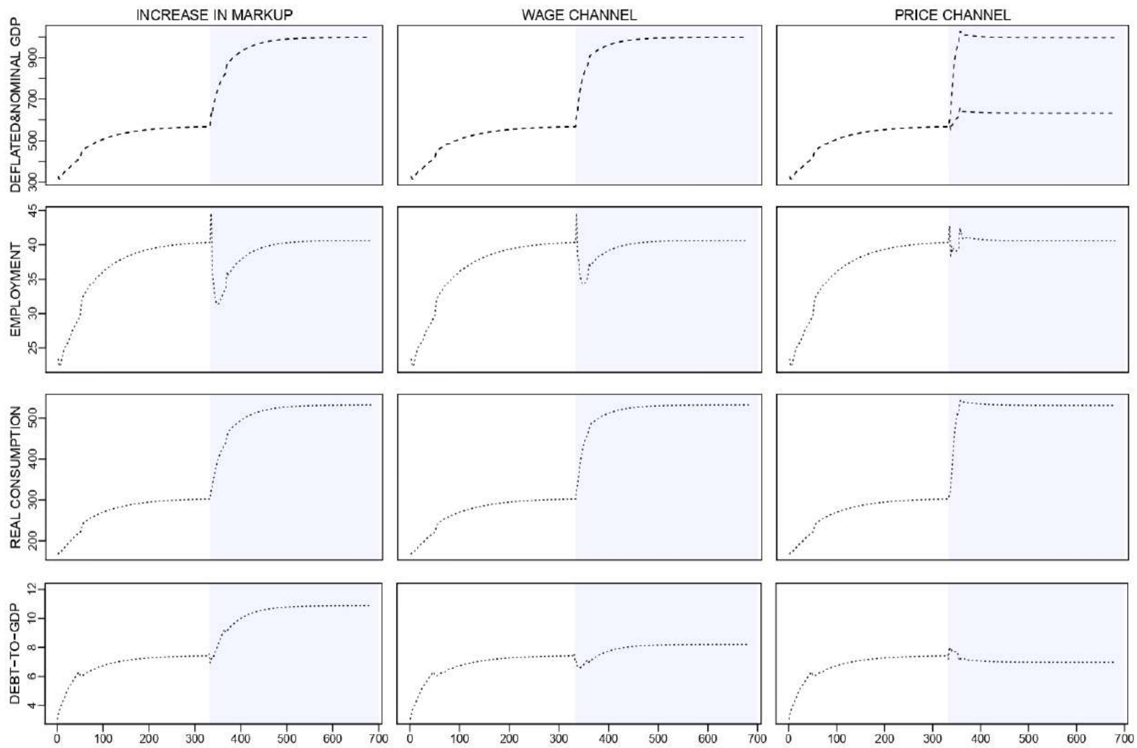
Time spam=700 periods. The sheds enclose all the simulations while the lines represent the average simulation. In blue those simulations hit by the productivity shock. $\alpha_{1w}= \alpha_{1C}= 0.7$, $\alpha_{2w}= \alpha_{2c} =0.03$

2.6.1 Public intervention to sustain macroeconomic growth

As has be seen so far, in all the scenarios analyzed, the increase in labor productivity leads to a strong reduction in aggregate working hours, leaving the production levels invariant. As long as these workers are out of the labor market, the economy is working below its potential and a portion of the population does not get access to the goods market. It seems that the capitalistic system does not have on its own the capabilities to share the productivity benefits across all people. Neither does it seems able to capitalize on such results in order to achieve macroeconomic growth. For this reason, some institutional forces are required: either an institutional imposed homogeneous reduction of the daily working hours that might leave people consuming the same[20] and working less, or some sort of economic aid to help recovery to pre-shock employment levels and achieve macroeconomic growth.

Figure 11 shows the results achievable once the state has a hands-on approach and intervenes in the economy by way of higher spending. This may take different forms, such as higher public consumption or labor subsidies. In this instance, we have only modified

Figure 11: Public intervention to deal with the technological displacement of labor



Time spam=700 periods. 100% labor productivity shock at t=350. α_{1w}=0.7, α_{1C}= 0.4, α_{2w}= α_{2c} =0.03.

the public rule to align public expenditures with the productivity curve. This intervention enables macroeconomic growth to be fully realised, employment levels to return to pre-shock levels, and total production to increase substantially. Such action that results in a greater public debt is accompanied by an increase in GDP, hence the Debt-to-GDP ratio is unaffected. The increase in Debt-to-GDP attained in the markup scenario is identical to that obtained without government involvement. (see Figure 5). The current level of macroeconomic growth is stable because the level of the autonomous demand is higher and the public forces can absorb future shocks whenever they occur.

If we had implemented a temporary measure, even if the state could have injected enough money into circulation for employment levels to restore to pre-shock levels, we would have

[20]There are in any case distribution issues. Those that reduce the working hours are only the workers and, for instance, in the markup scenario the share of production to be shared among workers is lower.

had to sacrifice the public fiscal balance (that would have made the measure ineffective). The resultant stationary state would have been unstable due to the fact that the GDP levels attained would have constantly produced public surplus (to be redistributed among consumers) and there would have been no force to anchor the production level. Even little variations from the achieved stationary state solution would have restored production levels to pre-shock levels, preventing stable economy growth. In fact, the public state does not have any tool to handle the business cycle at levels higher than those in line with public expenditures (combined with the multiplier mechanism).

In conclusion, we argue that, even in a population-stable society, macroeconomic growth is achievable if worker productivity rises. It is conceivable because efficiency advances, on the one hand, free up labour force for use in the manufacture of different goods, and, on the other hand, urge (and allow) the public sector to boost its expenditures if it is unwilling to accept high unemployment. This finding differs slightly from the conclusion reached by traditional Sraffian-Supermultiplier models, in which development is achieved by a steady rise in the various variables reflecting the autonomous component. This result also resembles the perspective of a number of scholars who viewed the capitalist system's depressions as technologically induced (e.g., Delli Gatti et al. (2012))

2.6.2 The possible private forces that help achieve macroeconomic growth

As we have already seen, the price mechanism can help sustain a sort of macroeconomic growth. However, this is only possible under some fiscal rules (that allow fiscal surplus redistribution), and the level achieved is unstable and still below the economy's full potential. In fact, the valorization of the accumulated monetary stocks (even with a public expenditure fixed in real terms) together with positive propensities to consume on wealth, leads to an increase in the aggregate demand and to higher investment levels. However, such dynamics, as shown in Figure 6, do not assure employment to fully recover its pre-shock levels and therefore macroeconomic growth is lower with respect to the scenario with public intervention (Figure 11), and anyway unstable.

Some other private forces may emerge in the multisectoral framework, where the total income reallocation, reshuffling the demand shared among firms, can boost the economy to higher GDP levels. The employment reduction (that happens to be only in those sectors where the productivity rate is higher than the growth rate) generally impacts, in terms of demand, all the *more basic goods* sectors, according to the distribution of the consumption bundles of the people that have been fired. In contrast, the higher incomes, that are concentrated in the hands of those still involved in the production, are generally directed toward sectors which produce *more luxury goods*. This means that the production structure has to adapt to the new consumers needs. In these adjustments there may be the seeds for macroeconomic growth because some companies will have to increase their capital levels and others to reduce it. Now, given the rigidity of the capital goods that prevents companies from immediately adjusting their level [21],whereas downsizing of the capital level might need time (sunk costs), at least if the required downsizing is greater than the periodic depreciation, an increase in the capital level is almost immediate. There is, therefore, a temporary oversizing of the aggregate capital level. Such oversizing, while it might be only a temporary dynamic[22], a zero-sum game in the proper time horizon (the time in which what is gained in the initial periods in terms of investment in the "new" sector is exactly what is lost in the "old" sector in x periods because of the minor capex), can be a structural feature of the

[21] In our model, in fact, firms can reduce their capital level only by avoiding the replacement of the depreciated capital. Things might be even exacerbated when the equipment at disposal do not deteriorate at each time but, instead, stop functioning after a certain date

[22] Unless without the existence of path dependency mechanisms (that are usually, at least partially, counterbalanced by stabilizing forces)

economy if the demand reshuffle happens constantly, before the offsetting forces have taken place integrally (which means higher investments and structurally lower utilization rate of the production capacity). Actually, this dynamic can also occur in a unisectoral framework when the growth in labour productivity, which reshuffles household income, forces a reallocation of total demand among firms. In any case, this mechanism strictly depends on the reshuffle timing, the intensity of this reshuffle and the depreciation rate of the capital good. The lower the depreciation rate the higher the firm rigidity (the periods needed to adjust the capital levels to the new demand levels) and thus the higher the possibility for the private sector to sustain growth.

In a multisectoral framework it is also important to take into consideration the impact of the different technical coefficients among business sectors.

Different worker productivity levels are incapable of having a major effect. In fact, the introduction of new industries with higher working hours per output has only effects on the price and quantity acquired of the new commodity[23], leaving all the macro variables unchanged.

Similarly, inequalities in nominal wages between industries have no effect on production or consumption, only on employment levels. For instance, if advances in productivity are spent in new sectors that pay lower nominal wages (relative to previous sectors), even if the economy fails to achieve macroeconomic growth, the productivity gains are distributed to a greater number of employees, albeit not uniformly. Higher employment levels results.

Due to the differing consumption propensities amongst classes, only lower (positive) markups in the new industries can positively (negatively) impact economic growth. However, economic progress cannot be achieved through the indefinite reduction of markup levels.

In addition, there may be significant repercussions if the relative prices of consumer and capital products vary between sectors. With a greater price of capital relative to consumption goods, there would be a further decrease in employment due to the decline in wage bill caused by the increase in the capital share. This, in turn, would impact the functional distribution and also the ratio of public debt to GDP (through the change in the investment share).

In conclusion, for the economy to achieve macroeconomic growth, an active public sector is required. Without it, the private sector would experience significant difficulties. Therefore, if the history of the capitalistic system is a story of productivity and progress, then it is also a story of increasing public debt.

2.6.3 Not quantities but quality

So far, we have made reference to the increase in labor productivity which do not come together with increases in the quality of the same products. Or, at least, we have talked about the delta positive saving in terms of working hour per output between increasing efficiency and higher quality.

However, in the case that the higher efficiency is simultaneously and completely offset by higher activities to be performed (for better products, for instance), there is no problem related to unemployment and growth (at least with unchanged prices). Economic growth is real and materializes in the form of better products.

Of course there may also be the reverse dynamics. An increase in labor required for quality improvement of the product is higher with respect to the efforts saved by the increase in labor productivity. In this case, given that the prices have to change, and keeping every thing equal, there would be a decrease in the average consumption bundle in terms of quantity while an increase in terms of quality. There would be a reallocation of the employment structure of the economy. In this case we cannot call this economic growth because what is

[23]For sake of simplicity, a divisibility approach in the acquisition of the consumption goods is assumed

gained in terms of quality is lost in terms of quantity. In fact, there is no positive increase in efficiency.

2.7 Distribution and growth in a unisectoral economy, the macro size effect

After analyzing the more short-term impacts of the process innovation on the economic variables and figuring out the necessary conditions required for the macroeconomic growth, we study how a different appropriation of the productivity gains may affect the long term macroeconomic growth rate. Specifically, in this Section, we analyze how the different distributive scenarios, affecting the level of the GDP differently, can affect the long term growth of the economy due to the feedback loop that the total production has on its own future trend through its influence on the labor productivity trajectory.

In the model we have built, the level of aggregate output influences the trajectory of labor productivity. Higher market sizes offer greater possibilities for rearranging and making the production structure more efficient, mainly through labor division. Moreover, with an increase in the level of R&D activities, also the probability of innovations is affected.

In this Section, we adopt the disaggregated version of the model (AB-SFC model) but we limit our artificial economy to one sector economy[24] because we want to show how the macro results obtained over time self-influence their future trend without any effects coming from the different composition of the consumption (production) structure (shown in Section 2.8). Moreover, in contrast to section 2.6, where the productivity increase emerged through an exogenous one-off shock, in the model used here the innovation process is modeled as an endogenous stochastic process that depends on the R&D level. Specifically for this reason, we are using a disaggregated version of the model in which both the household and the production sectors are populated by a multiplicity of agents. In fact, when discussing innovation, heterogeneity and interaction are fundamentals.

Taking advantages of the results shown in Section 2.6, we add an endogenous public intervention in which public expenditures rise with the level of economic productivity, so that the monetary demand required to stimulate the higher production and therefore sustain macroeconomic growth is now available.

The public sector, as always, injecting and draining money, stabilizes the economy. It controls the economy from reaching lower or higher production levels so that negative or positive spirals are also prevented. This implies that the different macro results achieved over time (higher/ lower employment and production) under the different distributive scenarios are flattened at the expense of different public debts. However, despite this equalization dynamic, because these adjustments take time and because of the path dependency nature of the innovation process, the different distributive scenarios still have an impact in terms of long-term growth.

As can be seen in Figure 12 and in the following table (Figure 13), in all the scenario macroeconomic growth is achieved, with non decreasing employment levels. The price and the wage channel perform better, in terms of macroeconomic performances, with respect the markup scenario. This occurs despite the gravitational force exerted by the public sector and is primarily attributable to the positive impact of monetary shocks under the price scenario and the negative impact of the shift in functional distribution under the markup scenario. These dynamics, which manifest shortly after the productivity gain and before convergence is established, still leave a mark on future growth. This reassembles the Kaleckian notion that business cycles influence the long-term path of the economy, which can also be regarded

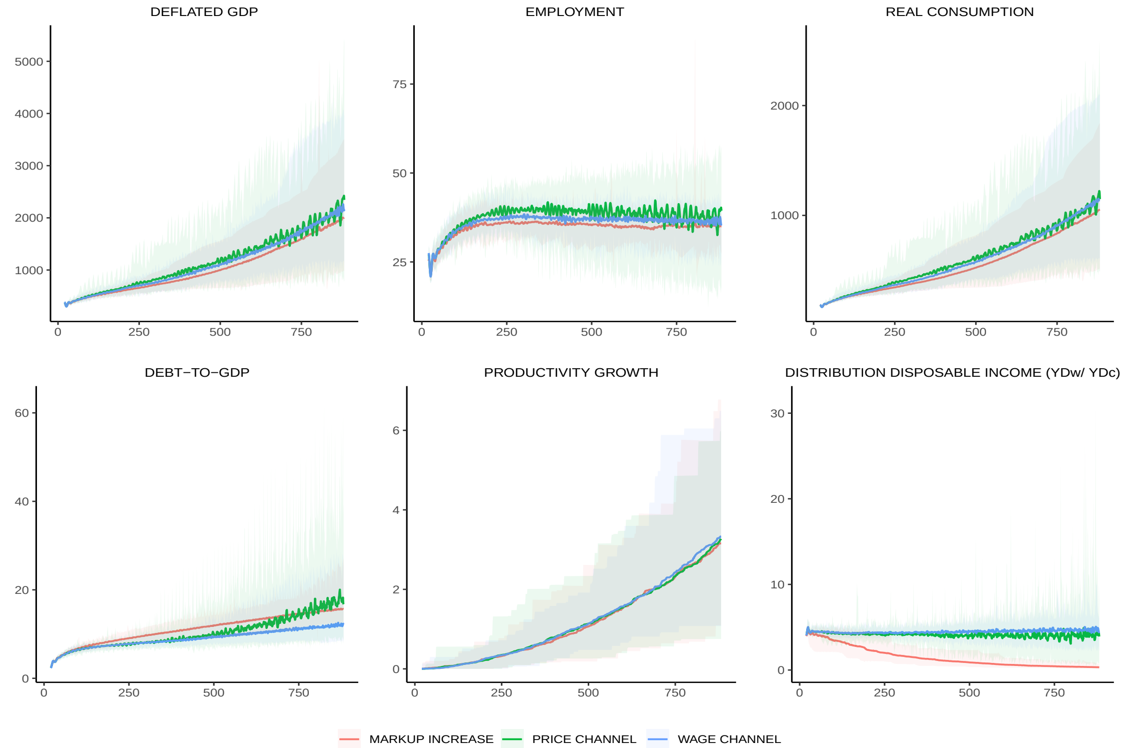
[24] All the increases in productivity are directed to increases in the quantity of the same good

as a sum of short-term periods.

Depending on the scenario, the gravitational force of the state results in varied debt-to-GDP ratios. Regarding the trend of this ratio under the price scenario, a few extra words are needed. This ratio increases despite the economy's positive spiral, which pushes the fiscal balance into surplus. This is due to the failure of the public debt to align with the new pricing system, as instead was the case in Figure 11. While convergence is proceeding, new inventions occur, and alignment with the deflationary pressure is never attained.

The employment rate converges to the same level across all simulations due to the state's stability role. The employment levels are likewise constant as a result of governmental expenditures that are tied to the level of productivity and as a result of the constant population levels.

Figure 12: Growth path in a unisectoral economy



Time spam=900 periods. 40 Montecarlo simulations for each scenario. The sheds enclose all the simulations while the lines represent the average simulation.

Figure 13: Growth path in a unisectoral economy

	MARKUP INCREASE	WAGE CHANNEL	PRICE CHANNEL
GDP growth mean	1,11E-02	1,25E-02	1,27E-02
GDP growth variance	2,21E-05	3,02E-05	4,9E-05
Employment growth mean	5,21E-05	6,61E-05	6,78E-05
Employment growth variance	4,12E-06	5,37E-06	2,15E-05
Real consumption growth mean	1,07E-02	1,15E-02	1,21E-02
Real consumption growth variance	2,20E-05	3,12E-05	5,11E-05
Debt-to-GDP growth mean	4,65E-06	1,02E-06	4,31E-06
Debt-to-GDP growth variance	8,67E-06	7,32E-06	2,41E-05

The growth rates represent the percentage variation in each period

In conclusion, even in a system with a stable population, macroeconomic growth is conceivable, if innovations occur and the government supplies the greater monetary demand necessary to promote higher production, and the distribution of income determines its rate. This section, where the Kaldor-Verdoorn Law (greater productivity raises real production, which in turn affects the probability of innovation) is fully at play, sheds light on the significance of the magnitude of the economy's activities in determining its future growth trajectory. This is also indicative of the impact population growth may have on productivity growth. In fact, despite the fact that population expansion, per se, does not indicate an increase in the average consumption bundle (but merely an increase in the level of production to be shared among more people), it will likely influence innovation via market size and, consequently, per capita consumption.

2.8 Distribution and growth in a multisectoral economy, the composition effect

In this section, the focus is on the meso levels and how the varied distributive scenarios can affect the long-term growth of the economy via the different production trajectories that emerge in response to different income disparities and consumption (production) structures.

Specifically, we investigate how the various consumption structures, which entail varying allocations of working hours between business sectors, influence productivity trends and, consequently, economic growth. We are not discussing a different distribution of company sizes (which will be the topic of the third chapter), but rather the potential of a different allocation of enterprises across sectors, with the distribution of company size and number of firms being identical.

To address these questions, we are finally utilising the model's final version, in which the multisectoral architecture has been deployed. As in Section 2.7, given for granted the conclusions shown in Section 2.6, we implement a public mechanism that indexes its expenditures to the level of labour productivity, compensating for the lack of monetary demand and allowing the entire economy to achieve positive growth rates while maintaining constant employment levels.

As depicted in Figure 14, which shows the trends of the main aggregate variables, and in the Table 15, which displays the mean averages and variances across all the simulations, macroeconomic growth is achieved with non-decreasing and stable employment levels in all of the scenarios.

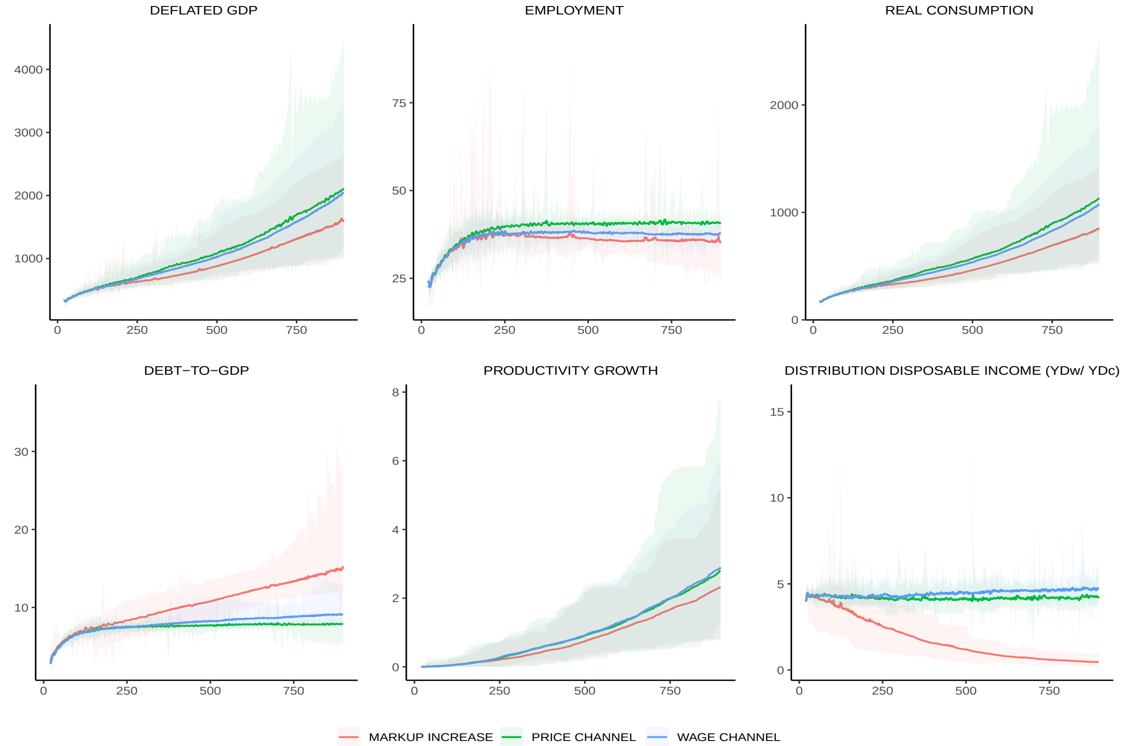
From the simulations emerge that the economy performs better under the wage and the price scenario. The growth rate is greatest under the price scenario and lowest under the markup scenario. The same results are observed in terms of the growth rate of actual consumption. These outcomes are achieved despite an uneven public effort. The markup scenario results in much higher debt-to-GDP ratios.

In order to demonstrate that, in the multisectoral framework, the differences between the distributive scenarios depend on both the *macro size* effect (discussed in the previous section) and the *composition effect* (subject of this section), Table 16 compares the results obtained in this section with those obtained in the preceding section. Given that the adopted models are identical, with the exception of the number of different goods produced, we compare the difference between scenarios in the one-good environment to the difference between scenarios in the multisectoral framework; the differences are computed for each pair of scenarios.

As can be seen, both in the unisectoral version and the multisectoral ones, the differences between scenarios are significant, which means that the different allocations of the productivity gains shape the future macroeconomic growth path in all the settings.

The only exception regards the differences between the price and the wage scenarios which appears to be barely important.

Figure 14: Growth path in a multisectoral economy



Time spam=900 periods. 40 Montecarlo simulations for each scenario. The sheds enclose all the simulations while the lines represent the average simulation.

Figure 15: Growth path in a multisectoral economy

	MARKUP INCREASE	WAGE CHANNEL	PRICE CHANNEL
GDP growth mean	8,75E-03	1,13E-02	1,17E-02
GDP growth variance	6,21E-06	1,09E-05	1,69E-05
Employment growth mean	7,22E-03	9,36E-03	9,88E-03
Employment growth variance	4,34E-08	1,01E-08	1,50E-08
Real consumption growth mean	7,07E-03	9,15-03	1,01E-02
Real consumption growth variance	5,70E-06	1,01E-05	1,56E-05
Debt-to-GDP growth mean	4,12E-06	5,82E-07	4,43E-07
Debt-to-GDP growth variance	9,77E-06	6,40E-08	3,44E-08

The growth rates represent the percentage variation in each period

Figure 16: Composition effect in multisectoral model

	MULTISECTORAL MODEL (macro size and composition effect)			UNILTISECTORAL MODEL (macro size effect)			DIFFERENCES OF RATIOS BETWEEN DIFFERENCES		
	MARKUP-WAGE	MARKUP-PRICE	PRICE-WAGE	MARKUP-WAGE	MARKUP-PRICE	PRICE-WAGE	$(M/W)_M$-$(M/W)_U$	$(M/P)_M$-$(M/P)_U$	$(P/W)_M$-$(P/W)_U$
Ratio between GDP growth means	77%	75%	104%	89%	87%	102%	-11%	-13%	2%
Abs. Diff in GDP growth means	-2,55E-03	-2,95E-03	4,00E-04	-1,40E-03	-1,60E-03	2,00E-04			
Ratio between Real consumption growth means	79%	70%	112%	93%	88%	105%	-14%	-18%	7%
Abs. Diff in Real consumption growth means	-1,93E-03	-3,03E-03	1,10E-03	-8,00E-04	-1,40E-03	6,00E-04			
Ratio between Employment growth means	77%	73%	106%	79%	77%	103%	-2%	-4%	3%
Abs. Diff in Employment growth means	-2,14E-04	-2,66E-04	5,20E-05	-1,40E-05	1,70E-06	5,40E-02			
Ratio between Debt-to-GDP growth means	708%	930%	76%	456%	105%	432%	252%	825%	-356%
Abs. Diff in Debt-to-GDP growth means	3,54E-06	3,68E-06	-1,39E-07	3,63E-06	3,39E-06	1,05E-03			

In the last columns, the discrepancies between the one good framework and the multisectoral framework in the ratio between scenarios are reported.

This exercise shows as the disparities between scenarios (especially between the markup and the wage/price channel) obtained in the multisectoral framework are significantly higher with respect to those obtained in the previous section. In an economy populated by many goods, the markup scenario is still worse in comparison to the others but, comparatively worse, with respect to the one-sector economy. These results show that the composition of the production (consumption) structure also counts in terms of future productivity; therefore not only the company size counts but also the allocation of the firms between sectors.

Less dispersion in the allocation of the working hours among the different industries is advantageous for economic growth because of the imitation dynamics that are at play in the economy. In terms of productivity trajectory, it is advantageous to have a greater number of workers in a smaller number of industries [25]. Consequently, what ultimately matters is the number of people who can benefit from gains in productivity.

The lower the number of people benefiting from the productivity gains, the more the heterogeneity of the consumption bundles, and the lower the future productivity gains as a result of a more fragmented allocation of working hours across sectors. In fact, keeping saturation levels constant, a distribution of productivity gains to fewer individuals will enhance the real income of only a small number of consumers, which will add variety to their consumption bundles.

A further and overwhelming confirmation comes from comparing the levels (and not the differences between scenarios) reached in this section with the previous ones. Table 15 and 13 show how the growth rates of the main macro variables (GDP, productivity and Real consumption) reached under the unisectoral model are above those reached in the multisectoral model. Indeed, in an economy producing identical items, the imitation effect is maximised. In a multisectoral framework, same outcomes would have been attained if distribution among individuals had been perfectly homogenous.

However, in contrast to the one-good setting, the kaldor-Verdoorn law cannot work fully, but applies only within specific limits. In fact, taking into account consumer behaviour and the well-known Engel's Law, advances in productivity can be self-reinforcing through a productivity-output-productivity cycle as long as the output per sector (company) increases. Once saturation levels are achieved and real income increases are allocated to other sectors[26],

[25] These outcomes are achieved despite the spillover effects modeled in our artificial economy, which allow all economic sectors to benefit from each productivity increase.

[26] In our artificial economy, even if production levels remain constant, productivity increases continue to

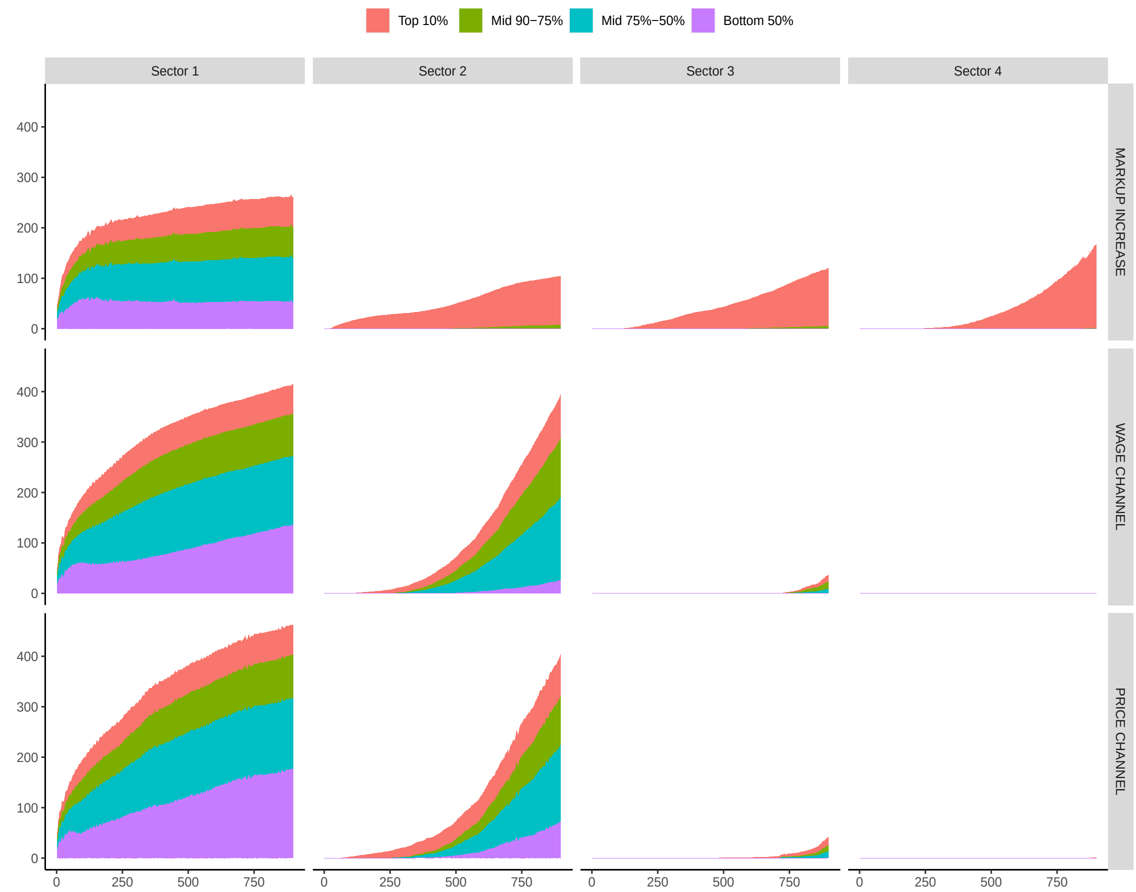
increases in labour productivity will benefit the production of the other sectors, while the old sectors may only enjoy economic spillover effects.

The fact that the one-good setting maximises the imitation dynamics is also the reason why we were unable to analyse the absolute differences across situations in the two settings. Because the levels attained were substantially different, we had to compare the disparities in ratios among the various scenarios.

It should also be emphasised that the different levels of Debt-to-GDP obtained under the price scenario in the unisectoral and multisectoral frameworks are a direct result of the varying economic productivity. In fact, despite the spillover effects, the highest levels of productivity and the lowest prices accentuate to the greatest extent the misalignment between a nominal GDP that responds promptly to price changes and a public debt that is more rooted to old prices. This does not have to conceal the fact that the price scenario requires the least public effort to accomplish macroeconomic development.

If we have determined that the markup scenario is the worst of all the analysed instances at the aggregate level, we must now examine the various quantiles of the income distribution to see whether this is true for everyone. To this end, the figure 17 illustrates the economic

Figure 17: Consumption evolution in a multisectoral economy



Time spam=900 periods. 40 Montecarlo simulations for each scenario. The sheds represent the average (across simulations) total consumption for the top 10% of income earners (in red), the mid 90-75% (in green), the mid 75-50% (in blue) and the bottom 50% (in purple).

performance from a consumption standpoint. For each distributive scenario, the average evolution of consumption for each quantile of income distribution is displayed. As is also obvious from this graph, the levels attained under the markup scenario are the most uneven and have the poorest aggregate performance. However, this scenario is optimal for the top 10% of individuals who can greatly expand their consumption bundles, consuming new types

occur with a non decreasing probability (timing) as a result of ongoing R&D efforts.

of commodities that are unavailable to others. In some way, this disregards the Smithian theory that increasing inequality leads to more prosperity. In actuality, the most prosperous circumstances are those in which economic inequality is minimised.

To conclude, it is important to note that the model replicates the usual "Kaldor Facts". Increasing worker productivity, increasing real wages, and a constant output to capital ratio. Over time, the job distribution shifts significantly from the most productive sector to the least productive ones. From the sectors that produce the items at the top of the hierarchy of needs to those that produce less vital goods. As a result of the reliance of the innovation process on previous sales, sectors with the largest sales experience the greatest productivity growth.

Table 6 shows the main stylised facts the model reproduces.

Table 6: Stylised facts

Standard Macroeconomic	**Long-run 'Kaldor' SF**
Procyclical real consumption	Growing labor productivity
Procyclical real investment	Roughly stable output-capital ratio
Procyclical real wages	Roughly stable profit rate
Procyclical labor productivity ('Smith effect')	
Endogenous self-sustained growth	

2.9 Concluding remarks

In this chapter we have looked at how the short run affects the long-run path of the economy. It is difficult to find something more path-dependent than the innovation process, whose gains over time depend on historical cumulated efforts whose destinations and intensities are shaped according to the ongoing economic dynamics. More precisely, we have explored how the productivity appropriation over time, according to the possible compensation mechanisms, may affect the future trend of productivity (and therefore the long run growth rate of the economy) through changes in the level of aggregate volumes and their allocation between sectors.

For this purpose, we built a multisectoral macroeconomic stock flow consistent agent-based model that reproduces a monetary economy of production with several consumption and capital sectors where a Schumpeterian and Keynesian engine are at the core, with productivity trends that diverge among economic sectors and consumers that buy goods according to a determined hierarchical ranking.

Firstly we show how the process innovation, understood as a force that emerges from internal and external competition leading to higher labor productivity, represents a necessary but not sufficient element for economic growth and also a possible source of economic instability (because of the technology-induced displacement of employees it incurs). We show how, in order to achieve macroeconomic growth, a public state with a hands-on approach is needed that increases its debt every time an increase in productivity occurs. Otherwise, only a few people can increase their consumption levels, at the expense of other workers that are removed from the labor market and lose access to the goods market, leaving the total production (consumption) invariant.

Then, based on Smith's heritage that the market size affects productivity growth, we analyze how different short-run appropriations of productivity gains, impacting differently on the GDP and shaping its composition (through distribution), outline the future productivity trajectories.

Productivity increases that are translated into rising markups negatively affect the macroeconomic performance (mainly because of the different consumption propensities) and lead to future lower productivity growth and slower economic growth. On the contrary, productivity gains followed by reduction in prices or increase in wages pave the way toward future high productivity and economic growth. This is the *macro* channel through which income distribution influences the long-term economic growth.

Then, shifting the nexus productivity-market size to the meso level, we show how the different distributive scenarios impact differently on the long-term economic growth through the concentration (dispersion) of the production at meso level, which eases (hampers) the imitation dynamics. We refer to this as the composition effect. When placing the focus on allocation of the volumes and working hours between the business sectors, even if the macro dimensions are unchanged, because of imitation dynamics, the wage scenario reaches higher growth rates with respect to the markup scenario. Indeed, the latter is characterized by higher income inequality and therefore higher production heterogeneity (because of Engel's curve).

So far we have explored, how the production volumes, at macro and meso levels, affect the productivity trend of the economy. In the following chapter, based on the idea that market concentration can be a possibility in a productive system where the competition among capitals is a background force, we will explore the dynamics between productivity, market concentration and economic growth. In this way, the company size distribution and, in general, the production organization (micro level) will also be taken into consideration in determining macroeconomic growth.

3 Productivity, market structure, income inequality and economic growth. Secular trends

3.1 Introduction and chapter structure

Over the course of capitalism's existence, humankind has witnessed a spectacular increase in productivity and product variety. However, this expansion has been associated with increasing inequality. For this reason, from the very beginning of the discipline, economists have investigated which were the causes, the consequences, and the interrelation between growth and inequality. Still, wealth distribution is one of today's most widely discussed and controversial issues.

The relationship between growth and inequality is a long lasting nexus. It dates back to the time of Adam Smith, according to which the capitalist societies, in contrast to the ancient forms of production where everyone was the owner of both the mean of production and the output produced, were characterized by the coexistence of increasing inequality and prosperity. For the author, was an enigma to study how, under this advanced society, poor could be less poor. The main answer he gave to the question was the division of labor that, according to him, allows increasing level of labor productivity and, through this, the coexistence of "rentiers" and a working class whose needs are progressively better satisfied. In this sense, the market forces were seen as a tool of emancipation of the poor, that, however, came at the expense of an increasing alienation of the labor force (because of the labor division).

The "classical economists" were quite divided about the future growth. The Ricardian and the Malthusian models emphasized the tendency towards the stationary state, because of the scarcity of the natural resources. Instead, those rooted in the Smithian and Marxian tradition emphasize the progressive nature of economic growth, even if well aware of the possibilities of crises. Differently from the period when Malthus and Ricardo wrote, at the time of Marx, the question was no longer whether the agriculture sector was able to feed a growing population or whether the land prices would have risen, but the most striking fact was the misery of the industrial proletariat; workers crowded into urban slums, very long working day and very low wages. For this reason, in Marx's opinion, the capitalist production system could have grown endlessly (with crisis and some tendencies), with no natural limit to the process. The problems were rather concerning the production and distribution sphere, and all the contradictions behind it.

Then, in the twentieth-century, the marxian view of the polarization of the distribution among the social classes was in some way reverted by Simon Kuznets. According to the author, long lasting growth would benefit everyone.

Evidently, the different views on economic growth and income distribution are strictly related to the role technological change plays in each economic theory.

At this extent, the present chapter focuses on the very long-term dynamics of the capitalist system and examines the connection between process innovation, market concentration, and economic growth. Taking a very long-term perspective, this study examines how the dynamics associated with structural change (particularly changes in employment allocation and consumption/production structure), which are inexorably behind economic growth, involve also modifications in the market structures and income distribution which, in turn, affect the rate of economic growth. In essence, we study whether the dynamics inherent to the capitalistic system may result in a secular tendency toward which the economy may move in the long-run.

For the purpose of our research, we have adopted a multi-sectoral macroeconomic Agent based - Stock Flow consistent model (AB-SFC). The model is grounded on a theoretical framework depicting a monetary economy of production (e.g. Graziani, Lavoie) where the principle of effective demand determines the level of output, while innovation is characterized by a typical Schumpeterian process of creation and destruction. The functional income distribution is determined as in the classical theory, and it is the result of the struggle between the capitalists and the working class. The model is based on the one presented in chapter 2. Only a few adjustments have been made in order to properly tackle the issues related to inequality and market concentration. Particularly, we have implemented a more complex firm structure in which diverse labour skills are necessary to operate the business and each sort of worker is compensated differently, based on their job. In addition, we have modified the manner in which the innovation process influences our artificial economy over the simulation periods.

Sections 3.2 and 3.3 present some empirical evidence, and a high-level review of the existing literature, which is focused on the nexus under analysis, is provided.

Section 3.4 explores the possible secular trends that come with economic growth and the structural changes. Specifically, we investigate how the employment reduction at sectoral level, which logically comes with the coexistence of increasing labor productivity and consumers' preference for variety, can have repercussions in terms of market structure and personal distribution. We show that, anytime sectoral employment declines, in absence of rising markups or higher market concentration, the personal distribution shifts toward the workers. Such result, which translates Marx's idea about the tendency of the rate of profit to fall into the tendency of the personal income distribution to move toward the workers, can only be counterbalanced by an increase in the markups or in the market concentration

Section 3.5 highlights the amendments to the model presented in chapter 2. Sections 3.6, adopting the SFC-ABM model, analyses the growth patterns that can occur under the scenarios highlighted in section 3.4, which differ in the degree of market concentration and income inequality. Assuming that the productivity trend depends on the level of sales (because of the possibilities it opens in terms of labor division), the degree of market concentration and income inequality influence the rate of economic growth through the allocation of the level of sales among business sectors and firms.

In our artificial economy, macroeconomic growth is driven by the interplay between technological change, which frees up labor force, and the public sector that increases its debt every time a process innovation occurs (while the ratio Debt-to-GDP is untouched).
The technological change, instead, as has been widely acknowledge in literature (starting from A. Smith, and then revitalized by more contemporaneous authors such as Kaldor, Verdoorn, Marshall, Young and Arrow), depends on the level of sales because of the possibilities it opens in terms of labor division[27]. The link market size-productivity exists at all levels; macro, meso and micro level.

[27]the multitude of the activities per-worker can be progressively and infinitely reduced the higher are the production volumes per unit of production. This reduction entails all the benefits related to the activity repetition (standardization) such as experience curve, mechanization and time saving in task shifting. Higher production volumes are associated to higher productivity gains also because of the increasing efforts in research activities that would result, and the non-linear dynamics embedded in the research and development process (that, for instance, comes from the rationalization of activities and the elimination of the repetitions).

3.2 Evidence

Over the last three decades advanced economies, have witnessed a number of significant structural changes such as rising market concentration, widening income inequality and secular stagnation (Syverson, 2019).

3.2.1 Market concentration

Despite the notoriously difficulties in testing and measuring market power, a number of studies focused on the topic.

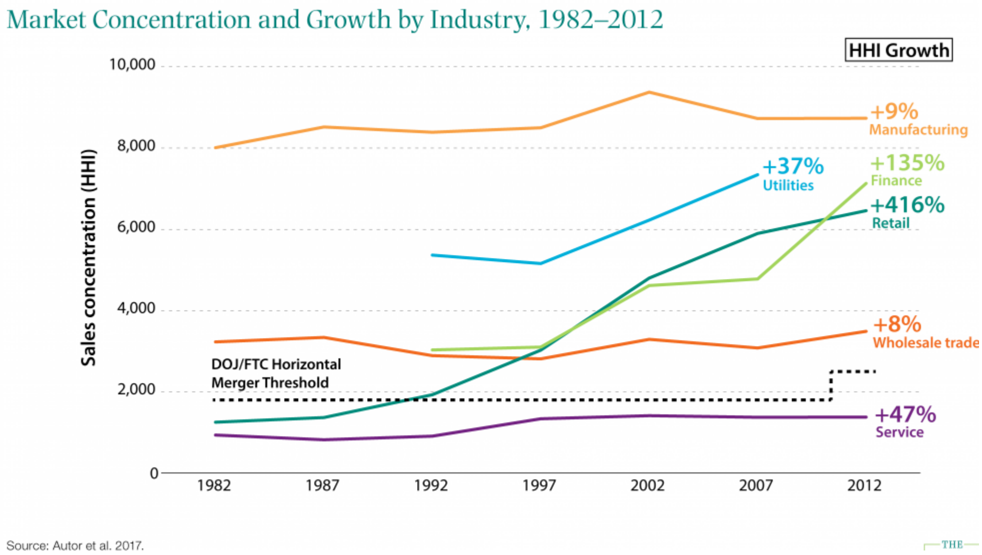
Some papers point out that the general increase in market concentration can be demonstrated by the rise in markups above marginal cost (e.g., Hall (2018), De Loecker et al. (2020), Autor et al. (2020)). Others see this via the increase in profits. (e.g., Barkai (2020), De Loecker et al. (2020)).

According to Grullon et al. (2019), since the early 1990s, market concentration is increased in more than 75% of US industries. Diez et al. (2019) put together a firm-level cross-country dataset from 2000 onward to show that the measures related to markups, profitability, and concentration have all risen. They also show that the rise in markups has been concentrated in the top 10% of the companies in the overall markup distribution, which are firms that have over 80% of the market share.

According to Autor et al. (2020), the market concentration across the vast bulk of the US private sector has risen. This reflects the increased specialization of leading firms on core competencies and large firms getting bigger. The share of U.S. employment in firms with more than 5,000 employees rose from 28% in 1987 to 34% in 2016.

Figure 18 shows the result Autor and Salomons (2017) got from a micro panel data from the US Economic Census since 1982.

Figure 18: Market concentration



Concentration is not only about the increase in the market shares hold by companies. As has been extensively studied by K. Marx, capital concentration refers also to the concentration of the capital control in the hands of a few subjects. According to Marx, private ownership becomes a limit to the development of capital itself. *"The world would still be without railways if it had to wait until accumulation had got a few individual capitals far enough to be adequate for the construction of a railway. Centralization, however, accomplished this in the twinkling of an eye, by means of joint-stock companies"* (Marx, 1867—1976, Vol. I, p. 780).

Capital centralization in the sense of Marx, has never been a very popular subject in the academic literature and, because of the difficulties in the empirical validation, only a few papers have been published on the topic. In a IMF working paper, Santos (2015) assesses integrated ownership and control links through a network analysis in the corporate sector of the Gulf Cooperation Council (GCC) countries. Applying input-output theory and different definitions of control on the distribution of consolidated debt (involving entities under the direct and indirect control of shareholders and their debt), he finds that corporate ownership is strongly concentrated in the GCC countries. Vitali et al. (2011) examine the ownership concentration and control among 43060 transnational corporations (TNC). Taking into account two measures of network centrality, the network control and the network value, the authors find that, in the year 2007, just 737 shareholders controlled the 80% of the total global operating revenue, and nearly 40% of TNC operating revenue was controlled by an interconnected core of 295 TNCs. Brancaccio et al. (2018) extended the analysis of Vitali et al. (2011) from one to many years providing a global empirical investigation of centralization in terms of ownership and control, not only within but also across corporations. The authors have found that the fraction of top holders holding cumulatively the 80% of the global economic value of the firms considered in the sample studied is always under the fraction of 2%.

3.2.2 Inequality and economic growth

According to the Center on budget and policy priorities the broad facts of income inequality over the past decades are easily summarized as follows:

- It was not until the second half—or even the final third—of the nineteenth century that a significant rise in the purchasing power of wages occurred (Piketty, 2014). After a period of increase in inequality, in the period 1870-1914 there is a stabilization of inequality at an extremely high level.

- The years from the end of World War II to the 1970s were ones of substantial economic growth and broadly shared prosperity. Incomes grew rapidly and at roughly the same rate up and down the income ladder. The gap between the income ladders did not change much during this period.

- From the beginning of the 1970s, economic growth slowed and the income gap widened. Income growth for households in the middle and lower parts of the distribution slowed sharply, while incomes at the top continued to grow strongly. The concentration of income at the very top of the distribution rose to levels last seen nearly a century ago, during the "Roaring Twenties."

- Wealth is much more highly concentrated than income. The share of wealth held by the top 1 percent rose from 30 percent in 1989 to 39 percent in 2016, while the share held by the bottom 90 percent fell from 33 percent to 23 percent.

The concentration of the wealth in the hands of few in the last decades, especially among western countries, both in the functional and personal distribution, have been extensively documented in literature. Few examples are Stiglitz (2012), Piketty et al. (2014) and Karabarbounis and Neiman (2014).

3.3 Literature Review

3.3.1 Innovation and market structure

The nexus between innovation process and market structure has always been object of study in the economic discipline. No consensus has been recorded yet; there are proponents of the theory according to which more competition leads to innovation and others that support exactly the opposite.

The arguments in favor of the former refer to the degree of competition and its interconnection with the propensity to invest in innovation. Also the degree of imitation is positively correlated to the degree of competition thanks to the lower barriers among competitors and the higher resulting business dynamism. Instead, in less competitive markets, capitalists do not have incentives to innovate because are not afraid to lose their market shares.
From the other side, the biggest fan of the oligopolistic nature of the innovation process was probably Schumpeter. In 1912, he stressed the relevance of the oligopolistic structure in pushing the capitalist class, in search of future extra profits, to invest in R&D activities. In 1942, the author further added that such market environment is more prone to innovation because of the reduced uncertain entrepreneurs have to face and because of the higher internal resources (that concentration ensures) that can be addressed to finance all the research activities. Schumpeter's idea was then restored by Also Nelson and Winter in 1982.

The neo-schumpeterian views, which supports the oligopolistic structures through micro/industrial approaches, states a two way relationship between market structure and innovation. Market structure affects innovation and innovation affects market structure.

Aghion et al. (2005), instead, demonstrates a nonlinear 'inverted-U' pattern between competition and innovation. Innovation is low at both low and high concentration level.

Sylos-Labini (1983) highlighted that market concentration helps the diffusion and the allocation of the productivity gains. Barriers and rivals distances, hampering the sharing of the technological improvements, make more difficult to translate more efficient production lines into lower prices for all the customers.

The relationship between market structure and innovation is also evident in Adam Smith's writings. Smith's idea that higher market size leads to higher labor productivity can be transposed at the firm level. More concentrated production units are more likely to see labour productivity growth.

The connection between innovation and market structure is also evident in K. Marx's writings. Well known is his Law of capital concentration that is analyzed in various sections of Marx's Capital. To Marx, capitalism involves a large number of highly competitive companies, each with a desire to expand. This desire causes companies to expand their accumulation and hire more workers. However, the increased working bargaining power, which follows from the erosion of the reserve army, forces the capitalists invest in new machineries that embody labor-saving technologies. Therefore, due to the internal (between capitalists and workers) and external competition (between companies), capitalists try to increase the amount of machinery used in production. At this point, companies that produce a larger quantity of goods have an advantage over smaller companies, because they can use the machineries more efficiently and can produce at a lower cost and thus charge a lower price. Smaller companies cannot compete with such prices and therefore exit the market. For this reason, capital ownership becomes always more concentrated into fewer hands. Therefore, due to competition, there is a propensity to divide "the entire social capital into many individual capitals"; yet, there is also a centripetal tendency toward market concentration.

More recently, Lima (2000) has proposed a growth model that combines the Schumpeterian view (more market concentration more innovation) with the typical post-keynesian macro nexus distribution-growth (e.g., Rowtorn and Dutt), according to which an inequality distribution affects negatively the economic growth. The author investigate to what extent the effects offset each other and which one prevails.

3.3.2 Market structure and inequality

Before presenting the different theoretical positions on the interconnection between market concentration and income inequality, a few theoretical positions about economic inequality are mentioned below:

- Inequality arise endogenously in the capitalistic process (e.g., Adam Smith, Joseph Schumpeter, Karl Marx).
  Marx (1890) stressed more the inequality between classes; the capitalist class earns profits only "exploiting" the working class (in relative and absolute terms). Smith saw the income disparity as being "natural" and "useful" because of the economic prosperity it allows, with poor being less poor. Schumpeter, an ardent defender of capitalism's ability to encourage innovation and growth, considered inequality as the source of entrepreneurs' incentive to keep innovating.

- Inequality has social and/or political reasons. Governmental activity and the role of institutions affects inequality through different channels: influencing the workers' bargaining power, deciding the degree of globalization, deciding the support toward the union membership and with all the Central bank policies (e.g. Farber et al. 2021 Acemoglu and Robinson 2002; Piketty and Saez 2014, Stiglitz (2016))
  "*The history of the distribution of wealth has always been deeply political, and it cannot be reduced to purely economic mechanisms[..] some powerful mechanisms pushing toward convergence (the main one is the diffusion of knowledge, "rising human capital hypothesis, strong demographic and economic growth, productivity or innovation), others toward divergence (slow economic growth and high return on capital)*" (Piketty et al. (2014))

There are a number of theoretical and empirical studies that tries to clarify the link between market concentration and inequality.
The first finding that can be found in the specialized literature states that higher markups come from technological change that leads to market concentration. Autor et al. (2020), for instance, emphasizes the role of technological change and productivity gains in driving the market concentration and the rise of superstar firms. These firms, then, exploit their dominant position increasing their markups. In support of their statement, they found that the more concentrated industries (that commonly are those that have experienced faster growth of productivity and innovation) are those that have experienced the larger fall in the labor share and such declines have been reached through changes in the market share more than because of general fall for the average firm.

Another stream of the literature points out that the increases in the markups are mainly driven by market power positions generated through entry barriers, rather than through improvements in operating efficiency. De Loecker et al. (2020) find that in the US economy the markups over the marginal costs have remained roughly constant between 1950-1980 while have grown steadily from then, rising from the 21% to the 61%. Also the distribution of the markups has changed: while the median is constant, the upper percentiles have gone up substantially and the majority of firms see no increase in markups and lose market share. Akcigit and Ates (2021) and Aghion et al. (2019) argue that a decline in technology diffusion from leaders to followers and the advancement in information and communication technology could have contributed to the rise in firm inequality and low growth. The "declining business dynamism" is the factor driving the market concentration and the increases in markups that has as mean the decrease in knowledge diffusion. It can also be the result of lobbying and regulations (Gutiérrez and Philippon, 2019).

There is another explanation that put together the rent seeking and efficiency explanation hypothesis. Crouzet and Eberly (2019) see that two aforementioned hypotheses, rather than mutually exclusive, can be regarded as two alternative equally-likely scenarios that arise depending on the sources of rising concentration. In this view, concentration might be good, if triggered by productivity-enhancing technological innovations, or bad, if due to entry barriers giving rise to market power. The effects of concentration are not necessarily pre-determined by its sources, but they result from the dynamic interaction between technical change and market power, and their relationship with the changing institutional environment. In other words, it may happen that a rising market concentration, even if triggered by technical change, eventually result in rent-extracting activities due to the emergence of technological entry barriers.

Some other authors, instead, have pointed out that the shift in the distribution in favor of the capital share is due by the so called "investment-profit puzzle" (e.g Stockhammer (2005) and Orhangazi (2019)), that has allowed the rise of the corporate sector as net lender. According to this stream of literature, despite the historically low interest rates, increasing profitability and high funds availability, the investment rate of U.S. non-financial corporations has been constantly slowing down from 32% in the 1980s to 26% in the 2010s (Gutiérrez and Philippon, 2016). Moreover, this investment gap is stronger in concentrating industries, where, in view of diminishing profitable investment outlets, monopolistic rents are largely distributed to shareholders (Gutiérrez and Philippon, 2016).

3.3.3 Inequality and economic growth

This Section briefly shows some of the most important positions with regard the link between economic growth and inequality.
This is a well-known topic, always been on the agenda of the economic discipline. Already the "father of economics" Adam Smith was wondering how the poor class could be, under this advanced society, less poor. The main answer he gave to such question was the division of labor that, through the increasing level of productivity, allowed the coexistence of the "rentiers" with a working class whose needs were progressively better satisfied, showing as prosperity and inequality might go hands in hands in the capitalist system. Kuznets famously proposed an inverted U-curve between per capita income and income inequality. Starting from a low value, an increase in the per capita GDP tended to raise inequality. But this relation eventually flattened out at sufficiently high per capita GDP level, and, then, further increases in the GDP level tend to reduce inequality. The explanation is that, in the early development of an economy, new investment opportunities occur for those who already have the capital to invest, while an influx of cheap rural labor to the cities holds down wages for the working class thus widening the income gap and escalating economic inequality. Whereas, in mature economies, the main source of growth is the human capital accrual that takes the place of physical capital accrual. At this point, economic inequality is expected to decrease because of the processes associated with industrialization, such as democratization and the development of a welfare state. Increases in per capita income emerge and economic inequality effectively decreases.

Historically, the researchers have divided themselves between those that thought inequality was good for the economy and those that thought it was not. On the one hand, inequality is said to promote growth by fostering aggregate saving (Kuznets (1955) and Kaldor (1955)) because of the higher saving propensities of the top earners. For this reason, countries with a high share of wages will not be able to accumulate capital as rapidly as those with a low share of wages or will not have enough emphasis in promoting the realization of high-return projects (Binswanger et al., 1993) or by stimulating R&D (Foellmi and Zweimüller, 2006). On the other hand, inequality is expected to hamper growth by promoting expensive fiscal policies (e.g. Perotti (1993); Alesina and Rodrik (1994)); by inducing an inefficient state bureaucracy (Acemoglu et al., 2011); by hampering human capital formation (Galor and Moav, 2004); by leading to political instability (Benabou, 1996); or by undermining the legal system (Glaeser et al., 2003); or by weakening aggregate demand (those at the bottom spend a larger fraction of their income than those at the top) reducing opportunity that jeopardize the country's long-term prospects (Stiglitz). The problem may be compounded by monetary authorities' flawed responses to this weak demand.

3.3.4 Reference agent based models

As far as the evolutionary literature is taken into consideration, we have a flourishing number of works that try to deal with the nexus productivity, market concentration, inequality and economic growth.

All the multisectoral models have as reference point the pioneer work of Saviotti and Pyka (2004), who have developed a model in which entrepreneurs endogenously create new sectors, once existing ones are saturated. Saviotti and Pyka (2008) have then adapted this framework to study, among others, the impact of technological change on employment.

Ciarli et al. (2019) study the relation between income distribution and growth, mediated by structural change on the demand and supply side. Using the results from a multi-sector growth model, they compare two growth regimes that differ in three aspects: labor relations, competition and consumption patterns. Regime one, that is similar to Fordism, is relatively less unequal, more competitive and exhibits significantly higher output and productivity and lower unemployment with respect to regime two that is similar to the "post-Fordism" world (less competitive and more unequal).

Dosi et al. (2021b) developed a model of endogenous creation of new sectors based on the K+S framework (Dosi et al., 2010) and employ it to, inter alia, study the creation and destruction of labor. Their model seems currently set up to study the evolution of capitalism from world war two to the late seventies.

Dawid and Hepp (2021), building on the EURACE model, examine the impact of technical change on industry concentration and firm dynamics. Under different technological change scenarios (one that works on innovation frequency and the other on the innovation intensity), they show how the innovation leads to an increase in the heterogeneity of productivity in the firm population and to increased market concentration. If technological change occurs in many small innovation steps the induced market concentration as well as the emerging firm heterogeneity is substantially smaller with respect to the case where the frequency is lower but the innovation intensity is higher. The authors highlighted also that, in the regime characterized by an increase of the size of the frontier jumps along the technological trajectory, the evolution of the wage inequality has an inverted U-shape with a large fraction of workers profiting in the very long run from high wages offered by dominant firms. Indeed, whereas initially the increasing heterogeneity of firm productivity translates into increasing wage inequality because these can sort among the high skilled workers, but then, in the long run, the large firm size of most innovative firms implies that also more low skilled workers have to be employed and the increased competition on the labor market pushes up wages.

Like our works, their analyses do not focus on the 'dark side' of industry concentration in terms of market power and rent extraction.

Mellacher (2021) has developed a Schumpeterian agent based model where features from the Schumpeter Mark I model (centered around the entrepreneur which has the leading role in the birth of new industries) and Mark II model (which emphasizes the innovative capacities of the firms) are combined in order to reproduce the dynamics observed since the 1980s with regard to inequality and declining business dynamism. In the model, the author has reproduced a sort of a wave-like evolution of inequality that builds upon a more secular trend. The model shows growing inequality when the industry starts and, than, an increasing equality because of the higher competition follows. After, secular inequality arises because the sectoral size is such that entry diminishes and the diffusion of technological progress decreases (because an increase in the technological distance penalty to imitation).

Turco and Terranova (2021) analyze the underlying causes of the recent increase in market concentration and study how inequality and concentration are driven by (the absence of) knowledge spillovers. Revisiting Sylos Labini's (1967) theory of oligopoly and technical progress (concentration is driven by technical change that generates technological discontinuities), in their model, concentration (consumers sensitivity to prices) is due by the fact that heterogeneous firms do not have equal access to capital-embodied innovations because of a knowledge gap, that is the difference between the degree of capital good's technical advancement and the

firm's accumulated technological knowledge. This leads to higher mark-ups, shift in the income distribution that in turn negatively affects aggregate demand and economic growth.

3.4 Labor productivity, market concentration and income inequality

This section shows how the growth of the average consumption bundle, achieved during the history of capitalism, had to come with a shift in the market structure and/or in the income distribution. Specifically, starting from the assumption that there has been a significant growth of the consumption levels, and that the Engel's curve is at play, the inevitability of certain combinations, in terms of economic growth, market concentration and income inequality, is demonstrated[28].

Looking at the production side, if full utilization of the resources is assumed (and are left aside all the considerations about natural resources availability), what is left to explain the average per capita real growth is the trajectory of the labor productivity. Increasing levels of production, in terms of quantity, quality, or variety, can be only achieved thanks to increasing levels of labor productivity; otherwise, increasing levels of some productions can only come at the expense of other productions that have to decrease their volumes.

Figure 19 shows which are the possible ways through which real growth occurs and the consequent dynamics in terms of demand and employment level, in the innovating sector and in the economy as whole.

The innovation process (IP), which is considered as the only source of growth of the average per capita consumption, is understood as the mechanism that leads the levels of labor productivity to increase and, in turn, the working hours per-output to be decreased or the quality of the goods produced to be increased, while keeping unchanged the required amount of working hours per output.
In the 2nd and the 4th case, because growth materializes in sectors different from the innovating one, employment displacement in the innovating sector emerges. Instead, in the the 1st and the 3rd case since growth materializes in the innovating sector, no employment shift occurs. Therefore, among the four, only the second and the fourth case imply structural change. This result emerges because of the consumers needs, which are hierarchically

[28] On the contrary, the discussion on the possible sequence of events or the reasons behind certain dynamics are left aside.

Figure 19: Growth paths

	GROWTH SOURCE	WORKING HOURS PER OUTPUT in innovating sector	TRANSMISSION MECHANISM	GROWTH DIRECTION	GROWTH LOCUS	GDP GROWTH	INNOVATING SECTOR DEMAND	INNOVATING SECTOR EMPLOYMENT	REST OF THE ECONOMY DEMAND	REST OF THE ECONOMY EMPLOYMENT	STRUCTURAL CHANGE	EXAMPLE
	AGGREGATED DYNAMIC											
1)	Innovation process (IP)	Decreased	Real income increase	Quantity	Innovating sector	YES	+	=	=	=	NO	Higher demand for meat produced intensively
2)	Innovation process (IP)	Decreased	Real income increase	Quantity	elsewhere	YES	=	-	+	+	YES	More efficient apparel production allows higher demand for electronics
3)	Innovation process (IP)	Invariant	-	Quality	Innovating sector	NO	=	=	=	=	NO	Higher quality cars at same labor productivity per car
4)	Innovation process (IP)	Decreased	Real income increase	Quality	elsewhere	YES	=	-	=	+	YES	More efficient diary production allows higher demand for better housing

ordered. The benefits coming from the increase in labor productivity do not translate in a sectoral demand increase. A portion of the labor workforce has to shift from one industry to another, so that the production structure has to adapt to the new consumers needs. Always because of the consumers preferences for variety, the first case can only represent a temporary dynamic in the sectoral cycle. Sooner or later, the demand will stop grow (especially when population trends are not considered) and structural change has to emerge. On the contrary, the third case represents a potential never ending real component of economic growth, especially when the market competition is focused more on quality than on prices, that, by the way, may not show up in the GDP trend.
In light of what has been stated so far, it is evident that in an economy where the level of employment per output decreases, structural changes are an inevitable consequence of the economic growth.[29].
However, the dynamics associated with the structural change permanently affect market structure and personal distribution at the sectoral level.

Table 20 shows how, keeping the markup unchanged (and, therefore, the functional distribution), the reduction of the employment level in the innovating sectors leads the personal distribution to progressively and inexorably move in favor of the working class. This result holds regardless of whether productivity gains are translated into price reductions or whether wages are tied to the productivity trend. In the first case, the lower prices, which follow the reduction of the employment level per firm, drives down the nominal profits (while the real ones are unchanged) that suffer from the invariance of the output level. On the contrary, nominal wages remain constant (and the real ones increase).

Figure 20: Increases in labor productivity in absence of higher levels of markups and market concentration. A numerical example

N° FIRMS	EMPLOYMENT	OUTPUT	EMPLOYMNET PER-FIRM (n=q/pr)	OUTPUT PER FIRM (q)	LABOR PRODUCTIVITY (pr)	HERTFIELD INDEX	WAGE (w)	FIRM WAGE BILL (W=w*n)	PRICE (p=(1+μ)*(w/pr))	FIRM PROFIT (∏=q*p-W)	WAGE SHARE (ΣW/Σ∏)	PERSONAL WAGE SHARE (w/∏)
50	500	1000	**10,0**	20,0	2	**2%**	10	100	6,0	20,0	**5**	**0,5**
50	250	1000	**5,0**	20,0	4	**2%**	10	50	3,0	10,0	**5**	**1,0**
					⋮							
50	30	1000	**0,6**	20,0	33	**2%**	10	6	0,4	1,2	**5**	**8,3**

Assumptions: Markups equal to 20%, no changes in the firm capital structure, equal market shares between firms, productivity gains translates into lower prices.

When the nominal wages are those that respond to the increase in productivity, the outcome is the same. As shown in annex A, while the wages increase, the nominal profits

[29] Actually, under certain conditions, if population levels increase, there might be economic growth without having employment shift from one sector to another.

remain constant, because of their dependence on the wage bills, which are invariant[30].

The shift in the personal distribution, which is unique to the innovating sector, is caused by the loss of labour force in the innovative industry and the maintenance of steady capital ownership. In fact, despite the fact that neither the factor shares nor the sectoral income share appropriated by the working class vary over time, the number of employees who profit from it declines over time. In the same time, if certain conditions which allows macroeconomic growth are met (as shown in the previous chapter, Section 2.6), other employers, who operate businesses in new sectors, capture the fraction of real profit not captured by those operating in the old industries.

An increase in markup levels (profit rates) is one strategy to maintain the same level of personal distribution. Specifically, once output has stabilised, markups must increase at the same rate as productivity. In other words, the capitalist class must usurp all productivity gains; the higher the pace of productivity increase, the higher the markup level.

However, when the classical concept of competition (which leads to the assumption of the uniformity of profit rates) is taken into account, it is difficult to envisage an infinite growth in markups.

Altering the market structure of the sector by increasing market concentration is another method for ensuring that the personal distribution does not change; the production level of the businesses must increase at a rate faster than the productivity growth rate. In this manner, not only do employees quit the innovative industry, but also the capital owners. Table 21 illustrates the potential movements of the personal distribution in two contexts that mimic varying levels of market concentration. Because we have already discussed the prospect of markup increases, we will assume in this situation that markups remain constant and that any productivity improvements are shared with the economy through reduction in prices.

Figure 21: Increases in labor productivity in absence of higher levels of markups. A numerical example

	N° FIRMS	EMPLOYMENT	OUTPUT	EMPLOYMNET PER-FIRM (n)	OUTPUT PER FIRM (q)	LABOR PRODUCTIVITY (pr=q/n)	HERTFIELD INDEX	WAGE (w)	FIRM WAGE BILL (W=w*q/pr)	PRICE (p=(1+μ)*(w/pr))	FIRM PROFIT (∏=q*p-W)	WAGE SHARE (ΣW/Σ∏)	PERSONAL WAGE SHARE (w/∏)
1st scenario	50	500	1000	**10,0**	20,0	2	**2%**	10,0	100	6,0	20,0	**5**	**0,5**
	25	250	1000	**10,0**	40,0	4	**4%**	20,0	200	6,0	40,0	**5**	**0,5**
						⋮							
	3	30	1000	**10,0**	333,3	33	**33%**	166,7	1667	6,0	333,3	**5**	**0,5**
2nd scenario	50	500	1000	**10,0**	20,0	2	**2%**	10,0	100	6,0	20,0	**5**	**0,5**
	20	250	1000	**12,5**	50,0	4	**5%**	20,0	250	6,0	50,0	**5**	**0,4**
						⋮							
	2	30	1000	**15,0**	500,0	33	**50%**	166,7	2500	6,0	500,0	**5**	**0,3**

Assumptions: Markups equal to 20%, no changes in the firm capital structure, equal market shares between firms, productivity gains translate into price decrease.

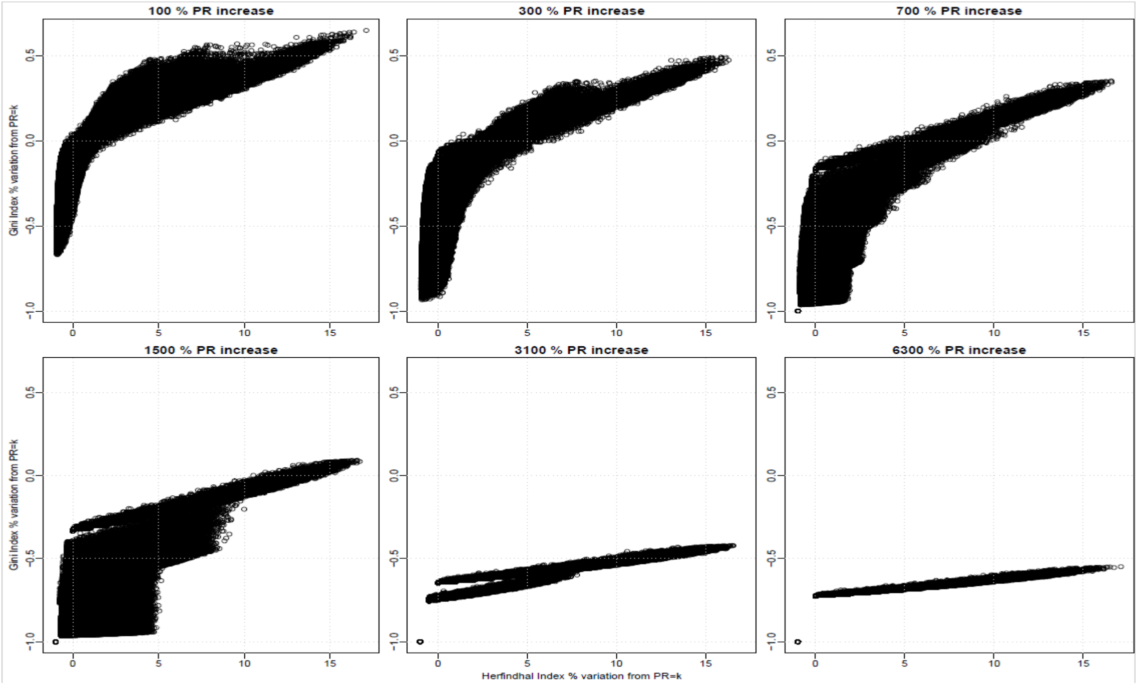
In the first scenario, the market concentration is just sufficient to maintain the original capitalist-worker ratio and income inequality, whereas in the second scenario, the exit of the firms allows the output of the incumbents to be increased to such an extent that the concentration soars and the income distribution shifts in favour of capitalists.

In Figure 22, as opposed to Figure 21, in which the market structure changes as a result of a reduction in the number of firms and the market shares are allocated equally among the firms, the market structure has been permitted to evolve freely. Since the number of firms is chosen at random, as are their market shares, every type of market structure has been taken

[30] Higher wages balance out with a lower level of employment per firm.

into account. The only limitation imposed by the numerical simulation is that the randomly chosen market shares (and number of enterprises) must be such that every capitalist earns at least the nominal salary.

Figure 22: Increases in labor productivity associated with any possible change in the market structure and invariant markups. Numerical simulations

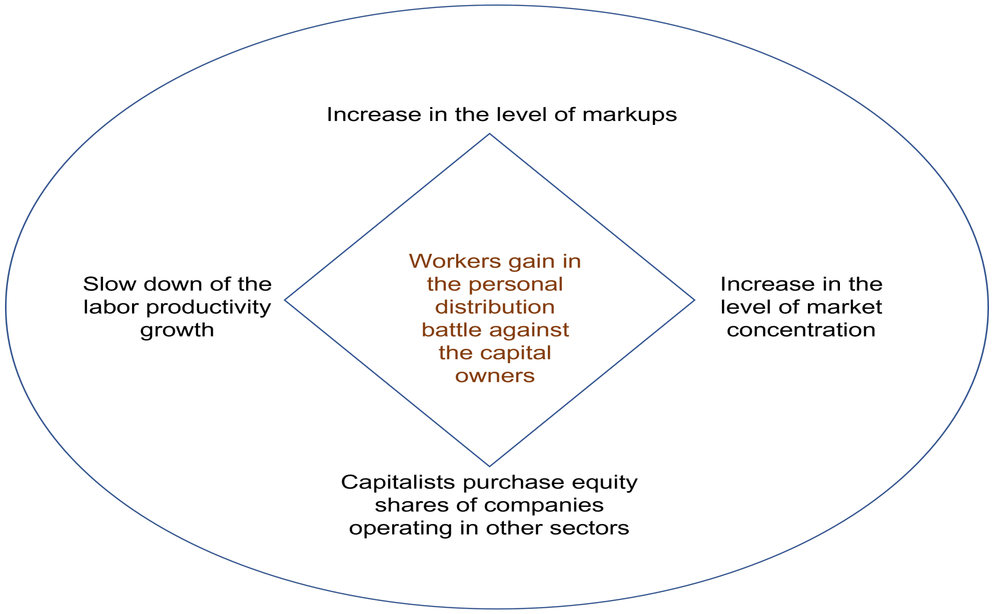


Assumptions: Markups equal to 20%, productivity gains translated into price decrease.

Figure 22 confirms that, in order to maintain the same personal distribution between capitalists and employees, market concentration must increase according to productivity growth. The figure also demonstrates that at some point, when labour productivity reaches extremely high levels, not even market concentration is sufficient to restore the prior level of personal distribution (no matter which are the starting points, which, by the way, are also chosen randomly). At that time, the only method for capitalists to regain their position is to acquire equity shares in companies operating in other industries, those industries that have likely benefited from the increased demand made feasible by increases in labor productivity.

In conclusion, structural change, which occurs because the sectoral labour productivity per output growth rate is greater than the sectoral output growth rate, leads to a drop in sectoral employment and a shift in the personal distribution towards employees in the innovating sector. This outcome, which translates Marx's theory of the tendency of the profit rate to decline into the tendency of the personal income distribution to move toward the workers, can only be counterbalanced by an increase in markups or market concentration. If markups cannot be increased indefinitely, market concentration alone would not be sufficient to maintain the previous level of distribution in a scenario where employment per sector continues to decline. At this point, only the acquisition of shares in companies in new sectors would be able to maintain the previous levels of distribution. Eventually, the capitalist class will no longer find labour productivity enhancements appealing. According to what has been stated so far, given the stabilisation of the population level and the rate of globalisation, these results should become even more apparent in the near future. Figure 23 provides a summary of all the findings of this section.

Figure 23: Secular tendencies and counter tendencies of the capitalistic system in the innovating sectors



3.4.1 Further considerations

Now it is clear how structural changes have to be related also with changes in income inequality and market structure. However, when considering structural change, both the dynamics of the innovative sector (the one with rising labour productivity levels and steady output) and those of the sectors that benefit from the greater incomes generated by the efficiency improvements should be taken into account (if macroeconomic growth is attained). These two sides compliment one another.

As shown in Figure 24, the patterns outlined in Section 3.4 are reverted, when considering the rest of the economy. The income inequality remains stable only if the level of market concentration lowers, being the markups constant.

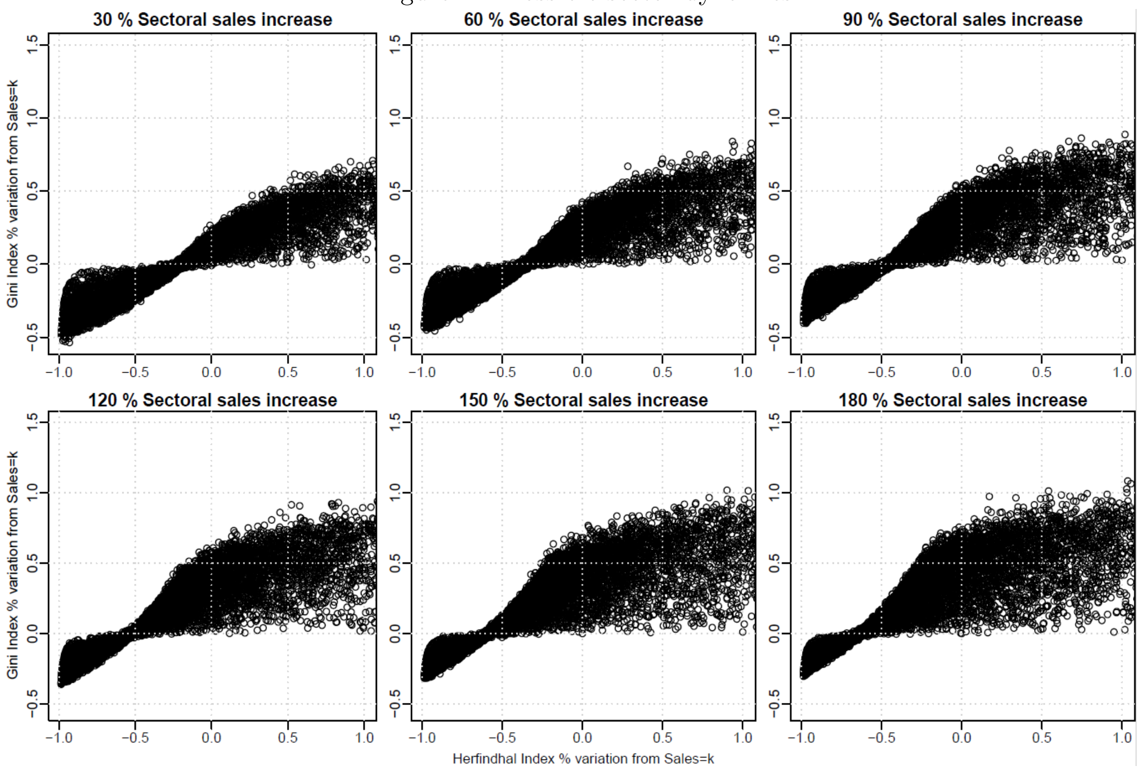
Now, if we had the opportunity to believe that market concentration in the innovative sector was a viable way for capitalists to retain the same income distribution, we cannot say that the reduction in the market concentration is a necessary outcome in the ”new sectors”. In fact, there are no inherent forces that contrast the income disparity. Nonetheless, we cannot even assert that this is impossible. When sectors grows most probable new enterprises enter into the market.

Depending on the movements of the capital owners, different scenarios may emerge in terms of market concentration (capital structure) and income inequality. Assuming, for instance, that the employees who are no longer needed migrate into other business sectors, thereby allowing for macroeconomic growth, the level of income inequality in the new sectors may tend to rise if the number of firms (capital owners) does not increase proportionally. Indeed, the shift of workers into new industries results in greater wage bills and, thus, higher profits (while wages remain constant). In contrast, if the capital structure also changes, the distribution of income may not change in this direction.

3.5 The model

To study the interactions between labor productivity growth, market concentration, income distribution and growth, and to test the results obtained in Section 3.4, we have taken the

Figure 24: Possible sector dynamics



SFC-ABM multisectoral model developed in the second chapter, and we have made some amendments to properly tackle the issues related to inequality and market structure. This Section shows the amendments made to the reference model.

3.5.1 Firm organizational structure

First, we redesigned the organisational structure of the enterprises in order to add real income variability not just between sectors but also between the various organisational layers of the firms. Similar to the work of Caiani et al. (2019), firms require different types of workers with different skills. Specifically, the firm's workforce is composed of top managers, middle management and blue collars. In our model, these three groups, together with the capitalist class, make up the four social classes.

The level of employment is a function of the firm's size and the productivity levels, and the ratios between the layers are given exogenously and remain constant through time. The organization's workforce structure is determined starting from the blue-collar workers. Then, the amount of persons working in middle management or as top managers is simply a function of it.

$$N_{BC,i,t} = S_{i,t} / \sum (ykratio_i * klratio_i) \quad (1)$$

$$N_{MM,i,t} = N_{i,t} * \lambda_{MM} \quad (2)$$

$$N_{TM,i,t} = N_{i,t} * \lambda_{TM} \quad (3)$$

λ_{MM} and λ_{TM} are the exogenous and time-invariant ratios of employees engaged in middle management (MM) or as top managers (TM) for every blue collar worker (BL) (BC). The wages of blue collar workers are determined as follows:

$$w_{BC,i,t} = w_{BC,i,2} * (1 + ind * deltapr_{i,t} + ph * (-un_{t-1,bc} + un_{t-2,bc}) \quad (4)$$

ind is a parameter that reflects the indexation degree of wages to productivity growth (*deltapr*). *ind* equals 1 if productivity is entirely shared with the workers, otherwise, it is equal to 0 if productivity is shared through the price channel (in this study, productivity never results in higher markups). ph reflects the distribution of the power relationship between capitalists and employees in the wage setting (Phillips curve) and $un_{t-1,bc}$ is the unemployment rate among blue collar workers. For the sake of simplicity, the wages of the upper tiers are determined by multiplying the wages of the lowest layer by a factor. These wage multipliers are the inverse of the ratio indicating the number of TM (MM) per BC. In contrast, the Phillips curve is unique to the single type of worker. The following formula is used to calculate the earnings of the upper layers:

$$w_{MM,i,t} = w_{BC,i,2} * (1/\lambda_{MM}) * (1 + ind * deltapr_{i,t} + ph * (-un_{t-1,MM} + un_{t-2,MM}) \quad (5)$$

$$w_{TM,i,t} = w_{BC,i,2} * (1/\lambda_{TM}) * (1 + ind * deltapr_{i,t} + ph * (-un_{t-1,TM} + un_{t-2,TM}) \quad (6)$$

In the capital sector, the organisational structure is simplified for simplicity's sake. There is only one layer (blue collar employees), and labour productivity is not firm-specific, but rather based on the average level of productivity among consumption-sector businesses. The compensation is computed as follows:

$$w_{k,t} = w_{i,t} * (1 + ind * 1/n * \sum deltapr_{i,t} + ph * (-un_{t-1} + un_{t-2}) \quad (7)$$

To lower the amount of complexity, the labour market is modelled in a simple manner, disregarding all rigidities associated with skill development, labour availability, and matching processes. Moreover, we adopted a divisibility approach in the hiring process, as we did in the purchase of capital and consumption goods. This means that companies hire full-time employees and a part-time worker to cover the remaining hours.

3.5.2 Public sector

Taking advantage of the analysis performed in the second chapter, we have introduced a mechanism of public expenditures that addresses the technological-induced labor displacement, avoids potential economic crises, and allows macroeconomic growth (and a per capita expansion of the consumer bundle). Specifically, the public expenditures are aligned to the levels of productivity.

The population level remains stable over time. This may appear to be a bold assertion, especially in light of the fact that we are investigating the very long-term development of the capitalist production system. In any case, it would have just introduced a degree of complication without much improving the results.

3.5.3 The household sector

The consumption patterns are exactly identical to the model presented in the second chapter. The only thing that changes regards the consumption propensities among the social classes. These are not fixed but change in accordance with the income levels. Therefore, the workers in the upper layers have lower propensity to consume with respect to the blue collars.

3.5.4 Productivity function

The standard stochastic approach utilised in the evolutionary literature (e.g., Dosi et al. (2010)) to mimic the innovation process employs a Bernoulli draw to determine the invention probability. The resulting probability is positive correlated to R&D expenditures and, therefore, to sales level. However, the increases in probability are smaller as R&D expenditures increase. In fact, the function has a positive fist derivative (with respect the level of R&D expenditures) but a negative second derivative (at least for reasonable values of the resulting probabilities).

This suggests that, given an equal level of aggregate R&D, the innovation probability at the macro level increases with the number of enterprises. This implies that an economy with a high level of market concentration has a lower innovation probability, as larger firms with greater R&D expenditures have a higher probability than smaller firms, but not proportionally.

However, the aggregate higher likelihood achievable in a more competitive environment does not directly imply a more advanced technological frontier. Indeed, the higher probability at the macro level, which is the results of several firms, will be diffused through time among the production units and cannot be exploited by a handful of enterprises alone. Nonetheless, when imitation dynamics are included, more competitive environments can also exhibit great technical frontier. In this situation, according to the degree of imitation, the inventions are shared by all businesses, and all enterprises are able to reap the rewards of productivity advances.

However, based on Smith's legacy that market size influences productivity development and transferring it to the firm level, we believe that the productivity function has to be convex with respect to the level of sales. In fact, we believe that the labour productivity of ten farmers cultivating one acre each is much lower than that of a single production that cultivates all ten acres. There are numerous causes, and each has been emphasised extensively within the economic discipline. They refer, for instance, to the indivisibility of activities, division of labour, standardisation, and mechanisation. The convexity with respect to the sales level is further supported by the possibility that the outcomes of the research activities, which are linked to the sales level, may not be linear with respect to the efforts (because, for instance, of the elimination of the duplication and the knowledge diffusion).

For this reason, we have modified the stochastic process so that, even if the imitation dynamics are in play, more concentrated markets perform better. The amendment is straightforward. We took the standard equation for the innovation probability and elevated it to the power of α (higher than 1).

$$pinn_{i,t} = [1 - exp(-\tau * \sum_{t=x}^{y} RD_{i,t})]^{\alpha} \tag{8}$$

α gives the non-linearity, changing the the concavity of the probability function (making the second derivative positive). The higher α the more pronounced is the convexity and the non-linearity. Its values are still bounded between 0 and 1. While we have modified the function that determines the innovation probability, we have left unchanged the function that determines the innovation intensity.

3.5.5 Different model's settings

Due to the choice of a long-term perspective, we escape the conventional correlation between more concentration and higher markups. In fact, we begin with the premise that all productivity gains cannot be appropriated by capitalists for extended periods due to market competing pressures, as described by classical economists. Therefore, even if we speak of market concentration, we always refer to environments that include some degree of competition which, over time, drive the markups toward their "natural" level. This is especially true if we visualize the concentration process as coexisting with globalisation, where market concentration come with market expansion and, therefore, the power relationships among capitals may remain intact. In our model, therefore, all productivity gains result in a decrease in the pricing of consumer products. This decision was also made since the relationship between the distribution of productivity increases and economic growth was thoroughly examined in the second chapter.

The model's scenarios include an environment that is characterized by competition and one that is more susceptible to market concentration. The different market configurations are generated by altering the parameters relevant to entry barriers, the subsample sizes available to households when selecting their suppliers, and the price sensitivity of consumers. All of these factors influence consumers' loyalty to a particular supplier ant this stickiness applies to the consumption market and the capital market also. Due to the fact that R&D activities and the innovation process occur in the industry producing capital goods, it is crucial that the level of market concentration in the capital sector also evolves. Obviously, this one is a consequence of the structure of the industry producing consumer goods.

One limitation of the model is that the structures of the industries, within each configuration of the model, apply to all sectors; sectors that grow and sectors where saturation levels are reached (where efficiency gains cause employment levels to fall) have the same inclination towards competition or market concentration, and this does not fully respect the results described in Section 3.4.

3.6 Results

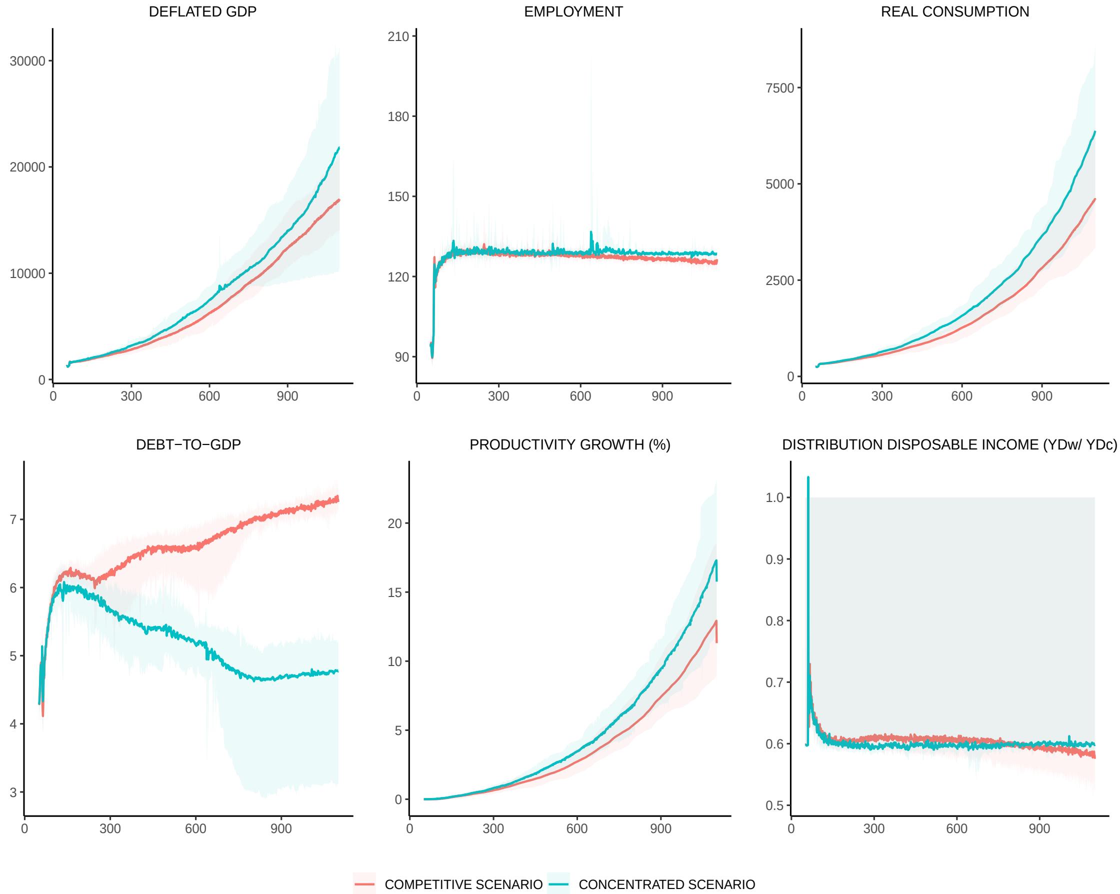
This section presents the outcomes of the ABM-SFC model, which simulates a multisectoral economy in which economic growth is accompanied by structural transformations, where the employment structure of the economy evolves through time in accordance to consumers' growing and changing wants. To test the results described in Section 3.4 and determine which combination of market concentration and income distribution produces the greatest economic growth, we run the model under two distinct scenarios: one in which the economy is susceptible to a high level of market concentration, and the other in which competition prevails. In contrast to the combinations highlighted in Section 3.4, the relationship between markups, income distribution and economic growth has been omitted; indeed, it was the subject of the second chapter, which investigates the short and medium-run dynamics. Moreover, given that this chapter focuses on the extremely long-term dynamics of the capitalistic system, if some form of competition among capitals is conceivable, it is hard to imagine that the increase in the markup levels can be a long-term solution to the tendency of the income distribution (at the individual level) to move toward the workers.

Figure 25 depicts the outcomes of the Montecarlo simulations conducted under the two settings.

The scenario susceptible to market concentration (in blue) achieves the best results in every dimension. Despite the fact that greater concentration increases income disparity, economic growth is still more pronounced. This implies that having fewer production units, everything else being equal, is more important than the sectoral production dispersion resulting from income inequality. The concentration of production in a few hands outperforms a competitive environment where income earners are more homogeneous and production is divided among a few business sectors, despite the high inequality that arises, which, in turn, implies a high degree of heterogeneity in consumer consumption and, consequently, a high degree of production dispersion. All of this replicates the situation in which the micro-level sales aggregation outperforms the sector-level sales aggregation.

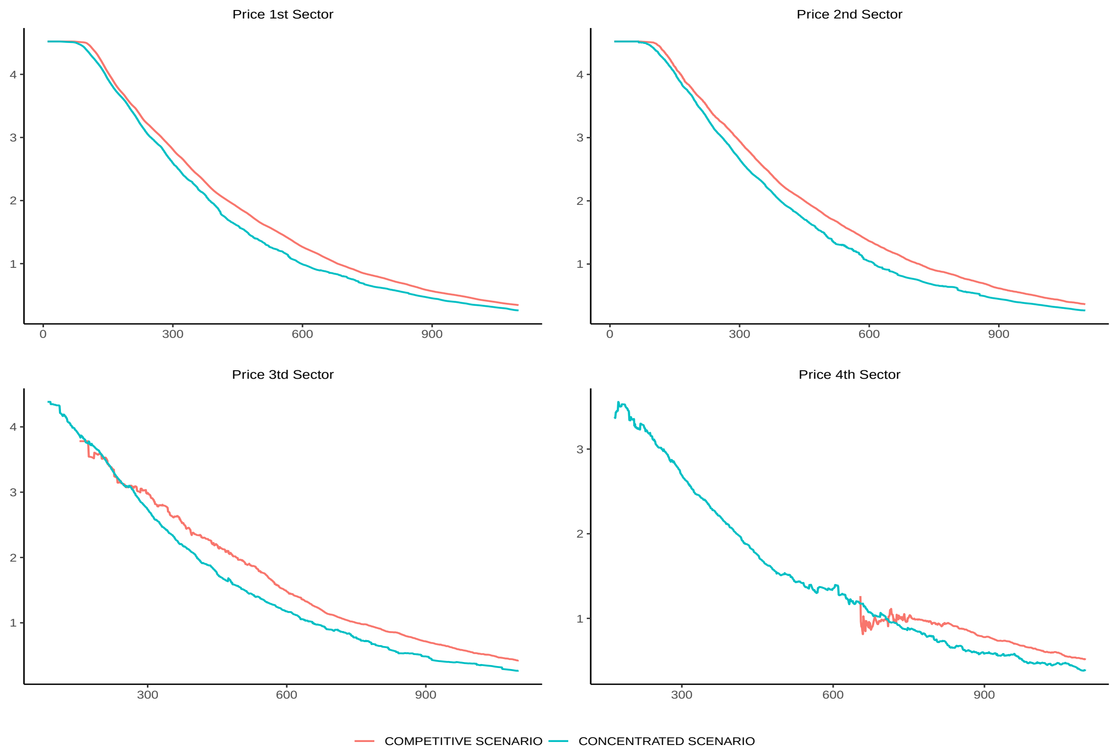
The higher growth achieved under concentrated markets are captured by all workers, also those with the lowest job rank. The price dynamics presented in Figure 26 makes this point quite evident. Indeed, given that wages remain constant and what matters is the price evolution of the consumption good, the scenario with higher concentration results in lower prices across all industries and at all times.

Figure 25: Multi-sectoral economy: Main macro variables



Time spam=1100 periods. 40 Montecarlo simulations for each setting.

Figure 26: Multi-sectoral economy: Price dynamics

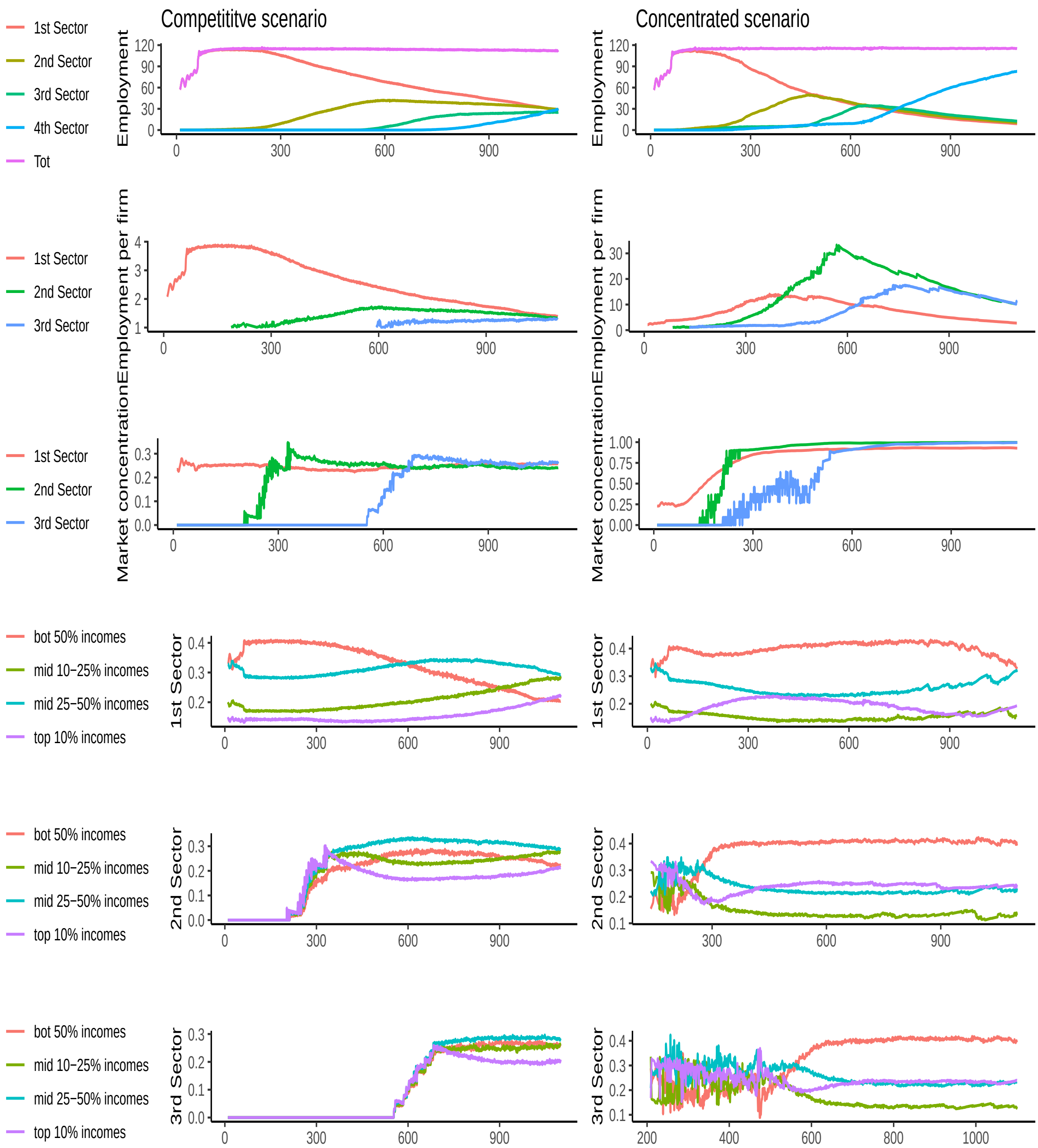


Time spam=1100 periods. 40 Montecarlo simulations for each scenario

Figure 27 depicts the employment levels in the major industries and the income distribution between social classes.

The third row of the graph depicts the varying levels of market concentration resulting

Figure 27: Multi-sectoral economy: Sectoral inequality indexes



Time spam=1100 periods. 40 Montecarlo simulations for each scenario. more competitive vs market concentration

from the two scenarios. In the first scenario, the market structure remains steady throughout time, whereas in the second scenario, the level of concentration soars and reaches severe levels.

As can be seen, the overall employment level does not change as a result of rising public spending, which grows with the labor productivity, and the assumption of constant population levels. Despite this, the employment structure is continuously changing. While some sectors see a decline in employment, as a result of labour productivity increasing faster than output (due to saturation levels), other sectors increase their labour force in response to rising demand that is not sustained by a sufficient growth in labor productivity. Due to the higher development in labour productivity, the scenario with high concentration demonstrates a more rapid and dramatic shift in the employment structure relative to the competitive environment. As can be seen, the employment reorganization and, more specifically, the employment reduction in those sectors that are already saturated, reduces over time until it stabilises (the reasons for this are discussed in Section 3.7.1).

In general, the average level of employment per business (in each sector) increases during the beginning of the sector cycle and decreases afterward. Due to the enterprises' increased market share, the inverted U-shaped dynamics are highlighted even more in the concentrated environment. In a competitive setting, the progressive reduction of labour force per unit of production accelerates the firm's approach to zero employment. This provides insight into the potential for such an environment to stably increase labour productivity, which finds its primary source in labour specialisation.[31].
As can be seen in the final three rows of the Figure 27, the average level of employment per firm has a considerable impact on the income distribution. In fact, as explained in Section 3.7.2, not only does the income inequality between capital owners and workers depend on the employment level, but so does the inequality among workers (whose number for each role is entirely determined by the output level, as explained in Section 3.5.1).

In the competitive scenario, the translation of productivity gains into lower prices and the reduction of the average level of employment per firm results in a shift of the personal income distribution toward the working class (as previously explained in Section 3.4), while the functional distribution remains unchanged (because of the invariance of the markups). This trend is such that, at the end of the simulation periods, the bottom class of the distribution, which experiences a considerable fall in its income share, is comprised of capital owners rather than blue collar employees, as was the case at the beginning of the simulation.

In contrast, when markets get more concentrated, while the sectoral overall employment level declines, the average employment per business rises because the sectors output level is distributed among fewer production units. Due to the emergence of "superstar enterprises" and, therefore, the disappearance of the middle class, inequality levels increase. However, this cannot persist indefinitely. Indeed, once the good markets are highly concentrated, the average employment per company must decline because the sectors production level cannot increase (because saturation levels have already been reached) and labour productivity per output continues to rise, whereas higher concentration is difficult to attain. Therefore, inequality levels must decrease. In this scenario, inequality is only a temporary phenomenon that emerges in sectors that grow in size (if the number of capitalists does not increase proportionally with the increase in sectoral employment levels) and flattens once sectors are old, where the decline in the employment level per firm cannot be counterbalanced by increasing degree of market concentration[32]. In this situation, since higher concentration is not possible, only a rise in markups or the acquisition of capital shares in new industries can restore the old distributional levels. Otherwise, future expansion is improbable.

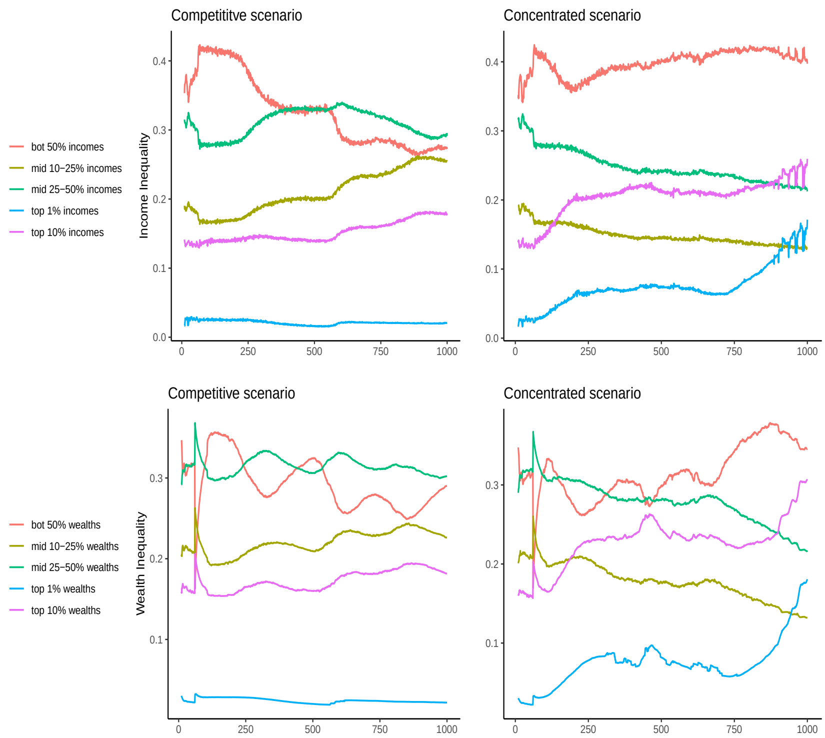
The combination of the dynamics of employment per business and income distributional, as represented in in Figure 27, illustrates that the results presented in Section 3.4 are only applicable when structural change occurs. At the beginning of a sector's life cycle, when its size is expanding, the typical relationships emerge: greater concentration - greater inequality and invariant market structure - invariant income inequality.

To explore how the different movements across the business sectors combine together, Figure 28 depicts the trend of the wealth inequality at the macro level.

[31] Indeed, lower employment means lower possibilities for a better organized and efficient production

[32] Clearly, for this to occur, productivity must continue to improve over time, despite the probable absence of capitalist incentives to pursue a productivity struggle.

Figure 28: Multi-sectoral economy: Aggregate inequality



Time spam=1000 periods. 40 Montecarlo simulations for each scenario

Because we are working with productivity increases that are passed on to consumers via the price channel, we do not have income inequality resulting from variations in wages between sectors; rather, we only have disparity within sectors (the nominal wages are the same in all the sectors). Inequality in the entire economy emerges as a result of the aggregation of sectoral disparity; each sectoral inequality represents a portion of the total economy, whose significance diminishes over time as its employment share declines. Figure 28 demonstrates that, in the concentrated scenario, despite the fact that sectoral inequality becomes a transitory phenomena at a certain point, the levels of income inequality in the overall economy increase over time. Due to the slow drop in employment levels of enterprises operating in highly concentrated industries, it takes a very long period for high levels of inequality to diminish in the old sectors. In addition, when these sectoral disparities lessen, so does their effect on the economy as a whole.

Likewise, wealth disparity increases in the competitive scenario. In fact, as a result of the shift in income distribution toward the working class, capital owners have fallen to the bottom of the distribution while workers have risen to the top 10 percent of wealth holders.

3.7 Few further considerations

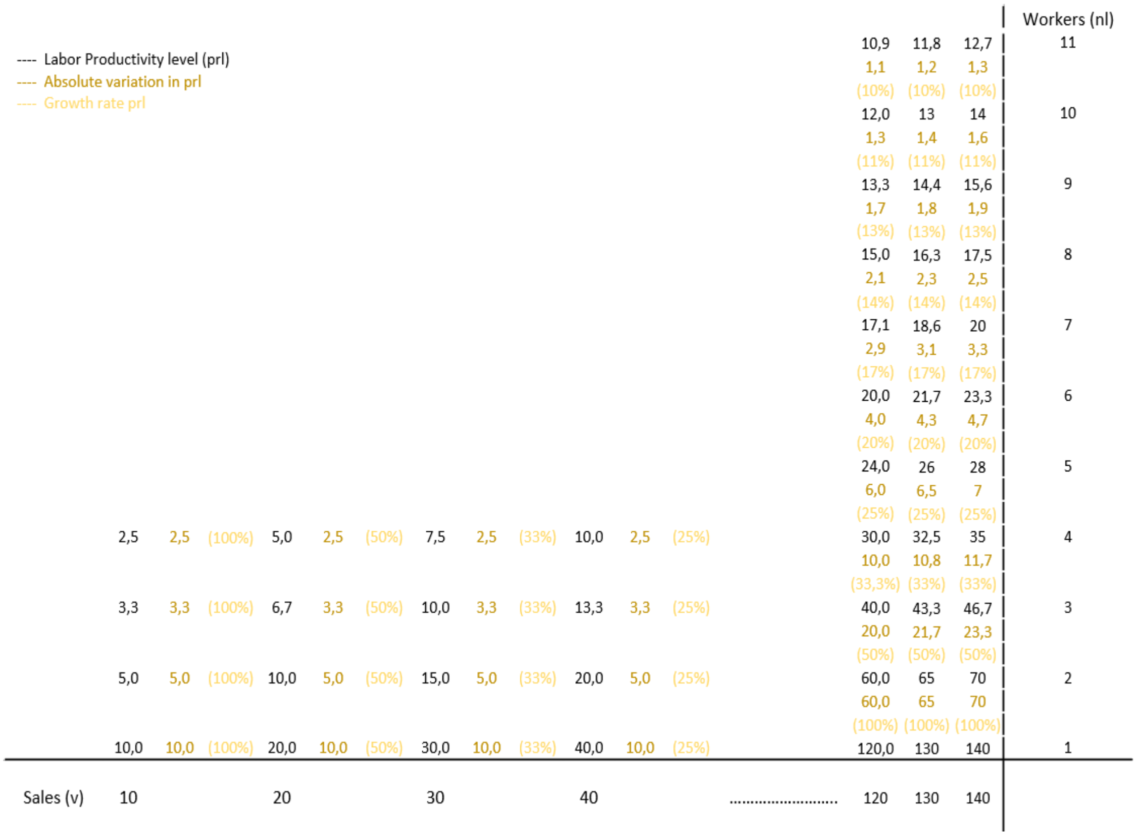
3.7.1 On the labor productivity long-term trend

A few points regarding the long-term trend of labour productivity are worth mentioning. The long-term productivity trajectory decides whether or not the worker will ever be liberated from labour, and at what rate, at least in the innovative industries. Obviously, this is not a topic we wish to address, but we hope to at least spark some reflections.

Despite the fact that gains in labour productivity are capitalised over time, resulting in capitalization that compounds and labour productivity that increases exponentially, the reduction, in absolute terms, in the laborforce of the innovating industry has a downward trend. In other words, once saturation levels are reached, if labour productivity continues to rise (at constant rates), the number of personnel released from the innovative industry decreases progressively. This is due to saturation thresholds that prevent sectors from expanding indefinitely; as a result, lower employment levels necessitate a greater percentage increase in productivity in order to continue releasing the same number of workers. This is owing to the nonlinear nature of applying a percentage to an ever-decreasing sum. Specularly, due to the percentages game, the same amount of absolute delta sales can be achieved through diminishing labour productivity gains.

A numerical example is provided in Figure 29

Figure 29: Decreasing labor releasing



A constant absolute reduction in employment, which corresponds to an increasing reduction, in percentage term, necessitates an increasing variation in the productivity level. Employment and productivity are two sides of the same coin.

Given that the innovation process modelled in the model, despite being stochastic, results in fairly constant percentage increases in productivity (resulting in exponential levels of labour productivity), the sectors tend to stabilise the absolute drop in employment and, consequently, the employment level.

Although the absolute reduction in employment is still attainable over time if we consider all sectors of the economy (including workers who migrate from one sector to another), the stabilisation of employment levels in the old sectors, assuming it corresponds to the real world, adds a complexity to the conclusions presented in Section 3.4. In fact, the steady stabilisation of employment levels must coincide with the gradual weakening of the propensity of personal distribution to shift toward employees.

3.7.2 On Income inequality

Leaving aside all the details about how income inequality creates wealth inequality and how this, in turn, affects it, we might claim that the aggregate income inequality is simply the result of the income inequality generated within and between firms (sectors). Every income is a multiple of the lowest income. The conjunction of these factors defines the level of income inequality in aggregate.

If markups are constant, the inequality between capital owners and workers operating in a certain enterprise cannot be that the product of the firm size. It depends specifically on the wage bill and the number of employees who benefit from it, as well as the number of capitalists, and their share ownership. The level of profit (Π) is determined as follows:

$$\Pi = \mu * (\sum w_i * n_i) \tag{9}$$

where w_i and n_i are respectively the nominal wage and the number of workers of the i^{th} type of worker. The ratio between the profit per person (Π_p) and the particular j^{th} nominal wage indicates the extent of income inequality (I) between the j^{th} type of worker and the capital owner.

$$I_{\Pi_p/w_j} = \Pi_p/w_j = [\mu * (w_j * n_j + \sum w_i * n_i) * \zeta]/w_j \tag{10}$$

where ζ is the share of capital hold by the capitalist. As shown from equation 10, if the capital share remains constant, every increase in employment, regardless of the type of workers interested, increases the level of inequality. In addition, whatever increase in wages, while does not change the level of inequality between the capital owner and the type of worker interested, increases the level of income disparity with respect to the other types of workers.

In contrast, the inequality level does not change if the increase in the number of employees comes among with a reduction of ζ. For the same reason, if the reduction of ζ comes along with the increase in wages, then the income distribution shifts toward employees.

In conclusion, the variation in income inequality between capital owners and workers is the result of a disparity between the variation in capital per capitalist relative to variations in nominal wages and number of workers. Unless the capital structure evolves appropriately with the employment structure, the likelihood is that the larger the firm the greater the income inequality.

Also the income inequality among workers can be attributed to the size of the company. Indeed, this disparity, which is given by the wage difference

$$I_{(w_i/w_j)} = w_i/w_j \tag{11}$$

can easily rise with the company's size, since the bigger the number of workers, the greater the need for capitalists to employ workers who perform management/control duties. And in this position, as it is quite evident empirically (which demonstrates that only large corporations can afford staff who earn thousands of times more than "basic" employees), it is easier to negotiate a larger wage because capitalists seek to match the interests of the top management with their own (Principal-Agent Problem).

3.8 Concluding remarks

While the second chapter is focused on the influences the short term has on the long-term path of the economy, this one focuses on the secular dynamics of the capitalistic system.

We start exploring which can be the secular trends that come with economic growth and the structural changes forces, which are naturally behind it. Specifically, we show how the reduction of the employment, at the sectoral level, which logically comes with increasing level of labor productivity and consumers preference for variety[33], can have repercussions in terms of market structure and personal distribution. Whenever a reduction of the sectoral employment level occurs, there is a shift of the personal distribution toward the workers. Only an increase in the markups or in the level of market concentration can restore the previous distribution equilibria. If the classical understanding regarding the competition is assumed, the following combination in terms of variations in market structures and income distribution can emerge:

- invariant market structure - personal distribution that moves toward workers;
- increasing level of market concentration - invariant personal distribution;
- level of market concentration that increases sharply - personal distribution that moves toward the capital owners.

This results translate Marx's idea about the tendency of the rate of profit to fall[34] into the tendency of the personal income distribution to move toward the workers. When structural change occur, for the system to maintain the personal distribution unchanged, either an increase in the markups level or an increase in the market concentration is required.

Then, given the potential combinations of market concentration and income inequality that result from increasing productivity and consumers' preference for variety, we analysed the growth patterns that can occur in these scenarios. Assuming that the productivity trend depends on the level of sales, because of the possibilities it opens in terms of labor division, the degree of market concentration and income inequality influence the rate of economic growth. In fact, these levels influence the productivity trajectory through the sales allocation among business sectors and firms. For the purpose of our research, we have taken the SFC-ABM multisectoral model developed in the second chapter, and we have made some amendments to properly tackle the issues related to inequality and market structure. Particularly, we have implemented a more complex firm structure in which diverse labor skills are necessary to operate the business and each sort of worker is compensated differently based on the type of job. In addition, we have modified the manner in which the innovation process influences our artificial economy during the simulation periods.

Keeping the level of markups unchanged, the simulations showed that the following results can occur in the long-term:

- unchanged market structures, beyond the shift of the income distribution toward the workers, show a low pace of the productivity growth and therefore low economic growth;
- market structure inclined to market concentration leave the income distribution unchanged, and show sustained labor productivity growth (and therefore economic growth);
- in settings in which the level of market concentration increases sharply, although significant shifts of the income distribution toward the capital owners occur, highly positive results in terms of productivity pace are reached. While inequality soars, the economy grows at high rates, with superstar firms that emerge and the middle class disappearing;
- settings characterized by different inclinations to market concentration can alternate. Highly concentrated market structures, which exhibit high levels of inequality and economic growth, cannot persist indefinitely and may result in frameworks where the

[33] With the exception of production systems that must meet the needs of a growing population. In this case, even if saturation levels are reached and labor productivity increases, the absolute employment per sector cannot decline and only the employment shares across sectors change.

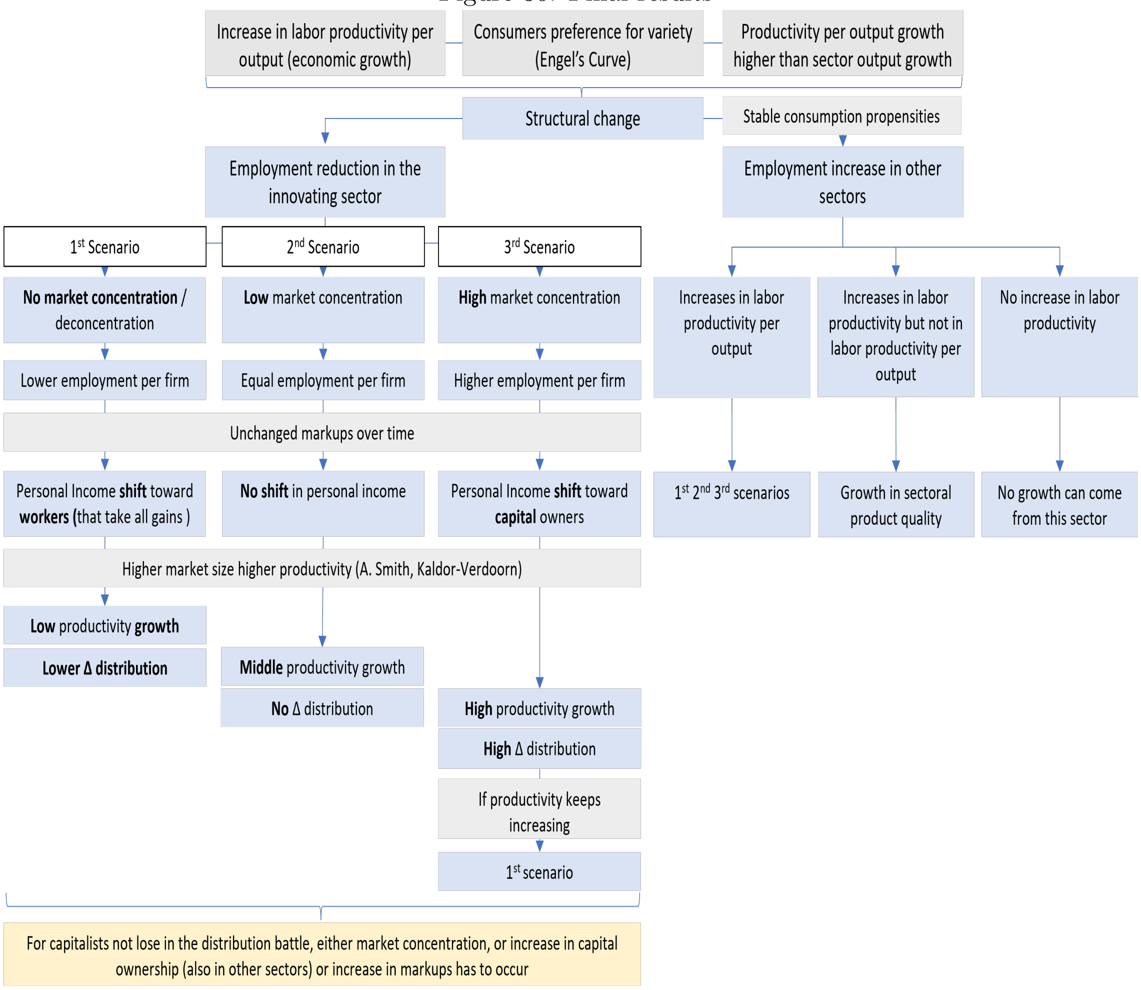
[34] Marx spoke about the fratricidal competition among capitals that (under the capital deepening mode of accumulation) would drive up the the organic composition of capital leading the rate of profit to fall

labour force per firm, such as the income disparity, must decrease due to the impossibility of the output per firm to increase further (given that higher levels of concentration may be no longer attainable while labour productivity keeps increasing). In this case, income inequality would emerge as a temporary phenomenon only.

These results, which are only valid in those sectors where the employment levels reduce over time, are an inevitable outcome if higher consumption levels, in terms of variety, have to be achieved. In fact, these patterns are not a obligatory result when the economic growth does not come along with structural change. In these cases, where the sectoral output level grows more than the labor productivity per output, the usual patter higher market concentration-higher inequality occurs and higher growth is easily reached under the market structures more inclined to concentration.

The final results of the chapter are reported in figure 30.

Figure 30: Final results



A Appendix

Figure 31: Labor productivity increase without any change in the market structure: example

	N° FIRMS	EMPLOYMENT	OUTPUT	EMPLOYMNET PER-FIRM (n)	OUTPUT PER FIRM (q)	LABOR PRODUCTIVITY (pr=q/n)	HERTFIELD INDEX	WAGE (w)	FIRM WAGE BILL (W=w*q/pr)	PRICE (p=(1+μ)*(w/pr))	FIRM PROFIT (∏=q*p-W)	WAGE SHARE (ΣW/Σ∏)	PERSONAL WAGE SHARE (w/∏)
1st scenario	50	500	1000	**10,0**	20,0	2	**2%**	10,0	100	6,0	20,0	**5**	**0,5**
	25	250	1000	**10,0**	40,0	4	**4%**	20,0	200	6,0	40,0	**5**	**0,5**
						⋮							
	3	30	1000	**10,0**	333,3	33	**33%**	166,7	1667	6,0	333,3	**5**	**0,5**
2nd scenario	50	500	1000	**10,0**	20,0	2	**2%**	10,0	100	6,0	20,0	**5**	**0,5**
	20	250	1000	**12,5**	50,0	4	**5%**	20,0	250	6,0	50,0	**5**	**0,4**
						⋮							
	2	30	1000	**15,0**	500,0	33	**50%**	166,7	2500	6,0	500,0	**5**	**0,3**

Markups are equal to 20%, no changes in the firm capital structure and equal market shares are assumed

B Appendix

CONSUMPTION GOOD INDUSTRY

PRODUCTION LEVELS

$$Q^e_{i,t} = Q^e_{i,t-1} + \beta_1 * (Q^d_{i,t-1} - Q^e_{i,t-1}) \tag{1}$$

$$Q_{i,t} = min\{Q^e_{i,t} * (1+d) - INV_{i,t-1}\ ,\ K^{net}_{i,t} * ykratio_{i,t}\} \tag{2}$$

$$Q^s_{i,t} = Q_{i,t} + INV_{i,t-1} \tag{3}$$

INVESTMENT AND CAPITAL LEVELS

$$g^e_{i,t} = g^e_{i,t-1} + \beta_2 * (g_{i,t-1} - g^e_{i,t-1}) \tag{4}$$

$$S^e_{i,t+dk} = S^e_{i,t} * (1+d) * (1+g^e_{i,t}) \tag{5}$$

$$K^t_{i,t+dk} = S^e_{i,t+dk}/ykratio_{i,t}/ut \tag{6}$$

$$K^f_{i,t+dk} = \sum_{j=t-z+dk}^{t+dk} K^{net}_{i,j} \tag{7}$$

$$K^{net}_{i,t} = \sum_{j=t-z}^{t} K^{inst}_{i,j} - da_{i,j} \tag{8}$$

$$K^d_{i,t} = K^t_{t+dk} - K^f_{i,t+dk} \tag{9}$$

$$I_{i,t} = K^d_{i,t} * pk_{j,t} \tag{10}$$

Where $p_{j,t}$is the capital good price supplied by th j^{th} capital good firm

LABOR PRODUCTIVITY AND WAGE SETTING

$$pr_{i,t} = \sum_{j=t-z}^{t} K^{net}_{i,j}/(\sum K^{net}_i) * klratio_{i,j} \tag{11}$$

$$deltapr_{i,t} = (pr_{i,t} - pr_{i,t-1})/pr_{i,t-1} \tag{12}$$

$$w_{i,t} = w_{i,t} * (1 + ind * deltapr_{i,t} + ph * (-un_{t-1} + un_{t-2}) \tag{13}$$

$pr_{i,t}$ is an average among all the capital vintages acquired over time

EMPLOYMENT LEVEL AND WAGE BILL

$$N_{i,t} = Q_{i,t}/ykratio_{i,t}/pr_{i,t} \tag{14}$$

$$W_{i,t} = N_{i,t} * w_{i,t} \tag{15}$$

DEBT LEVELS AND INSTALLMENTS

$$L_{sh,i,t} = \begin{cases} D_{i,t-1} - W_{i,t}, & if \quad D_{i,t-1} > 0 \\ D_{i,t-1} + W_{i,t}, & if \quad D_{i,t-1} < 0 \end{cases} \tag{16}$$

$$L_{lg,i,t} = \begin{cases} I_{i,t}, & if \quad D_{i,t-1} > W_{i,t} \\ I_{i,t}, & if \quad D_{i,t-1} \leq W_{i,t} \end{cases} \tag{17}$$

$$Rcc_{sh,i,t} = \sum_{j=t-z}^{t} L_{sh,i,j}/u \quad (18)$$

$$Ri_{sh,i,t} = \sum_{j=1}^{u} L_{sh,i,t-j+1} * (u-j+1)/u * (r_{sh,t}) \quad (19)$$

$$Rtot_{sh,i,t} = Rcc_{sh,i,t} + Ri_{sh,i,t} \quad (20)$$

$$a = \sum_{j=1}^{z} j/z \quad (21)$$

$$Rtot_{lg,i,t} = \sum_{j=1}^{z} L_{lg,i,t-j+1} * (1+r_{lg,t})(z+1-j)/z/a \quad (22)$$

$$Rcc_{lg,i,t} = \sum_{j=1}^{z} L_{lg,i,t-j+1} * (z+1-j)/z/a \quad (23)$$

$$Ri_{lg,i,t} = Rtot_{lg,i,t+dk} - Rcc_{lg,i,t+dk} \quad (24)$$

The repayment structure here explained is only about the debt contracted in one period only[35].

PRICE SETTING

$$Pc_{i,t} = (1+\mu)\{w_t * (1+r_{sh,t})/(ykratio_{i,t} * pr_{i,t}) + Pk_{i,t} * (1+r_{lg,t})/a/(ykratio_{i,t} * ut)\} \quad (25)$$

DEMAND, QUANTITIES SOLD, SALES AND INVENTORIES

$$Q^d_{i,t} = \sum_{w=1}^{n_w} Q^d_{w,t} + \sum_{k=1}^{n_k} Q^d_{k,t} + Q^d_{s,t} \quad (26)$$

$Q^d_{w,t}$,$Q^d_{k,t}$,$Q^d_{s,t}$, only the portions addressed to the i^{th} firm

$$Q^{sold}_{i,t} = \begin{cases} Q^s_{i,t}, & if \quad Q^d_{i,t} > Q^s_{i,t} \\ Q^d_{i,t}, & if \quad Q^d_{i,t} \leq Q^s_{i,t} \end{cases} \quad (27)$$

$$S_{i,t} = Q^{sold}_{i,t} * Pc_{i,t} \quad (28)$$

$$INV_{i,t} = INV_{i,t-1} + Q_{i,t} - Q^{sold}_{i,t} \quad (29)$$

PROFITS, CASH AND UNRETAINED PROFITS

$$\pi_{i,t} = S_{i,t} - W_{i,t} + INV_{i,t} - da_{i,t} - r_{sh,t} * W_{i,t} - r_{lg,t} * da_{i,t} \quad (30)$$

$$D_{i,t} = D_{i,t-1} + S_{i,t} - W_{i,t} - Rtot_{lg,i,t} - Rtot_{sh,i,t} - U\pi_{j,t} \quad (31)$$

$$U\pi_{i,t} = \begin{cases} \pi_{i,t}, & if \quad D_{i,t} > \pi_{i,t} \\ \pi_{i,t}, & if \quad 0 < D_{i,t} \geq \pi_{i,t} \\ 0, & if \quad D_{i,t} < 0 \end{cases} \quad (32)$$

[35]Clearly, in the model, in each period new debt are demanded and the total installments are a sum of what explained here. Moreover, we use constant installment for the long-term debt that follows the capital depreciation dynamics. Variable installment for the short-term debt that anyway is a revolving debt (u=1).

CAPITAL GOOD INDUSTRY (KI)

PRODUCTION LEVELS

$$Q_{j,t} = \sum_{i=1}^{n_{fc,sec}} K^d_{i,t}/dk \tag{33}$$

$$S_{j,t} = Q_{j,t} * pk_{j,t} \tag{34}$$

Only few i^{th} firms select the j^{th} supplier

LABOR PRODUCTIVITY AND WAGE SETTING

$$pr_{j,t} = pr_{j,t-1} * (1 + \sum_{i=1}^{n_{fc,sec}} deltapr_{i,t}/n_i) \tag{35}$$

$$deltapr_{j,t} = (pr_{j,t} - pr_{j,t-1})/pr_{j,t-1} \tag{36}$$

$$w_{j,t} = w_{j,t} * (1 + ind * deltapr_{j,t} + ph * (-un_{t-1} + un_{t-2}) \tag{37}$$

PRICE SETTING

$$pk_{j,t} = (1 + \mu) * w_{j,t}/pr_{j,t}/(1 - \gamma) \tag{38}$$

INNOVATION PROCESS

$$RD_{j,t} = S_{j,t} * \gamma \tag{39}$$

$$pinn_{j,t} = 1 - exp(-\tau * \sum_{y=last_{j,t}+1}^{t} RD_{j,t}) \tag{40}$$

$$inn_{j,t} = \begin{cases} 1, & if \quad innovates \\ 0, & if \quad not \end{cases} \tag{41}$$

(42)

$deltakl_{j,t}$ is the value obtained from a draw in a Beta distribution

$$mktinn_{j,t} = \begin{cases} 1, & if \quad deltakl_{j,t} > 0 \\ 0, & if \quad deltakl_{j,t} \leq 0 \end{cases} \tag{43}$$

$$pim_{j,t} = 1 - exp(-\tau * \sum_{y=last_{j,t}+1}^{t} RD_{j,t}) \tag{44}$$

$$im_{j,t} = \begin{cases} 1, & if \quad mktinn_{j,t} = 0 \quad and \quad imitates \\ 0, & if \quad mktinn_{j,t} = 1 \end{cases} \tag{45}$$

$maxKpr_{sec,t}$ is the best technology in the sector
$maxKpr_{eco,t}$ is the best technology in the economy

$$Kpr_{j,t} = Kpr_{j,t-1} * (1 + deltakl_{j,t}) * mktinn_{j,t} + (maxKpr_{sec,t} - Kpr_{j,t-1}) * im_{j,t} + spill * (maxKpr_{sec,t} - Kpr_{j,t-1}) \tag{46}$$

EMPLOYMENT LEVEL AND WAGE BILL

$$N_{j,t} = Q_{j,t}/pr_{j,t} \tag{47}$$

$$N_{r,j,t} = RD_{j,t}/w_{j,t} \tag{48}$$

$$W_{j,t} = N_{j,t} * w_{j,t} + RD_{j,t} \tag{49}$$

CASH AND PROFIT

$$\pi_{j,t} = S_{j,t} - W_{j,t} \tag{50}$$

$$U\pi_{j,t} = \begin{cases} \pi_{j,t}, & if \quad D_{j,t} > \pi_{j,t} \\ \pi_{j,t}, & if \quad 0 < D_{j,t} \geq \pi_{j,t} \\ 0, & if \quad D_{j,t} < 0 \end{cases} \tag{51}$$

$$D_{j,t} = D_{j,t-1} + \sum_{i=1}^{n_{fc,sec}} K^d_{i,t} * p_{j,t} - W_{j,t} - U\pi_{j,t} \tag{52}$$

GOVERNMENT SECTOR

EXPENDITURES AND TAXES

$$G_t = G * (1 + pri, t) \tag{53}$$

$$Tx_t = ((\sum_{w=1}^{n_w} YD_{w,t}/(1-\theta)) + \sum_{k=1}^{n_k}(B_{k,t-1} * + rb_{t-1} Dep_{k,t-1} * rd_{t-1}) + U\pi_{b,t} + U\pi_{i,t} + U\pi_{j,t}) * \theta \tag{54}$$

DEFICIT AND PUBLIC DEBT

$$Def_t = \begin{cases} 0, & if G_t - Tx_t - \pi cb, t - rb_t * B_{t-1} < 0 \\ G_t - Tx_t - \pi cb, t - rb_t * B_{t-1}, & if G_t - Tx_t - \pi cb, t - rb_t * B_{t-1} \geq 0 \end{cases} \tag{55}$$

$$D_{s,t} = \begin{cases} 0, & if G_t - Tx_t - \pi cb, t - rb_t * B_{t-1} \geq 0 \\ G_t - Tx_t - \pi cb, t - rb_t * B_{t-1}, & if G_t - Tx_t - \pi cb, t - rb_t * B_{t-1} < 0 \end{cases} \tag{56}$$

$$B_t = B_{t-1} + Def_t - D_{s,t} \tag{57}$$

$$Dpil_t = B_t / Y_t \tag{58}$$

HOUSEHOLD SECTOR

DISPOSABLE INCOME, CONSUMPTION, WEALTH, BONDS AND DEPOSITS

$$YD_{w,t} = (w_{w,t} + rb_t * B_{w,t-1} + rd_t * Dep_{w,t-1}) * (1-\theta) \tag{59}$$

$$YD_{k,t} = (U\pi_{k,t-1} + rb_t * B_{k,t-1} + rd_t * Dep_{k,t-1}) * (1-\theta) \tag{60}$$

$$C_{w,t} = \alpha_{1w} * YD_{w,t} + \alpha_{2w} * V_{w,t-1} \tag{61}$$

$$C_{k,t} = \alpha_{1c} * YD_{k,t} + \alpha_{2c} * V_{k,t-1} \tag{62}$$

$$V_{w,t} = V_{w,t-1} + YD_{w,t} - C_{w,t} \tag{63}$$

$$V_{k,t} = V_{k,t-1} + YD_{k,t} - C_{k,t} \tag{64}$$

$$B_{w,t} = V_{w,t-1} * (\lambda_0 + \lambda_1 * rb_t - \lambda_2 * (YD_{w,t}/V_{w,t-1}) \tag{65}$$

$$B_{k,t} = V_{k,t-1} * (\lambda_0 + \lambda_1 * rb_t - \lambda_2 * (YD_{k,t}/V_{k,t-1}) \tag{66}$$

$$Dep_{w,t} = V_{w,t} - B^d_{w,t} \tag{67}$$

$$Dep_{k,t} = V_{k,t} - B^d_{k,t} \tag{68}$$

$$TDep_t = (\sum_{i=1}^{n_{fc}} U\pi_{i,t} + \sum_{j=1}^{n_{fk}} U\pi_{j,t} + U\pi_{b,t}) * (1-\theta) \tag{69}$$

BANKING SECTOR

PROFITS, CASH, UNRETAINED PROFITS AND ADVANCES

$$\pi_{b,t} = \sum_{i=1}^{n_{fc}} Ri_{lg,i,t} + \sum_{i=1}^{n_{fc}} Ri_{sh,i,t} + rb_t * B_{b,t-1} + rr_t * (res_{t-1} - rd_t * (Dep_{w,t-1} + Dep_{k,t-1}) \tag{70}$$

$$D_{b,t} = D_{b,t-1} + \sum_{i=1}^{n_{fc}} Ri_{lg,i,t} + \sum_{i=1}^{n_{fc}} Ri_{sh,i,t} + rb_t * B_{b,t-1} + rr_t * (res_{t-1} - rd_t * (Dep_{w,t-1} + Dep_{k,t-1}) + adv_t \tag{71}$$

$$U\pi_{b,t} = \begin{cases} \pi_{b,t}, & if \quad D_{b,t} > \pi_{b,t} \\ \pi_{b,t}, & if \quad 0 < D_{b,t} \geq \pi_{b,t} \\ 0, & if \quad D_{b,t} < 0 \end{cases} \tag{72}$$

$$adv_t = \begin{cases} -D_{b,t}, & if \quad D_{b,t} < 0 \\ 0, & if \quad D_{b,t} \geq 0 \end{cases} \tag{73}$$

OUTSTANDING DEBT AND NON PERFORMING LOANS

$$Ls_t = Ls_{t-1} + \sum_{i=1}^{n_{fc}} (L_{sh,i,t} + L_{lg,i,t} - Rcc_{sh,i,t} - Rcc_{lg,i,t}) - NPL_{sh,t} - NPL_{lg,t} \tag{74}$$

$$NPL_{sh,t} = \sum_{t=t}^{t-z} \sum_{i=1}^{n_{fc}} (L_{sh,i,t} - Rcc_{sh,i,t}) \tag{75}$$

$$NPL_{lg,t} = \sum_{t=t}^{t-z} \sum_{i=1}^{n_{fc}} (L_{lg,i,t} - Rcc_{lg,i,t}) \tag{76}$$

i indicates the i^{th} firm that has gone in bankruptcy

CENTRAL BANK PROFITS

$$\pi cb,t = rb_t * B_{cb,t-1} - rr_t * res_{t-1} \tag{77}$$

CENTRAL BANK RESERVES

$$res_t = -Ls_t + Dep_{w,t} + Dep_{k,t} + \sum_{i=1}^{n_{fc}} D_{i,t} + \sum_{j=1}^{n_{fk}} D_{j,t} + D_{b,t} + +D_{s,t} + TDep_t \tag{78}$$

WHOLE ECONOMY

EMPLOYMENT, CONSUMPTION AND GDP

$$N_t = \sum_{i=1}^{n_{fc}} N_{i,t} + \sum_{j=1}^{n_{fk}} N_{j,t} + \sum_{j=1}^{n_{fk}} N_{r,j,t} \tag{79}$$

$$C_t = \sum_{i=1}^{n_w} C_{w,t} + \sum_{k=1}^{n_k} C_{k,t} + C_{s,t} \tag{80}$$

$$Y_t = C_t + \sum_{j=1}^{n_f k} S_{j,t} \tag{81}$$

NOTATION and PARAMETER VALUES

Table 7: Notation

Description	Symbol
Parameter that aligns debt repayment with capital productive capacity	a
Advances from the Central Bank to the bank system	$advt$
w^{th} worker purchased public bond	$B_{w,t}$
k^{th} capitalist purchased public bond	$B_{k,t}$
Total consumption	C_t
w^{th} worker amount spent in consumption	$C_{w,t}$
k^{th} capitalist amount spent in consumption	$C_{k,t}$
State consumption	$C_{s,t}$
i^{th} consumer industry firm cash	$D_{i,t}$
j^{th} capital industry firm cash	$D_{j,t}$
Bank cash	$D_{b,t}$
Public sector cash	$D_{s,t}$
i^{th} firm annual depreciation (considering different vintages)	$da_{i,t}$
i^{th} firm actual labor productivity growth rate	$deltapr_{i,t}$
w^{th} worker deposits	$Dep_{w,t}$
k^{th} capitalist deposits	$Dep_{k,t}$
i^{th} firm expected output growth rate	g_i^e
i^{th} firm Investment bill	$I_{i,t}$
i^{th} firm installed capital	K_i^{inst}
i^{th} firm installed capital net of depreciation	K_i^{net}
i^{th} firm desired real net capital level	K_i^t
i^{th} firm future real net capital level	K_i^f
i^{th} firm demanded real net capital level	K_i^t
i^{th} firm demanded short debt	$L_{sh,i,t}$
i^{th} firm demanded long debt	$L_{lg,i,t}$
i^{th} firm last period innovation has occurred	$last_{j,t}$
i^{th} firm employment level	$N_{i,t}$
Short-term non performing loans	$NPL_{sh,t}$
Long-term non performing loans	$NPL_{lg,t}$
Number of firms in the capital sector, in the sec^th sector	$n_{fk,sec}$
Number of firms in the capital sector	n_{fk}
Number of firms in the consumption sector	n_{fc}
Number of workers	n_w
Number of capitalists	n_k
Number of capitalists	n_k
i^{th} consumption industry firm price	pcj,t
j^{th} capital industry firm price	pkj,t

Description	Symbol
j^{th} capital industry firm probability of imitation	$pim_{j,t}$
j^{th} capital industry probability of innovation	$pinn_{j,t}$
i^{th} firm actual labor productivity (considering different vintages embodying different labor productivities)	$pr_{i,t}$
j^{th} consumption industry firm labor productivity	$pr_{j,t}$
i^{th} firm demanded output	Q_i^d
w^{th} worker demanded output	$Q_{w,t}^d$
k^{th} capitalist demanded output	$Q_{k,t}^d$
state demanded output	$Q_{s,t}^d$
i^{th} firm expected output	Q_i^e
i^{th} firm production	Q_i
i^{th} firm production	Q_i
Bank reserves hold at the Central Bank	res_t
i^{th} firm long-term debt repayment	$Rcc_{lg,i,t}$
i^{th} firm interest expenses on long-term debt	$Ri_{lg,i,t}$
i^{th} firm installments on long-term debt	$Rtot_{lg,i,t}$
i^{th} firm short-term debt repayment	$Rcc_{sh,i,t}$
i^{th} firm interest expenses on short-term debt	$Ri_{sh,i,t}$
i^{th} firm installments on short-term debt	$Rtot_{sh,i,t}$
j^{th} capital good firm R&D expenses	$RD_{j,t}$
Not-accruing interest transitory deposits for all the unretained profits	$TDep_t$
Total unemployment rate	un_t
k^{th} capitalist profit	$U\pi_{k,t}$
j^{th} capital good firm unretained profits	$U\pi_{j,t}$
i^{th} consumer good firm unretained profits	$U\pi_{i,t}$
Bank unretained profits	$U\pi_{b,t}$
Central bank profits	$U\pi_{cb,t}$
i^{th} firm wage bill	$W_{i,t}$
i^{th} firm nominal wages	$w_{i,t}$
w^{th} worker wage	$w_{w,t}$
w^{th} worker disposable income	$YD_{w,t}$
k^{th} capitalist disposable income	$YD_{k,t}$

Table 8: Benchmark parameters

Description	Symbol	Value
Workers propensities to consume on income	α_{1w}	0.7
Workers propensities to consume on wealth	α_{2w}	0.03
Capitalists propensities to consume on income	α_{1c}	0.7
Capitalists propensities to consume on wealth	α_{2c}	0.03
Fimrs markup	μ	0.2
Bill purchase propensities	λ_0	0.635
Bill purchase propensities function of interests	λ_1	0.4
Bill purchase propensities function of yd/v	λ_2	0.3
Sales expectation correction	β_1	0.4
Sales expectation growth correction	β_2	0.4
Desired level of inventories	d	0.01
Labour productivity in capital sector	pr_{inv}	7
Capital utilization rate	ut	0.8
R&D investment propensity (% over sales)	γ	0.05
Firm search capabilities	τ	0.007
Beta distribution parameters(innovation process)	bb	(3,3)
Products for unit of capital	$ykratio$	2
Units of capital per unit of labour	$klratio$	3.5
Wages elasticity of labor productivity increases	ind	1 or 0
Wages elasticity of employment rate	ph	0.2
Units of capital per unit of labour	$klratio$	3.5
Capital useful life	z	20
Short term debt repayment period	u	1
Interest rate on short term debt	r_{sh}	0.01
Interest rate on short term debt	r_{lg}	0.01
Interest rate on Central Bank reserves	rr_t	0.01
Productivity gains spillovers across all the economy	$spill$	0.01

C Appendix

SOURCE CODE

The following code, through switching mechanisms, reproduces all the versions of the model that have been adopted along the entire thesis.

```
library(ggplot2)
library(DescTools)
library(doParallel)
library(future)
library(Rsolnp)
library(Rlab)
library(dplyr)
library(robustbase)
library(lattice)
library(TTR)
library(gdata)
rm(list=ls(all=TRUE))
start_time <- proc.time()
POP=100
nlavoratorimax=1500
nPeriods=1000
nSector=4
nSectorwage=4
Sectorlux=0
nlayers=3
layersmult=c(3)
nfirmmax=c(120)
MC=20
dk=3
z= 20
u= 1

SHH=0.1
nfirmmaxinv=c(19)
SHinv=1
pesodeltap=c(0,0.55)
deltacambioinv=0
parametromaccheronico_inv=0

conc=1
EQ=0
capmaxgexp=20
TMBS=0
assetbk="YES"
ds=1.1       #1.1.

#SCRITTURE-----------
all=0
for (i in 1 :z) {
all=all+ i/z
```

```
}
#all=1
allr=0

b=0
for (i in 1 :z) {
b= b + (((i^2)+i)/2)/(all*z)
}
cw=1:nSector
time=seq(1:nPeriods)
seqz=t(matrix(c(seq(0,1-1/z,by=1/z)),z,nfirmmax))
color=rainbow(nSector)
'%ni%' <- Negate('%in%')

############SPACE
↪  ALLOCATION##############################################################

alpha2_w=matrix(data=0,nrow=1,ncol=nPeriods)
conscmax=matrix(data=0,nrow=1,ncol=nSector)
conswmax=matrix(data=0,nrow=1,ncol=nSector)
conoscenza=matrix(data=0,nrow=MC,ncol=nPeriods+dk+1)
D_pil=matrix(data=0,nrow=MC,ncol=nPeriods+dk+1)
GDP=matrix(data=0,nrow=MC,ncol=nPeriods+dk+1)
GDP_currentprice=matrix(data=0,nrow=MC,ncol=nPeriods+dk+1)
klratio=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
N=matrix(data=0,nrow=MC,ncol=nPeriods+dk+1)#employment
nSector_attivi=matrix(data=0,nrow=MC,ncol=(nPeriods+dk+1))
npar=c(rep(0,40))
liquidity=matrix(data=0,nrow=MC,ncol=nPeriods+dk+1)
parametro=matrix(data=0,nrow=20,ncol=30)
parametro.frame=data.frame(parametro)
redundant=matrix(data=0,nrow=MC, ncol=nPeriods+dk+1)
residuosaturazione=matrix(data=0,nrow=MC,ncol=nPeriods+dk+1)
r_b=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
r_l_short=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
r_l_long=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
r_d=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
r_r=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
risultati=matrix(data=0,nrow=8,ncol=3)
risultati_c=matrix(data=0,nrow=8,ncol=3)
sett=matrix(data=0,nrow=nSector,ncol=(nPeriods+dk+1))
y=matrix(data=0,nrow=MC,ncol=nPeriods+dk+1)
ykratio=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
prs=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
gesoper=matrix(0,nPeriods,1)
geso=matrix(0,nPeriods,1)
nsus=matrix(0,4,4)


#############PARAMETER
↪  SETTING##########################################################
```

```
ACCELERATORE="YES"
DEFAULT="YESpiùsevero"
entry="YES"
risorse="nonlimitate"
leverage_s="full"
leverage_l="full"
consumo="no"
monopolio=c("NO")
ind=c(0)
tau_suimm=0.001
spill=0.03#0.08
perimit=0.08
esppr=c(3)
PHILIP="NO"
Spillover=c("NO")
PARALLEL="NO"
SUSSIDI=c("NO")
SUSSIDISUL="NO"
maxnumemplo=130
minnumemplo=100
TURNDEFICIT=c("NO")
FUNZIONE="CRESCITAESPONENZIALE"
PRSHOCK=c("NO")
tsh=350
prs[tsh]=1#0.4
RD=c(0.0,0.0,0.0)
RDD=c(0.06)

ind_c=c(1)
ind_cw=0

r_b[2:nPeriods]=0.01
r_l_short=0.01
r_l_long[2:nPeriods]=0.01
r_d[2:nPeriods]=0.01
r_r[2:nPeriods]=0.01

propensensi=matrix(0,1,4)
propensensi[1,]=c(0.7,0.03,0.7,0.03)

payratio="esogeno"
payratio_c=1
lambda0 =0.635
lambda1 =0.4
lambda2 =0.3

percentsus=1
theta=0.2
gesoper[2:nPeriods]=0.000#4
gendoper=0
```

```
geso[]=300
mltpr=0

gmediamobile=10
#MULTIVEDIAMO="YES"
#geso[550:700]=1

if (PHILIP=="YES") {ph=c(1)} else{ph=0}
annind=1
adjex=0.4
beta=0.4
inv=0.0
mu=0.2#c(0, 0.1,0.5,4)
ut= 0.8
prop= 1

coefftec=array(0,c(2,nSector,4))
coefftec[1,1,1]=1     #ykratio
coefftec[1,2,1]=1
coefftec[1,3,1]=1
coefftec[1,4,1]=1
coefftec[2,1,1]=3     #klratio
coefftec[2,2,1]=3
coefftec[2,3,1]=3
coefftec[2,4,1]=3

coefftec[1,1,2]=2.5
coefftec[1,2,2]=2
coefftec[1,3,2]=2
coefftec[1,4,2]=4.5
coefftec[2,1,2]=1
coefftec[2,2,2]=2
coefftec[2,3,2]=2
coefftec[2,4,2]=2

coefftec[1,1,3]=2.5
coefftec[1,2,3]=1
coefftec[1,3,3]=1
coefftec[1,4,3]=1
coefftec[2,1,3]=1
coefftec[2,2,3]=4.21
coefftec[2,3,3]=4.21
coefftec[2,4,3]=4.21

coefftec[1,1,4]=0.01
coefftec[1,2,4]=0.1
coefftec[1,3,4]=0.1
coefftec[1,4,4]=3.5
coefftec[2,1,4]=2.5
coefftec[2,2,4]=2.5
coefftec[2,3,4]=2.5
```

```
coefftec[2,4,4]=2.5

#coefftec=coefftec[,,c(2,3)]
ncombpersensivity=1
prr_inv=3.5

espw=rep(0,nSector)
espc=rep(0,nSector)
espw[1]=1
espc[1]=1

conswmax=matrix(data=0,nrow=1, ncol=nSectorwage)
conscmax=matrix(data=0,nrow=1, ncol=nSectorwage)
conswmax[1:nSector]=rep(1700,nSector)
conscmax[1:nSector]=rep(1700,nSector)
conswwmax=2.5
#conscwmax=c(8000)

tau_suinninv=c(0.0045)

###### MULTIVARIATE ANALYSIS
↪ ##########################################################

contatore=1
parametro.frame[1:length(ind),contatore]=ind
colnames(parametro.frame)[contatore] <- "ind"
npar[contatore]=length(ind)

contatore=contatore + 1
parametro.frame[1:length(monopolio),contatore]=monopolio
colnames(parametro.frame)[contatore] <- "monopolio"
npar[contatore]=length(monopolio)

contatore=contatore + 1
parametro.frame[1:length(PRSHOCK),contatore]=PRSHOCK
colnames(parametro.frame)[contatore] <- "PRSHOCK"
npar[contatore]=length(PRSHOCK)

contatore=contatore + 1
parametro.frame[1:length(ind_c),contatore]=ind_c
colnames(parametro.frame)[contatore] <- "ind_c"
npar[contatore]=length(ind_c)

contatore=contatore + 1
parametro.frame[1:nrow(propensensi),contatore]= 1:nrow(propensensi)
colnames(parametro.frame)[contatore] <- "propensensi"
npar[contatore]=nrow(propensensi)

contatore=contatore + 1
parametro.frame[1:length(esppr),contatore]=esppr
colnames(parametro.frame)[contatore] <- "esppr"
```

```
npar[contatore]=length(essppr)


contatore=contatore + 1
parametro.frame[1:ncombpersensivity,contatore]= 1:ncombpersensivity
colnames(parametro.frame)[contatore] <- "coefftec"
npar[contatore]=ncombpersensivity

contatore=contatore + 1
parametro.frame[1:length(SUSSIDI),contatore]=SUSSIDI
colnames(parametro.frame)[contatore] <- "SUSSIDI"
npar[contatore]=length(SUSSIDI)

contatore=contatore + 1
parametro.frame[1:length(TURNDEFICIT),contatore]=TURNDEFICIT
colnames(parametro.frame)[contatore] <- "TURNDEFICIT"
npar[contatore]=length(TURNDEFICIT)

contatore=contatore + 1
parametro.frame[1:length(mu),contatore]=mu
colnames(parametro.frame)[contatore] <- "mu"
npar[contatore]=length(mu)

contatore=contatore + 1
parametro.frame[1:length(SHH),contatore]=SHH
colnames(parametro.frame)[contatore] <- "SHH"
npar[contatore]=length(SHH)

contatore=contatore + 1
parametro.frame[1:length(nfirmmax),contatore]=nfirmmax
colnames(parametro.frame)[contatore] <- "nfirmmax"
npar[contatore]=length(nfirmmax)

contatore=contatore + 1
parametro.frame[1:length(nfirmmaxinv),contatore]=nfirmmaxinv
colnames(parametro.frame)[contatore] <- "nfirmmaxinv"
npar[contatore]=length(nfirmmaxinv)

contatore=contatore + 1
parametro.frame[1:length(Spillover),contatore]=Spillover
colnames(parametro.frame)[contatore] <- "Spillover"
npar[contatore]=length(Spillover)

contatore=contatore + 1
parametro.frame[1:length(ph),contatore]=ph
colnames(parametro.frame)[contatore] <- "ph"
npar[contatore]=length(ph)

contatore=contatore + 1
parametro.frame[1:length(prr_inv),contatore]=prr_inv
colnames(parametro.frame)[contatore] <- "prr_inv"
```

```
npar[contatore]=length(prr_inv)

contatore=contatore + 1
parametro.frame[1:length(conc),contatore]=conc
colnames(parametro.frame)[contatore] <- "conc"
npar[contatore]=length(conc)

contatore=contatore + 1
parametro.frame[1:length(pesodeltap),contatore]=pesodeltap
colnames(parametro.frame)[contatore] <- "pesodeltap"
npar[contatore]=length(pesodeltap)

contatore=contatore + 1
parametro.frame[1:length(DEFAULT),contatore]=DEFAULT
colnames(parametro.frame)[contatore] <- "DEFAULT"
npar[contatore]=length(DEFAULT)

contatore=contatore + 1
parametro.frame[1:length(entry),contatore]=entry
colnames(parametro.frame)[contatore] <- "entry"
npar[contatore]=length(entry)

contatore=contatore+1
parametro.frame[1:length(RDD),contatore]=RDD
colnames(parametro.frame)[contatore] <- "RDD"
npar[contatore]=length(RDD)

contatore=contatore+1
parametro.frame[1:length(tau_suinninv),contatore]=tau_suinninv
colnames(parametro.frame)[contatore] <- "tau_suinninv"
npar[contatore]=length(tau_suinninv)

contatore=contatore+1
parametro.frame[1:length(r_l_short),contatore]=r_l_short
colnames(parametro.frame)[contatore] <- "r_l_short"
npar[contatore]=length(r_l_short)

contatore=contatore+1
parametro.frame[1:length(conswwmax),contatore]=conswwmax
colnames(parametro.frame)[contatore] <- "conswwmax"
npar[contatore]=length(conswwmax)

ncombination=prod(npar[1:contatore])
parametri=matrix(data=0,nrow=ncombination,ncol=contatore)
colnames(parametri)=colnames(parametro.frame)[1:contatore]
parametri.checambiano=matrix(data=0,nrow=max(npar),ncol=length(which(npar>1
↪ )))
colnames(parametri.checambiano)=colnames(parametro.frame)[which(npar>1)]
parametri.checambiano=parametro.frame[1:max(npar),which(npar>1)]

Storeallmean=array(0, dim=c(ncombination*MC,nPeriods,100))
```

```
parametri[,1]=rep(parametro.frame[1:npar[1],1],1)
for (i in 2:contatore) {
parametri[1:ncombination,i]=rep(parametro.frame[1:npar[i],i],rep(prod(npar[
↪  1:(i-1)]),npar[i]))}
########################################################################
↪  ########################################################################
↪  ######################################################################

#ff=function(ncomb){ #PARALLEL
for(ncomb in 1:ncombination) { #NO PARALLEL

########PARAMETER FOR EACH SIMULATION
↪  ##################################################
ind_c=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="ind_c")])
alpha1_w=propensensi[as.numeric(parametri[ncomb,which(colnames(parametro.fr
↪  ame)=="propensensi")]),1]
alpha2_w=propensensi[as.numeric(parametri[ncomb,which(colnames(parametro.fr
↪  ame)=="propensensi")]),2]
alpha1_c=propensensi[as.numeric(parametri[ncomb,which(colnames(parametro.fr
↪  ame)=="propensensi")]),3]
alpha2_c=propensensi[as.numeric(parametri[ncomb,which(colnames(parametro.fr
↪  ame)=="propensensi")]),4]
PRSHOCK=(parametri[ncomb,which(colnames(parametro.frame)=="PRSHOCK")])
mu=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="mu")])
SUSSIDI=(parametri[ncomb,which(colnames(parametro.frame)=="SUSSIDI")])
TURNDEFICIT=(parametri[ncomb,which(colnames(parametro.frame)=="TURNDEFICIT"
↪  )])
ph=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="ph")])
SH=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="SHH")])
conc=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="conc")])
Spillover=(parametri[ncomb,which(colnames(parametro.frame)=="Spillover")])
monopolio=(parametri[ncomb,which(colnames(parametro.frame)=="monopolio")])
ind=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="ind")])
pesodeltap=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="pes
↪  odeltap")])
entry=parametri[ncomb,which(colnames(parametro.frame)=="entry")]
DEFAULT=parametri[ncomb,which(colnames(parametro.frame)=="DEFAULT")]
tau_suinninv=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="t
↪  au_suinninv")])
conswmax[1:nSector]=as.numeric(parametri[ncomb,which(colnames(parametro.fra
↪  me)=="conswwmax")])
conscmax[1:(nSector)]=as.numeric(parametri[ncomb,which(colnames(parametro.f
↪  rame)=="conswwmax")])
prr_inv=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="prr_in
↪  v")])
RD[2]=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="RDD")])
nfirmmax=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="nfirm
↪  max")])
if(ind==0 & monopolio=="YES" & conswmax[1]==8000) {nfirmmax=32}
nfirmmaxinv=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="nf
↪  irmmaxinv")])
```

```
nCapitalistimax=nfirmmax+nfirmmaxinv+1
esppr=as.numeric(parametri[ncomb,which(colnames(parametro.frame)=="esppr")])
azz=1/SH                    #ri-sample
SHinv=SH

######################################################################
↪ ######################################################################
↪ ####################################################################

for (mc in 1:MC) {

#####SPACE ALLOCATION#################################################
↪ ##########
Defbeforeturning=matrix(0,1,nPeriods)
pfindagare=array(0,dim=c(4,50,nPeriods))
impresakperogniimpresac=array(0,dim=c(nfirmmax,nPeriods))
sussidiaticontrollo=matrix(0,1,nPeriods)

#PRODUCTION SECTOR
payratio_c=matrix(data=payratio_c,nrow=nfirmmax,ncol=nPeriods+dk+1)
aumprod=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
cambiw=array(0,dim=c(nlavoratorimax+nCapitalistimax,nPeriods+dk+1))
cambic=array(0,dim=c(nCapitalistimax,nPeriods+dk+1))
captot=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
convenienzanuovok=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
cu_inv=array(0,dim=c(nfirmmax,nfirmmaxinv,nPeriods+dk+1))
da=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1+z)
D_f_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
D_f_inv=matrix(data=0,nrow=nfirmmaxinv,ncol=nPeriods+dk+1)
dddt=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
default=array(data=0,dim=c(nfirmmax/nSector,nSector,nPeriods+dk+1))#nrow=nf
↪ irmmax,ncol=nPeriods+dk+1)
deltacu_cons=array(data=0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
Deltaq_CAPcapacit=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
deltad=array(data=0,dim=c(nlavoratorimax,nSector))
deltadc=matrix(data=0,nrow=nCapitalistimax,ncol=nSector)
deltakl=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
deltapr_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
dvlavk=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
mediadelta=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Eq_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Eq_inv=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
Egy=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
ERy_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
EqRD=array(data=0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
employpersector=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
firmmatch=array(0,dim=c(nfirmmaxinv,nPeriods+dk+1))
gy=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
indexfinv=array(1:nfirmmaxinv,dim=c(nfirmmaxinv,nPeriods+dk+1))
indexfatt=array(1,dim=c(nfirmmax/nSector,nSector,nPeriods+dk+1))
indexcom=array(1:nfirmmax,dim=c(nfirmmax/nSector,nSector,nPeriods+dk+1))
```

```
klratioinv=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
k_d=array(data=0,dim=c(nfirmmax/nSector,nSector,nPeriods+dk+1))
k=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
klratio=array(data=0,dim=c(nfirmmax/nSector,nSector,nPeriods+dk+1))
klstartnewsect=array(data=0,dim=c(nfirmmax/nSector,nSector))
kt=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
id=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
id_li=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
indexf=array(data=1:nfirmmax,dim=c(nfirmmax/nSector,nSector,nPeriods+dk+1))
inn_inv=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
inn_c=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
interestpayment_short=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1+u)
interestpayment_long=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1+z)
inventories_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
inventories_inv=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
l_short_d=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
l_shortperwage_d=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
inn=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
l_short_dinv=matrix(data=0,nrow=nfirmmaxinv,ncol=nPeriods+dk+1)
l_long_d=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
l_long_d_iniziale=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
lld=matrix(0,nlayers,nPeriods+dk+1)
ncapitspend=matrix(0,1,nPeriods+dk+1)
nricchpositive=matrix(0,1,nPeriods+dk+1)

leverage_long=matrix(data=1,nrow=nfirmmax,ncol=nPeriods+dk+1)
leverage_short=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
maxproducibile=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
mediakl=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
netcapcomp=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
netcapcomppesi=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
netcapcompfut=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
netcapcomppesifut=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
mkl=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
N_cons=array(data=0,dim=c(nfirmmax,nPeriods+dk+1,nlayers))
N_cons_vecc=array(data=0,dim=c(nfirmmax,nPeriods+dk+1,nlayers))
N_inv=array(data=0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
N_research_inn=matrix(data=0,nrow=nfirmmaxinv,ncol=nPeriods+dk+1)
NW_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
NW_inv=matrix(data=0,nrow=nfirmmaxinv,ncol=nPeriods+dk+1)
NWB=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)#
P_f_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
P_f_inv=matrix(data=0,nrow=nfirmmaxinv,ncol=nPeriods+dk+1)
P_f_inv_persector=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
pr_inv=matrix(0,nrow=nSector,ncol=nPeriods+dk+1)
p_inv=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
p_invli=array(data=0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
p_newimpresas=matrix(0,nfirmmax,1)
p_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
p_cons2=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
percentuale=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
```

```
pinn=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
q_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
q_inv=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
q_invt=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
qr_k=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Rcons_s=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Rcons_tot=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Rcons_tot_d=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
DeltaRcons_tot_d=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Rcons_tot_v=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Rcons_tot_dminusv=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
RDspesa=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
RDspesa_c=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
RDspesa_inn=array(data=0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
Rk_inst=array(data=0,dim=c(nfirmmax/nSector,nSector,nPeriods+dk+1))
Rk_inst2=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
Rk_fut=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)#Future capital
Rk=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)#Real stock of capital
Rinventories_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Rinventories_inv=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
s=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
ss=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
servicedebt_short_tot=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1+u)
servicedebt_short_cc=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1+u)
servicedebt_long_tot=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1+z)
servicedebt_long_cc=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1+z)
sett=matrix(data=0,nrow=nSector,ncol=(nPeriods+dk+1))
sommaallocare=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
sommaRk_inst=array(data=0,dim=c(nfirmmax/nSector,nSector,nPeriods+dk+1))
stockdebt_long=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
stockdebt_short=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
storicoRD=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
storicoRD_c=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
ueff=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
UP_f_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
UP_f_inv=matrix(data=0,nrow=nfirmmaxinv,ncol=nPeriods+dk+1)
UC_inv=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
UC_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
un=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
w=matrix(data=10,nrow=1,ncol=nPeriods+dk+1)
w_inv=array(data=0,dim=c(nfirmmaxinv,nSector, nPeriods+dk+1))
w_research=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
Wbd_cons=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Wbd_inv=matrix(data=0,nrow=nfirmmaxinv,ncol=nPeriods+dk+1)
Wbd_g=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
y_inv= array(data=0,dim=c(nfirmmaxinv, nSector,nPeriods+dk+1))
ykratio=array(data=0,dim=c(nfirmmax/nSector,nSector,nPeriods+dk+1))
ykratioinv=array(0,dim=c(nfirmmaxinv,nSector,nPeriods+dk+1))
cambio=matrix(data=0,nrow = nlavoratorimax,ncol=nPeriods)
#pfinvestigare=array(data=0,dim=
↪  c(nfirmmax/nSector*SH*azz,nlavoratorimax,nSector,nPeriods))
```

```
#pfcinvestigare=array(data=0,dim=
↪  c(nfirmmax/nSector*SH*azzc,nCapitalistimax,nSector,nPeriods))
piinvst=matrix(data=0,nrow = nfirmmax,ncol=nPeriods)

#HOUSEHOLDS
b_dc=matrix(data=0,nrow=nCapitalistimax,ncol=nPeriods+dk+1)
b_dw=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
cD_c=matrix(data=0,nrow=nCapitalistimax,ncol=nPeriods+dk+1)
cons_c=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
cons_w=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
cons_tot=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
consumorealeperperson=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
D_w=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
D_c=matrix(data=0,nrow=nCapitalistimax,ncol=nPeriods+dk+1)
potenzialespesa_c=matrix(data=0,nrow=nCapitalistimax,ncol=nPeriods+dk+1)
potenzialespesa_w=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
Rcons_d_w=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
↪  Rcons_w=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Rcons_d_c=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
#Rcons_d_cn=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
Rcons_c=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Rcons_tot_d=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Rcons_tot_v=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
Rcons_tot_dminusv=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
residui=matrix(data=0,nrow=3,ncol=nlavoratorimax)
spperlys=array(data=0,dim=c(nlavoratorimax,nSector,nlayers))
spperlyt=array(data=0,dim=c(nlavoratorimax,nPeriods+dk+1,nlayers))
spperlytys=array(data=0,dim=c(nSector,nlayers,nPeriods+dk+1))
v_c=matrix(data=0,nrow=nCapitalistimax,ncol=nPeriods+dk+1)
v_w=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
yd_c=matrix(data=0,nrow=nCapitalistimax,ncol=nPeriods+dk+1)
yd_w=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
w_c=array(data=0,dim=c(nfirmmax,nPeriods+dk+1,nlayers))

pf=array(data=0,dim=c(nfirmmax/nSector,nlavoratorimax,nSector))
#pfc=array(data=0,dim=c(nfirmmax/nSector*SH*azzc,nCapitalistimax,nSector))
dd=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)

#PERPERSON
b_dperworker=array(data=0,dim=c(nlavoratorimax,nPeriods+dk+1,nlayers))
consumorealedomandatoperlavoratore=array(0, dim=c(nlavoratorimax,nSector))
consumorealeperlavoratoren=matrix(0,
↪  nrow=nlavoratorimax*nlayers,ncol=nSector)
consumorealeperlavoratored=matrix(0,
↪  nrow=nlavoratorimax*nlayers,ncol=nSector)
consumorealeperlavoratore=array(data=0,
↪  dim=c(nlavoratorimax*nlayers,nSector,nPeriods+dk+1))
consumorealepercapitalista=array(data=0,
↪  dim=c(nCapitalistimax,nSector,nPeriods+dk+1))
consumorealepercapitalistan=matrix(0,nrow=nCapitalistimax,ncol=nSector)
consumorealepercapitalistad=matrix(0,nrow=nCapitalistimax,ncol=nSector)
```

```
D_perworker=array(data=0,dim=c(nlavoratorimax,nPeriods+dk+1,nlayers))
potenzialepesaworker=matrix(data=0,nrow=nlavoratorimax*nlayers,ncol=nPeriod
↪  s+dk+1)
spesaperpersonw=array(data=0, dim=c(nlavoratorimax*nlayers,nSector,
↪  nPeriods+dk+1))
spesaperpersonc=array(data=0, dim=c(nCapitalistimax,nSector, nPeriods+dk+1))
spesapercapitalist=array(data=0, dim=c(nCapitalistimax,nSector,
↪  nPeriods+dk+1))
v_perworker=array(data=0,dim=c(nlavoratorimax,nPeriods+dk+1,nlayers))
yd_perworker=array(data=0,dim=c(nlavoratorimax,nPeriods+dk+1,nlayers))
workersemployer=matrix(data=0, nrow=nlavoratorimax,ncol=nPeriods+dk+1)
#GOVERNMENT
b_s=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
D_state=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
Def=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
g=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Gspesainteressi=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
gtot=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
Rg=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
Rg_d=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
tax=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
NWG=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
sussidiati=matrix(data=0,nrow=nlayers,ncol=nPeriods+dk+1)
sussidio=matrix(data=0,nrow=nlayers,ncol=nPeriods+dk+1)
sussidiati_inv=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
sussidio_inv=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)

#BANK SECTOR
advance=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
cumulatononperforming=matrix(0,nrow=1,ncol = nPeriods+dk+1)
D_b=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
l_s=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
nonperformingloan_long=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
nonperformingloan_short=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
riserve=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
P_b=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
UP_b=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
long=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
short=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
long_cc=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)
short_cc=matrix(data=0,nrow=nfirmmax,ncol=nPeriods+dk+1)

#per assets
mediaklbk=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
mediapinvbk=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
q_invtbank=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
q_invtbankcum=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
id_lbk=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
Rk_instbk=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
klratio_bk=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
p_invbk=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
```

```
Rk_bk=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
Rk_bkcontr=matrix(data=0,nrow=nSector,ncol=nPeriods+dk+1)
#CB
b_cb=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
P_cb=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
h_s=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
NWCB=matrix(data=0,nrow=1,ncol=nPeriods+dk+1)
POP=matrix(data=POP,nrow=1,ncol=nPeriods+dk+1)

#DISTRIBUZIONE
ggiinnii=matrix(0,1,nPeriods+dk+1)
top1c=matrix(0,1,nPeriods+dk+1)
top10d=matrix(0,1,nPeriods+dk+1)
mid40d=matrix(0,1,nPeriods+dk+1)
bot50d=matrix(0,1,nPeriods+dk+1)

######STARTING VALUES#####################################################
 ↪  ##############

maxestrinv=((nfirmmaxinv)+1)*SHinv #per banca
for (i in 1:nSector){
ykratioinv[,i,2:(nPeriods+dk)]=coefftec[1,i,as.numeric(parametri[ncomb,whic
 ↪  h(colnames(parametro.frame)=="coefftec")])]
klratioinv[,i,2:(nPeriods+dk)]=coefftec[2,i,as.numeric(parametri[ncomb,whic
 ↪  h(colnames(parametro.frame)=="coefftec")])]
}
ykratio[,,2:(nPeriods+dk)]=rep(ykratioinv[1,,2],each=nfirmmax/nSector)
klratio[,,2:(nPeriods+dk)]=rep(klratioinv[1,,2],each=nfirmmax/nSector)
klstartnewsect[,]=klratio[,,2]

r_l_short[2:nPeriods]=as.numeric(parametri[ncomb,which(colnames(parametro.f
 ↪  rame)=="r_l_short")])

w_c[,(2:nPeriods),]=w[1]
pr_inv[,2]=prr_inv
p_invli[,,] = (1+mu)*(w[2]/pr_inv[,2])/(1-RD[2])
p_inv[,]=p_invli[1,1,2]
Eq_cons[indexf[,1,2],2]=geso[2]/(nfirmmax/nSector)#/nSector)#AA*(40*3)
Rk_inst[,,2]=Eq_cons[,2]/ykratio[,,2]/ut

crescitaprk=0
conswmax[2:nSector]=c(3,3.5,1200000)
conscmax[2:nSector]=c(3,5.5,1200000)

########################################################################
 ↪  ########################################################################
 ↪  ########################################################################
 ↪  ########################################################################
 ↪  ########################################################

#saveRDS(ncomb, file=paste0("./output/",ncomb,"MC",mc,"iniz","comb.rds"))
```

```
for (t in 2:nPeriods){

#### PRODUCTION IN THE CONSUMPTION SECTOR
↪  ###############################################
if(t>3){
Eq_cons[indexf[,,t],t] = round(Eq_cons[indexf[,,t],t-1] +
↪  adjex*(Rcons_tot_d[indexf[,,t],t-1]- Eq_cons[indexf[,,t],t-1]),2)
}else if(t==3){
Eq_cons[indexf[,,t],t]=Rcons_tot_d[indexf[,,t],t-1]}
q_cons[indexf[,,t],t] =round(pmax((pmin(Eq_cons[indexf[,,t],t]*(1+inv) -
↪  Rinventories_cons[indexf[,,t],t-1],(Rk[indexf[,,t],t-1]+Rk_inst[,,t][as⌟
↪  .vector(indexf[,,t])])*ykratio[,,t][as.vector(indexf[,,t])])),0),4)
maxproducibile[indexf[,,t],t]=(Rk[indexf[,,t],t-1]+Rk_inst[,,t][as.vector(i⌟
↪  ndexf[,,t])])*ykratio[,,t][as.vector(indexf[,,t])]
Rcons_s[indexf[,,t],t]=q_cons[indexf[,,t],t]+Rinventories_cons[indexf[,,t],⌟
↪  t-1]

#### INVESTMENTS AND CAPITAL INSTALLATION
↪  ################################################
if(t>3) {gy[indexf[,,t],t-1]=
↪  ifelse(round(Rcons_tot_d[indexf[,,t],t-2],2)>0,(Rcons_tot_d[indexf[,,t]⌟
↪  ,t-1]-Rcons_tot_d[indexf[,,t],t-2])/Rcons_tot_d[indexf[,,t],t-2],0)}
↪  #problema
if(t>4){Egy[indexf[,,t],t]=Egy[indexf[,,t],t-1]+beta*(gy[indexf[,,t],t-1]-E⌟
↪  gy[indexf[,,t],t-1])
}else if(t==4){ Egy[indexf[,,t],t]=gy[indexf[,,t],t-1]}
ERy_cons[indexf[,,t],t+dk] =
↪  Eq_cons[indexf[,,t],t]*(1+inv)*(1+pmin(Egy[indexf[,,t],t],capmaxgexp))
if (ACCELERATORE=="YES"){kt[indexf[,,t],t+dk] = as.vector(ERy_cons[indexf[,⌟
↪  ,t],t+dk]/ykratio[,,t][as.vector(indexf[,,t])]/ut)}

for (i in max(2,t+dk-z+1): (t+dk)){
↪  #Rk_fut[,t+dk]=Rk_inst[,(t+dk-z+1):(t+dk)]%*%seqz} else {
↪  #Rk_fut[,t+dk]=Rk_inst[,1:(t+dk)]%*%seqz[(z-t-dk+1):z]}
Rk_fut[indexf[,,t],t+dk]=Rk_fut[indexf[,,t],t+dk]+as.vector((Rk_inst[,,i][a⌟
↪  s.vector(indexf[,,t])]*(i+z-t-dk)/z))
}
k_d[,,t][as.vector(indexf[,,t])] =pmax(0,kt[indexf[,,t],t+dk]-
↪  Rk_fut[indexf[,,t],t+dk])
Rk_inst[,,(t+dk)][as.vector(indexf[,,t])] = k_d[,,t][as.vector(indexf[,,t])]

####### ENTRY PROCESS
↪  ##################################################################
if (entry=="YES" & length(indexf[,,t+dk][indexf[,,t+dk]>0])<nfirmmax)
↪  {entry_c=rbern(nfirmmax-length(indexf[,,t+dk][indexf[,,t+dk]>0]),conc)
       #& max(sett[,t])<=max(sett[,t:(t+dk+1)])
if (any(entry_c>0)){
ddd=entry_c*which(indexf[,,t+dk]==0)
ddd=ddd[which(ddd>0)]
dddt[1:length(ddd),t+dk]=ddd
```

```
settdalav=as.numeric(names(table(entry_c*which(indexf[,,t+dk]==0,arr.ind=T)⌋
↪  [,2])))
settdalav=settdalav[which(settdalav>0)]
indexf[,,(t+dk)][ddd]= ddd
indexf[,,(t+dk+1):(nPeriods+dk)]=indexf[,,(t+dk)]

for(i in settdalav){   #1:nSector){
ddds=ddd[which(ddd>(nfirmmax/nSector)*(i-1) & ddd<=(nfirmmax/nSector)*i)]
ykratio[,,(t+dk):(nPeriods+dk)][ddds+rep(nfirmmax,length(ddds))*rep(c(0:(nP⌋
↪  eriods+dk-t-dk)),each=length(ddds))] =
↪  mean(ykratio[,i,t+dk])
klratio[,,(t+dk):(nPeriods+dk)][ddds+rep(nfirmmax,length(ddds))*rep(c(0:(nP⌋
↪  eriods+dk-t-dk)),each=length(ddds))] =
↪  min(klratio[,i,t][which(klratio[,i,t]>0)])#mediakl[((nfirmmax/nSector)*⌋
↪  (i-1)+1):(nfirmmax/nSector*i),t]>0)])
Eq_cons[ddds,t+dk-1] = EQ*(unname(quantile(Eq_cons[((nfirmmax/nSector*(i-1)⌋
↪  +1):(nfirmmax/nSector*i)),t][Eq_cons[((nfirmmax/nSector*(i-1)+1):(nfirm⌋
↪  max/nSector*i)),t]>0]))[1]*prop)*(1+adjex)#dovrbbe essere per
↪  settore
if (length(Eq_cons[((nfirmmax/nSector*(i-1)+1):(nfirmmax/nSector*i)),t][Eq_⌋
↪  cons[((nfirmmax/nSector*(i-1)+1):(nfirmmax/nSector*i)),t]>0])==0)
↪  {Eq_cons[ddds,t+dk-1]=0}
} #questo viene cambiato nel matching
Rk_inst[,,(t+dk)][ddd] =
↪  Eq_cons[ddd,t+dk-1]/(1+adjex)/ykratio[,,(t+dk)][ddd]/ut
k_d[,,t][ddd]= Rk_inst[,,(t+dk)][ddd]}}

###### CAPITAL GOODS SOLD BY THE BANKING SECTOR
↪  ##########################################
if (assetbk=="YES"){
if(any(default==1)){
Rk_bk[,t]=rowSums(Rk_instbk)
Rk_bkcontr[,t]=Rk_bkcontr[,t-1]+(Rk_instbk[,t-1])
mediaklbk[,t]=rowSums(klratio_bk*(Rk_instbk/as.vector(rowSums(Rk_instbk[,])⌋
↪  )))
mediaklbk[,t][is.nan(mediaklbk[,t])]=0
mediapinvbk[,t]=rowSums(p_invbk*(Rk_instbk/as.vector(rowSums(Rk_instbk[,]))⌋
↪  ))
mediapinvbk[,t][is.nan(mediapinvbk[,t])]=0
}}

###### MATCHING FOR THE CAPITAL GOOD
↪  ####################################################
firmmatch[t]=length(which(k_d[,,t]>0))
firmmatchpersett=diff(c(0,sapply(1:nSector,function(x)length(which(indexf[,⌋
↪  ,t][which(k_d[,,t]>0)]<=(nfirmmax/nSector*x))))))
#vet=which(k_d[,,t]>0,arr.ind=TRUE)[,2]
vet=ifelse(k_d[,,t]>0,1,0)*rep(1:nSector,each=nfirmmax/nSector)#CAMBIO
vet=vet[vet>0]
```

```
#cu_inv=mapply(function(y,x) nlayers*w_c[y,t,1]*(1+r_l_short[t]/2*(u+1))/(y⌋
↪  kratioinv[,x,t]*klratioinv[,x,t])+p_invli[,x,t]*(1+r_l_long[t]*b)/ykrat⌋
↪  ioinv[,x,t]/ut/a,1:nfirmmax,rep(1:nSector,each=nfirmmax/nSector))
#mincu_inv=apply(cu_inv,2,min)
p_invbk_prmothers=sapply(1:nSector,function(x)unname(quantile(p_invli[,x,t]⌋
↪  ))[4])
#cu_bank=mapply(function(y,x)
↪  nlayers*w_c[y,t,1]*(1+r_l_short[t]/2*(u+1))/(ykratioinv[1,x,t]*mediaklb⌋
↪  k[x,t])+ds*p_invbk_prmothers[x]*(1+r_l_long[t]*b)/ykratioinv[1,x,t]/ut/⌋
↪  a,1:nfirmmax,rep(1:nSector,each=nfirmmax/nSector))
#cu_invwbk=rbind(cu_inv,cu_bank)
indexfinvwbk=c(indexfinv[,t],max(indexfinv[,t])+1)#+100 per identificare
↪  banca
#cu_invwbk[is.infinite(cu_invwbk)]=2000
sampleinv=replicate(firmmatch[t],sample(indexfinvwbk,maxestrinv, replace=F))
ppin=sapply(1:firmmatch[t],function(x)klratioinv[,,t][sampleinv[,x]])
↪  #invece che vet ci va il n impresa
posizioneinv=mapply(function(x)order(as.numeric((ppin[,x])),decreasing="TRU⌋
↪  E"),1:firmmatch[t])
piinv=sampleinv[maxestrinv*((1:firmmatch[t])-1)+posizioneinv[1,]]#trova
↪  azienda k piy conveinente
piinv2=sampleinv[maxestrinv*((1:firmmatch[t])-1)+posizioneinv[2,]] #perchh
↪  in uno ci potrbbe essere banca di mezzo
#piinvst[1:firmmatch[t],t,1]=piinv
#RIMANI=1 RIMANI CON IMPRESA PASSATA
#if (t>2){rimani=rbern(firmmatch[t],1-exp(pmin((-cu_invwbk[(nfirmmaxinv+1)*⌋
↪  ((1:firmmatch[t])-1)+piinv]+cu_invwbk[(nfirmmaxinv+1)*((1:firmmatch[t])⌋
↪  -1)+impresakperogniimpresac[(which(k_d[,,t]>0)),t-1]])/cu_invwbk[(nfirm⌋
↪  maxinv+1)*((1:firmmatch[t])-1)+impresakperogniimpresac[(which(k_d[,,t]>⌋
↪  0)),t-1]]*deltacambioinv,0))) # capire perchh impostato come se fosse
↪  diverso per ogni impresa sotto il cu
if (t>2){rimani=rbern(firmmatch[t],1-parametromaccheronico_inv*exp(pmin((-k⌋
↪  lratioinv[,,t][piinv]+klratioinv[,,t][impresakperogniimpresac[(which(k_⌋
↪  d[,,t]>0)),t-1]])/klratioinv[,,t][impresakperogniimpresac[(which(k_d[,,⌋
↪  t]>0)),t-1]]*deltacambioinv,0))) # capire perchh impostato come se
↪  fosse diverso per ogni impresa sotto il cu
rimani[is.na(rimani)]=0
ace=rbind(piinv,piinv2)
rimani=ifelse(impresakperogniimpresac[(which(k_d[,,t]>0)),t-1]==0,0,rimani)
piinv=(1-rimani)*piinv+(rimani)*impresakperogniimpresac[(which(k_d[,,t]>0))⌋
↪  ,t-1]
#piinv=ifelse(piinv==0,sampleinv[maxestrinv*((1:firmmatch[t])-1)+posizionei⌋
↪  nv[1,]],piinv)
}

if (any((piinv*piinv2)==(max(indexfinv[,t])+1)*(max(indexfinv[,t])+1))=="TR⌋
↪  UE"){
piinv[which(piinv*piinv2==(max(indexfinv[,t])+1)*(max(indexfinv[,t])+1))]=a⌋
↪  ce[1,which(piinv*piinv2==(max(indexfinv[,t])+1)*(max(indexfinv[,t])+1))⌋
↪  ]}
#=ifelse(piinv==piinv2 & piinv2==(max(indexfinv[,t])+1), ace[1,],piinv)
```

```
#piinv=ifelse(piinv==piinv2 & piinv2==(max(indexfinv[,t])+1), ace[2,],piinv)

k_d_dopobk=rep(0,firmmatch[t])
bkcapprimaloop=Rk_bk[,t]

if (any(Rk_bk[,t]>0) & any(piinv==max(indexfinv[,t])+1)){#se banca non ha a
↪  sufficienza? abbiamo salvato solo il primo.
for (i in which(piinv==max(indexfinv[,t])+1)){
if(Rk_bk[vet[i],t]<=0){piinv[i]=piinv2[i]}else{
k_d_dopobk[i]=min(k_d[,,t][which(k_d[,,t]>0)][i],Rk_bk[vet[i],t])
q_invtbank[vet[i],t]=min(k_d[,,t][which(k_d[,,t]>0)][i],Rk_bk[vet[i],t])
#q_invtbank[,t][is.infinite(q_invtbank[,t])]=0
q_invtbankcum[vet[i],t]=q_invtbankcum[vet[i],t]+q_invtbank[vet[i],t]
id_lbk[vet[i],t]=id_lbk[vet[i],t]+q_invtbank[vet[i],t]*ds*p_invbk_prmothers⌋
↪  [vet[i]]#serve per scalare
↪  npl
Rk_bk[vet[i],t]=Rk_bk[vet[i],t] -q_invtbank[vet[i],t]
id[,t][which(k_d[,,t]>0)][i] = id[,t][which(k_d[,,t]>0)][i]+
↪  q_invtbank[vet[i],t]*ds*p_invbk_prmothers[vet[i]]
if(k_d[,,t][which(k_d[,,t]>0)][i]>k_d_dopobk[i]){piinv[i]=piinv2[i]}
}}
Rk_instbk[,2:t]=0
↪  #bksettvenduto=ifelse(bkcapprimaloop-Rk_bk[,t]>0,1,0)*c(1:nSector)
Rk_instbk[,t]=Rk_bk[,t]
Rk_bkcontr[,t]=Rk_bkcontr[,t]-Rk_bk[,t]
#klratio_bk[,2:t]=0
klratio_bk[,t]=mediaklbk[,t]
#p_invbk[,2:t]=0
p_invbk[,t]=mediapinvbk[,t]
}else {piinv[which(piinv==max(indexfinv[,t])+1)]=piinv2[which(piinv==max(in⌋
↪  dexfinv[,t])+1)]}#seleziona i firm match per quelli che ancora devono
↪  prendere il capitale
impresakperogniimpresac[(which(k_d[,,t]>0)),t]=piinv
impresakperogniimpresac[,t:nPeriods]=impresakperogniimpresac[,t]

K_dabk=k_d[,,t][which(k_d[,,t]>0)]-k_d_dopobk
for (i in which(K_dabk>0) ){#FOR CAPITAL GOOD DEMANDS NOT SATISFIED BY THE
↪  BANK
q_invt[piinv[i],vet[i],t]=q_invt[piinv[i],vet[i],t]+K_dabk[i]
q_invt[,,t][is.infinite(q_invt[,,t])]=0
id_li[piinv[i],vet[i],t]=id_li[piinv[i],vet[i],t]+K_dabk[i]*p_invli[piinv[i⌋
↪  ],vet[i],t]
id_li[,,t][is.infinite(id_li[,,t])]=0
p_inv[which(k_d[,,t]>0),t][i]=p_invli[piinv[i],vet[i],t]

#if ( PRSHOCK=="YES" | any(convenienzanuovok==1)) {
klratio[,,(t+dk)][which(k_d[,,t]>0)][i]=klratioinv[piinv[i],vet[i],t]
klratio[,,(t+dk):nPeriods]=klratio[,,(t+dk)]
id[,t][which(k_d[,,t]>0)][i] = id[,t][which(k_d[,,t]>0)][i]+
↪  K_dabk[i]*p_invli[piinv[i],vet[i],t]#id[,t][is.infinite(id[,t])]=0
}
```

```
q_inv[,,t:(t+dk-1)]= q_inv[,,t:(t+dk-1)]+ as.vector(array(q_invt[,,t]/dk,di⌋
↪  m=c(nfirmmaxinv,nSector,dk)))#as.vector per quando dk è
↪  1
q_inv[,,t][is.infinite(q_inv[,,t])]=0
##########################################################################⌋
↪  #######################################################################⌋
↪  ######################################################################

for (i in max(2,t-z+1): t){
Rk[indexf[,,t],t]=Rk[indexf[,,t],t]+Rk_inst[,,i][as.vector(indexf[,,t])]*(i⌋
↪  +z-t-1)/z}
#for (i in max(3,t-z+1): t){
#sommaRk_inst[,,(t)][as.vector(indexf[,,t])]=sommaRk_inst[,,(t)][as.vector(⌋
↪  indexf[,,t])] +
↪  Rk_inst[,,i][as.vector(indexf[,,t])]
#        }  #Rk fine periodo, si può calcolare semplicemente
↪  apply((Rk_inst[,,(t-z):t])/z,3,sum) o piu o meno
rkpervec=matrix(Rk_inst[,,max(2,t-z+1): t],nfirmmax,length(max(2,t-z+1): t))
sommaRk_inst[,,(t)]=apply(rkpervec,1,sum)
pesorkinst=rkpervec/as.vector(sommaRk_inst[,,(t)])


indexfatt[,,t]=ifelse(Rk[,t-1]+Rk_inst[,,t]>0,1,0)
indexcom[,,t]=indexfatt[,,t]*indexf[,,t]
#startedfirm=matrix(data=0,nfirmmax)
#if(spill>0 & RDD>0){if(sum(indexcom[,i,t]-indexcom[,i,t-1])>0
#                                  klratio[,,t]
#                                 ,klstartnewsect)}

for (i in max(2,t-z+1): t){
mediakl[indexcom[,,t],t]=mediakl[indexcom[,,t],t] + Rk_inst[,,i][as.vector(⌋
↪  indexcom[,,t])]*(i+z-t)/z/(Rk[indexcom[,,t],t-1]+Rk_inst[,,t][as.vector⌋
↪  (indexcom[,,t])])*klratio[,,i][as.vector(indexcom[,,t])]}
mediakl[which(mediakl[,t]==0),t]=klratio[,,t][which(mediakl[,t]==0)]

###### WAGE SETTING
↪  ##############################################################
if (PHILIP=="YES" & t>2){
un[t-1]=1-sum(N_cons[,t-1,1])/POP[,t-1]}
deltapr_cons[indexcom[,,t],t]=(mediakl[indexcom[,,t],t]-klratio[,,2][as.vec⌋
↪  tor(indexcom[,,t])])/klratio[,,2][as.vector(indexcom[,,t])]
#if(t>5){mediadelta[,t]=rowMeans(deltapr_cons[,(t-annind):t])}#
w_c[indexcom[,,t],t,]=w[2]*(1+ind*deltapr_cons[indexcom[,,t],t]+ph*(-un[t-1⌋
↪  ]+un[2]))
#if(nlayers>1) {w_c[indexcom[,,t],t,2:nlayers]=t(t(w_c[indexcom[,,t],t,2:nl⌋
↪  ayers])*layersmult[2:nlayers])}
if(ind_c>0|ind_cw>0){
crescitaprk=rep(0,nSector)
dpr=matrix(deltapr_cons[,t],nfirmmax/nSector,nSector)
crescitanelsettore=ifelse(apply(dpr,2,sum)>0,1,0)
for (i in (crescitanelsettore*(1:nSector))){
```

```
crescitaprk[i]=mean (dpr[,i][which(dpr[,i]>0)])
}
if(spill>0){
zerosales=ifelse(sapply(1:nSector, function(x) sum(Rcons_tot[((nfirmmax/nSe⌋
↪  ctor)*(x-1)+1):((nfirmmax/nSector)*x),1:t]))>0,0,1)
crescitaprk=(crescitaprk)+zerosales*sapply(1:nSector, function(x)
↪  mean((klratioinv[,x,t]-klratio[,x,2])/klratio[,x,2]))}
}

pr_inv[,t]=pr_inv[,2]*(1+crescitaprk*ind_c)
w_inv[,,t]=w[2]*(1+ph*(-un[t-1]+un[2]))*(1+ind_cw*crescitaprk)
w_research[t]=w[2]*(1+ph*(-un[t-1]+un[2])+ind*mean(colMeans(matrix(data=del⌋
↪  tapr_cons[,t],nfirmmax/nSector,nSector))))

###### EMPLOYMENT
↪  ##########################################################################
N_cons[indexcom[,,t],t,1]= q_cons[indexcom[,,t],t]/as.vector(ykratio[,,t][a⌋
↪  s.vector(indexcom[,,t])]*mediakl[indexcom[,,t],t]) #ora ho diversi
↪  macchinari con diversi kl anche sul prezzo problema   #problema nan
if (SUSSIDI=="YES" & t>2 & any(round(mediakl[indexcom[,,t],t-1],6)<round(me⌋
↪  diakl[indexcom[,,t],t],6))=="TRUE")
↪  {
N_cons_vecc[indexcom[,,t],t,1]=
↪  q_cons[indexcom[,,t],t]/as.vector(ykratio[,,t][as.vector(indexcom[,,t])⌋
↪  ]*pmin(mediakl[indexcom[,,t],t-1],mediakl[indexcom[,,t],t])) #ora ho
↪  diversi macchinari con diversi kl anche sul prezzo problema   #problema
↪  nan
#if (sum(N_cons_vecc[indexcom[,,t],t,1]-N_cons[indexcom[,,t],t,1])>0){
#impaumpr=(mediakl[indexcom[,,t],t-1][which(mediakl[indexcom[,,t],t-1]>0)]<⌋
↪  mediakl[indexcom[,,t],t][which(mediakl[indexcom[,,t],t-1]>0)])*1
#sussidiaticontrollo[,t]=sum(N_cons[indexcom[,,t],t,1]-N_cons_vecc[indexcom⌋
↪  [,,t],t,1])
#sussidiati[,t]=sussidiati[,t-1]+(-sum(N_cons[indexcom[,,t],t,1]-N_cons_vec⌋
↪  c[indexcom[,,t],t,1]))*4.7177
#-sum((+q_cons[indexcom[,,t],t]-q_cons[indexcom[,,t],t-1])/mediakl[indexcom⌋
↪  [,,t],t-1]))/layersmult
#if (monopolio == "YES"){sussidiati[,t]=sussidiati[,t-1]+(-sum(N_cons[index⌋
↪  com[,,t],t,1]-N_cons_vecc[indexcom[,,t],t,1]))*nsus[2]}else
↪  if(ind==0){sussidiati[,t]=sussidiati[,t-1]+(-sum(N_cons[indexcom[,,t],t⌋
↪  ,1]-N_cons_vecc[indexcom[,,t],t,1]))*nsus[4]}else
↪  if(ind==1){sussidiati[,t]=sussidiati[,t-1]+(-sum(N_cons[indexcom[,,t],t⌋
↪  ,1]-N_cons_vecc[indexcom[,,t],t,1]))*nsus[3]}#1.05--4.7177-
sussidiati[,t]=sussidiati[,t-1]+(-sum(N_cons[indexcom[,,t],t,1]-N_cons_vecc⌋
↪  [indexcom[,,t],t,1]))
sussidiati[,t]=pmax(sussidiati[,t],0)

pesinegativo=(N_cons_vecc[indexcom[,,t],t,1]-N_cons[indexcom[,,t],t,1])/sum⌋
↪  (N_cons_vecc[indexcom[,,t],t,1]-N_cons[indexcom[,,t],t,1])
sussidio[,t]=sum(w_c[indexcom[,,t],t,1]*pesinegativo)*layersmult*percentsus⌋
↪  }#w_c[indexcom[,,t],t-1,1]*pesinegativo
if(nlayers>1) {N_cons[indexcom[,,t],t,2:nlayers]=N_cons[indexcom[,,t],t,1]
```

```
N_cons[indexcom[,,t],t,2:nlayers]=
 ↪  t(t(N_cons[indexcom[,,t],t,2:nlayers])/layersmult[2:nlayers])}
Wbd_cons[,t]= diag((N_cons[,t,])%*%t(w_c[,t,]))

###### LOANS
 ↪  ########################################################################
l_short_d[indexf[,,t],t]=abs(pmin(D_f_cons[indexf[,,t],t-1],0)) #sarebbe
 ↪  meglio differenziare
D_f_cons[indexf[,,t],t]=D_f_cons[indexf[,,t],t-1] +l_short_d[indexf[,,t],t]

#if (t>15 & risorse=="limitate") {
#  N_cons[indexcom[,,t],t]= pmin(q_cons[indexcom[,,t],t]/as.vector(ykratio[
 ↪  ,,t][as.vector(indexcom[,,t])]*mediakl[indexcom[,,t],t]),1.2*D_f_cons[i
 ↪  ndexcom[,,t],t]/w_c[indexcom[,,t],t]) #ora ho diversi macchinari con
 ↪  diversi kl anche sul prezzo problema   #problema nan
#  Wbd_cons[indexcom[,,t],t]= w_c[,t][indexcom[,,t]]*N_cons[indexcom[,,t],t]
#}
leverage_short[indexf[,,t],t]= if (leverage_s=="effettivo") {ifelse
 ↪  (Wbd_cons[indexf[,,t],t]>0,pmax(Wbd_cons[indexf[,,t],t] -
 ↪  D_f_cons[indexf[,,t],t],0)/Wbd_cons[indexf[,,t],t],0)} else{1}
l_shortperwage_d[indexf[,,t],t]=Wbd_cons[indexf[,,t],t]
l_short_d[indexf[,,t],t]=l_short_d[indexf[,,t],t] +
 ↪  l_shortperwage_d[indexf[,,t],t]
D_f_cons[indexf[,,t],t]= D_f_cons[indexf[,,t],t] - Wbd_cons[indexf[,,t],t]
 ↪  + l_shortperwage_d[indexf[,,t],t]

#l_long_d[,t]=pmax(id[,t]- D_f_cons[,t],0)  #qui non hai problema ma sullo
 ↪  short, per calcolo del leverag, potresti avere che stai caricando anche
 ↪  passate casse negative
l_long_d[,t]=id[,t]
D_f_cons[indexf[,,t],t]= D_f_cons[indexf[,,t],t] - id[indexf[,,t],t] +
 ↪  l_long_d[indexf[,,t],t]
leverage_long[indexf[,,t],t+dk]=if (leverage_l=="effettivo") {ifelse
 ↪  (id[indexf[,,t],t]>0,l_long_d[indexf[,,t],t]/id[indexf[,,t],t],0)}
 ↪  else{1}

for (i in 1:u){#rata variabile
servicedebt_short_cc[indexf[,,t],t+i-1]=servicedebt_short_cc[indexf[,,t],t+
 ↪  i-1]+l_short_d[indexf[,,t],t]*1/u
interestpayment_short[indexf[,,t],t+i-1]=interestpayment_short[indexf[,,t],
 ↪  t+i-1]+
 ↪  l_short_d[indexf[,,t],t]*(u-i+1)/u*(r_l_short[t])
}
servicedebt_short_tot[indexf[,,t],t]=
 ↪  servicedebt_short_cc[indexf[,,t],t]+interestpayment_short[indexf[,,t],t]
for (i in 1:z){ #rata constante
servicedebt_long_tot[,t+dk+i-1]=servicedebt_long_tot[,t+dk+i-1]+l_long_d[,t
 ↪  ]*(1+r_l_long[t]*b)*((z+1-i)+allr*(-z+i))/z/all
servicedebt_long_cc[,t+dk+i-1]=servicedebt_long_cc[,t+dk+i-1]+l_long_d[,t]*
 ↪  ((z+1-i)+allr*(-z+i))/z/all
}
```

```
interestpayment_long[,t]=servicedebt_long_tot[,t]-servicedebt_long_cc[,t]

###### DEPRECIATION
↪  ###################################################################-
if(t>=dk+2){
for (i in 1:z){
da[indexcom[,,t],(t+i-1)]=da[indexcom[,,t],(t+i-1)]+as.vector(Rk_inst[,,t][⌟
↪  as.vector(indexcom[,,t])]*p_inv[,(t-dk)][indexcom[,,t]])*(1+r_l_long[(t⌟
↪  -dk)]*b*leverage_long[indexcom[,,t],t])*((z-i+1)+allr*(-z+i))/z/all
}}


##### PRICE SETTING
↪  ######################################################################
#p_cons[indexcom[,,t],t]  = (1+mu)*(nlayers*(w_c[,t,1])[as.vector(indexcom[⌟
↪  ,,t])]*(1+r_l_short[t]/2*(u+1)*leverage_short[indexcom[,,t],t])/as.vect⌟
↪  or(ykratio[,,t][as.vector(indexcom[,,t])]*mediakl[indexcom[,,t],t]) +
↪  da[indexcom[,,t],t]/(Rk_inst[,,t][as.vector(indexcom[,,t])]+Rk[indexcom⌟
↪  [,,t],t-1])/ykratio[,,t][as.vector(indexcom[,,t])]/ut)
mediap_inv=diag(p_inv[indexcom[,,t],max(2,t-z+1):
↪  t]%*%t(pesorkinst[indexcom[,,t],]))
if(length(which(indexcom[,,t]>0))==1){mediap_inv=sum(p_inv[indexcom[,,t],ma⌟
↪  x(2,t-z+1):
↪  t]*pesorkinst[indexcom[,,t],])}
p_cons[indexcom[,,t],t] = (1+mu)*(nlayers*(w_c[,t,1])[as.vector(indexcom[,,⌟
↪  t])]*(1+r_l_short[t]/2*(u+1)*leverage_short[indexcom[,,t],t])/as.vector⌟
↪  (ykratio[,,t][as.vector(indexcom[,,t])]*mediakl[indexcom[,,t],t]) +
↪  mediap_inv*1/all/ykratio[,,t][as.vector(indexcom[,,t])]/ut)
if (t>=(z+2)& monopolio=="YES") {p_cons[indexcom[,,t],t]=
↪  (1+mu)*(nlayers*(w_c[,t,1])[as.vector(indexcom[,,t])]*(1+r_l_short[t]/2⌟
↪  *(u+1)*leverage_short[indexcom[,,t],t])/as.vector(ykratio[,,t][as.vecto⌟
↪  r(indexcom[,,t])]*klstartnewsect[as.vector(indexcom[,,t])]) +
↪  mediap_inv*1/all/ykratio[,,t][as.vector(indexcom[,,t])]/ut)}

#### CAPITAL GOOD SECTOR
↪  ###############################################################
y_inv[,,t]=q_inv[,,t]*p_invli[,,t]
RDspesa_inn[,,t]=y_inv[,,t-1]*RD[2]
storicoRD[,,t]=storicoRD[,,t-1] + RDspesa_inn[,,t]
probabilita=(1-exp(-tau_suinninv*storicoRD[,,t]))
probabilita=probabilita^esppr
inn_inv[,,t]=rbern(nSector*nfirmmaxinv,probabilita)
deltakl[,,t]=((rbeta(nSector*nfirmmaxinv,3,3)*0.5-0.25))
#deltakl[,,t]=((rbeta(nSector*nfirmmaxinv,2+pmax(pmin(4,(1+probabilita)^250⌟
↪  -15),-1.8),3-pmin(2.98,(1+probabilita)^250-15))*0.6-0.3))#*0.6-0.3
↪  #*0.2-0.1per severità rbeta(nSector,3,3)*0.5-0.1VA MAX 0.1 A MIN -0.1
aumprod[,,t]=ifelse(RDspesa_inn[,,t]>0 & deltakl[,,t]>0 &
↪  inn_inv[,,t]==1,1,0)
if (any(aumprod[,,t]==1)){
convenienzanuovok[,,t]=ifelse(aumprod[,,(t)]==1,1,0)
storicoRD[,,t][which(convenienzanuovok[,,t]==1)]=0
```

```
p_invli[,,t]=((1+mu)*(w_inv[,,t]/rep(pr_inv[,t],each=nfirmmaxinv)))/(1-RD[2
↪  ])
p_invli[,,(t):nPeriods]=p_invli[,,t]
if(FUNZIONE=="CRESCITALINEARE"){klratioinv[,,(t)]=ifelse(convenienzanuovok[
↪  ,,t]==1,klratioinv[,,t]+(deltakl[,,t]),klratioinv[,,t])}
else if (FUNZIONE=="CRESCITAZERO"){klratioinv[,,(t)]=ifelse(convenienzanuov
↪  ok[,,t]==1,klratioinv[,,t]+(deltakl[,,t]),klratioinv[,,t])}
else if (FUNZIONE=="CRESCITAESPONENZIALE"){klratioinv[,,(t)]=ifelse(conveni
↪  enzanuovok[,,t]==1,klratioinv[,,t]*(1+(deltakl[,,t])),klratioinv[,,t])}}

imit_inv=probabilita
klratioinv[,,(t)]=
↪  klratioinv[,,(t)]+(max(klratioinv[,,(t)])-klratioinv[,,(t)])*spill
klratioinv[,,(t)]=
↪  klratioinv[,,(t)]*abs(imit_inv-1)+imit_inv*sapply(1:nSector,
↪  function(x) klratioinv[,x,(t)]+(max(klratioinv[,x,(t)])-klratioinv[,x,(
↪  t)])*perimit)
↪  #max(klratioinv[,x,(t)])),each=nfirmmaxinv)
klratioinv[,,(t):nPeriods]=klratioinv[,,t]

#if (PRSHOCK=="YES" & t>=tsh){klratioinv[,,(t)]=klratioinv[,,t]*(1+(prs[t]))
#klratioinv[,,(t):nPeriods]=klratioinv[,,t]
#p_invli[,,t]=((1+mu)*(w_inv[,,t]/rep(pr_inv[,t],each=nfirmmaxinv)))
#p_invli[,,(t):nPeriods]=p_invli[,,t]}

N_research_inn[,t]=rowSums(RDspesa_inn[,,t])/w_research[t]
N_inv[,,t]=(q_inv[,,t])/rep(pr_inv[,t],each=nfirmmaxinv)
#N_invpersettore=q_inv[,,t]/rep(pr_inv[,t],each=nfirmmaxinv)

#if (SUSSIDI=="YES" &(t>tsh) & any(pr_inv[,t-1]<pr_inv[,t])) {N_inv_vecc=
↪  q_inv[,,t]/rep(pmin(pr_inv[,t-1],pr_inv[,t]),each=nfirmmaxinv)
#  sussidiati_inv[,t]=sussidiati_inv[,t-1]+(-colSums(N_inv[,,t]-N_inv_vecc)
↪  )#-colSums((+q_inv[,,t]-q_inv[,,t])/pr_inv[,t-1])
#  sussidiati_inv[,t]=pmax(sussidiati_inv[,t],0)
#  pesinegativo_inv=(N_inv_vecc-N_inv[,,t])/rep(colSums(N_inv_vecc-N_inv[,,
↪  t]),each=nfirmmaxinv)#non serve perchè il salario di ogni azienda è lo
↪  stesso nel settore capitale
#  sussidio_inv[,t]=ifelse(is.nan(colSums(w_inv[,,t]*pesinegativo_inv)*perc
↪  entsus)=="FALSE",colSums(w_inv[,,t]*pesinegativo_inv)*percentsus,0)}

Wbd_inv[,t]= rowSums(w_inv[,,t]*N_inv[,,t])
#anche inventories devono essere differenziate? ad oggi non serve a granche
D_f_inv[,t]= D_f_inv[,t-1] + rowSums(id_li[,,t]) - l_short_dinv[,t-1]
l_short_dinv[,t]=pmax( Wbd_inv[,t] + N_research_inn[,t]*w_research[t] -
↪  D_f_inv[,t],0)
D_f_inv[,t]=D_f_inv[,t] - (Wbd_inv[,t]) - N_research_inn[,t]*w_research[t]
↪  + l_short_dinv[,t]

##### GOVERNMENT SECTOR
↪  ################################################################
```

```
captot[t]= sum((Rk[indexf[,,t],t-1]+Rk_inst[,,t][as.vector(indexf[,,t])])*y⌟
↪  kratio[,,t][as.vector(indexf[,,t])])

Rg_d[indexcom[,,t],t]=geso[2]*Rcons_s[indexcom[,,t],t]/sum(Rcons_s[indexcom⌟
↪  [,,t],t])/p_cons[indexcom[,,t],t]
if(t<5){Rg_d[indexcom[,,t],t]=geso[2]*(1+deltapr_cons[indexcom[,,t],t])/p_c⌟
↪  ons[1,2]*((Rk[indexcom[,,t],t-1]+Rk_inst[,,t][as.vector(indexcom[,,t])]⌟
↪  )*ykratio[,,t][as.vector(indexcom[,,t])])/captot[t]}

#if (MULTIVEDIAMO=="YES" & t>500) {Rg_d[1,t]=0
#Rg_d[2,t]=(geso[t])/p_cons[1,2]}
Rg[indexcom[,,t],t]=pmin(Rg_d[indexcom[,,t],t], Rcons_s[indexcom[,,t],t])
Rcons_s[indexcom[,,t],t]=Rcons_s[indexcom[,,t],t]-Rg[indexcom[,,t],t]

##### HOUSEHOLD SECTOR
↪  ####################################################################
N[mc,t]=sum((N_cons[indexf[,,t],t,]))+sum(N_research_inn[,t]) +
↪  sum(N_inv[,,t])# tutti questi allocati alla ricerca non devono essere
↪  tracciati per le aziende??
employpersector[,t]=sapply(1:nSector, function (x) sum(ceiling(N_cons[(1+(x⌟
↪  -1)*nfirmmax/nSector):(x*nfirmmax/nSector),t,1])))
#numemplo=max(min(mean(tail(N[mc,],1)),maxnumemplo),minnumemplo)
numemplo=maxnumemplo-N[mc,t]
if (SUSSIDISUL=="YES" & t>60 & (numemplo>0)){#t<(tsh+100) &
sussidiati[,t]=(numemplo/alpha1_w)*(1+(numemplo/maxnumemplo))^2#min(t-61,7)
sussidio[,t]= mean(w_c[,2,1]*percentsus)#w_c[,2,1]#(t-40):t
}

floorN=matrix(floor((N_cons[,t,])),length(floor((N_cons[,t,]))),nlayers)
capN=matrix(ceiling((N_cons[,t,])),length(ceiling((N_cons[,t,]))),nlayers)
floorNINV=floor((N_inv[,,t]))
capNINV=ceiling((N_inv[,,t]))
floorNresearch=floor(sum(N_research_inn[,t]))
capNresearch=ceiling(sum(N_research_inn[,t]))

if(sum(N_cons[,t,])>0){
for (i in 1:nlayers) {
sapplyconsumo=sapply((1:nfirmmax)[indexf[,,t]], function(x) c(rep(w_c[,t,i]⌟
↪  [x],floorN[x,i]),rep(w_c[,t,i][x]*(N_cons[,t,i][x]-floorN[x,i]),ceiling⌟
↪  (N_cons[,t,i][x]-floorN[x,i])),rep(0,max(capN[,i])-capN[x,i])))
yd_perworker[1:sum(capN[,i]),t,i]=sapplyconsumo[which((sapplyconsumo)>0)]}}

if (any(sussidiati[,t]>0)){
for (i in 1:nlayers) { #devo mette solo il settore che ha innovazione
if (floor(sussidiati[i,t])>0)
↪  {yd_perworker[first(which(yd_perworker[,t,i]==0)):(first(which(yd_perwo⌟
↪  rker[,t,i]==0))+floor(sussidiati[i,t])-1),t,i]=sussidio[i,t]}
if (floor(sussidiati[i,t])>=0) {yd_perworker[first(which(yd_perworker[,t,i]⌟
↪  ==0)),t,i]=sussidio[i,t]*(sussidiati[i,t]-floor(sussidiati[i,t]))}
}}
```

```
for( i in 1:nSector){
if (any(capNINV[,i]>0)) {
dvlavk[i,t]=first(which(yd_perworker[,t,1]==0))
sapplyinv=sapply((1:nfirmmaxinv), function(x) c(rep(w_inv[,i,t][x],floorNINV[x,i]),rep(w_inv[,i,t][x]*(N_inv[,i,t][x]-floorNINV[x,i]),capNINV[x,i]-floorNINV[x,i]),rep(0,max(capNINV[,i])-capNINV[x,i])))
yd_perworker[first(which(yd_perworker[,t,1]==0)):(first(which(yd_perworker[,t,1]==0))+sum(capNINV[,i])-1),t,1]=sapplyinv[which(sapplyinv>0)]
}
if ((sussidiati_inv[i,t]>0)){
if (floor(sussidiati_inv[i,t])>0) {yd_perworker[first(which(yd_perworker[,t,1]==0)):(first(which(yd_perworker[,t,1]==0))+floor(sussidiati_inv[i,t])-1),t,1]=sussidio_inv[i,t]}
if (floor(sussidiati_inv[i,t])>=0) {yd_perworker[first(which(yd_perworker[,t,1]==0)),t,1]=sussidio_inv[i,t]*(sussidiati_inv[i,t]-floor(sussidiati_inv[i,t]))}
}}

if (capNresearch>0) {
if (floorNresearch>0) {yd_perworker[first(which(yd_perworker[,t,1]==0)):(first(which(yd_perworker[,t,1]==0))+floorNresearch-1),t,1]=w_research[t]}
yd_perworker[first(which(yd_perworker[,t,1]==0)),t,1]=w_research[t]*(sum(N_research_inn[,t])-floorNresearch)}

yd_perworker[,t,]= (yd_perworker[,t,]+r_b[t]*b_dperworker[,t-1,]+r_d[t]*D_perworker[,t-1,])*(1-theta)

yd_w[t] = (yd_w[t]+sum(Wbd_cons[,t])+sum(Wbd_inv[,t])+sum(N_research_inn[,t]*w_research[t])+sum(RDspesa_c[,t])+r_b[t]*b_dw[t-1]+r_d[t]*D_w[t-1]+sussidiati[,t]%*%sussidio[,t]+sussidiati_inv[,t]%*%sussidio_inv[,t])*(1-theta)      #yd_w[t]per gestire capitale iniziale
yd_c[,t]= cD_c[,t-1]+(r_b[t]*b_dc[,t-1]+r_d[t]*D_c[,t-1])*(1-theta)#-(RDspesa_c[,t])
tax[t]  = (yd_w[t]/(1-theta))*theta+(r_b[t]*(sum(b_dc[,t-1]))+r_d[t]*(sum(D_c[,t-1])))*theta

#Consumption workers and capitalist
spendibile=(t(t(v_perworker[,t-1,])*alpha2_w)) + t((t(yd_perworker[,t,])*alpha1_w))
lld[,t]=sapply(1:nlayers,function(x) length(which(spendibile[,x]>0))) # ti dice quanti spendono di primo layer (con sussidiati e inv e resear) e quanti di secondo e quanti di terzo layer
spendibile=spendibile[which(spendibile>0)] #vorrei fare andare prima il primo settore
potenzialepesaworker[1:length(spendibile),t]=spendibile #sono tutti in riga tutti i lavoratori top managers settore k....
potenzialespesa_w[t]=sum(spendibile)

#Consumption capitalist
```

```
potenzialespesa_c[,t]=alpha1_c*yd_c[,t] + alpha2_c*v_c[,t-1]
ncapitspend[,t]=length(which(potenzialespesa_c[,t]>0))

##########MATCHING FOR
↪  CONSUMPTION###########################################################
lav=length(spendibile)
dd[t]=lav+ncapitspend[,t]

p_newimpresas[]=0
p_newimpresas[indexf[,,t]]=(1+mu)*(nlayers*(w_c[,t,1])[as.vector(indexf
↪  [,,t])]*(1+r_l_short[t]/2*(u+1)*leverage_short[indexf
↪  [,,t],t])/as.vector(ykratio[,,t][as.vector(indexf
↪  [,,t])]*klratio[,,t][as.vector(indexf [,,t])]))
p_newimpresas[which(indexcom[,,t]>0)]=0

maxestr=pmin(rep(nfirmmax/nSector*SH*azz,nSector),sapply(1:nSector,function ⌋
↪  (x)length(indexf [,x,t][which(indexf
↪  [,x,t]>0)])))
consumorealepercapitalistan[]=0
consumorealeperlavoratored[]=0
consumorealeperlavoratoren[]=0

settatt=sapply(1:nSector, function(x) any(indexf [,x,t]>0)*x)
if(t==2){settatt[2]=2}
sample=vapply((1:nSector),function(x)replicate(dd[t],c(sample(indexf
↪  [,x,t][which(indexf [,x,t]>0)],maxestr[x],
↪  replace=F),rep(0,nfirmmax/nSector*SH*azz-maxestr[x]))),matrix(data=0,nr ⌋
↪  ow=nfirmmax/nSector*SH*azz,ncol=dd[t]))
if(any(maxestr==1)){
for(i in which(maxestr==1)){sample[1,,i]=indexf [,i,t][which(indexf
↪  [,i,t]>0)]}
}
sample=vapply(1:azz,function(x)sample[seq(nfirmmax/nSector*SH*(x-1)+1,nfirm ⌋
↪  max/nSector*SH*x),,],array(0,dim=c(nfirmmax/nSector*SH,dd[t],nSector)))
pp=apply(sample,c(1,2,3,4),function(x)p_cons[x,t]+p_newimpresas[x])
posizione=array(data=(mapply(function(x,y,z)order(as.numeric((pp[,x,y,z]))) ⌋
↪  ,1:dd[t],rep(1:nSector,each=dd[t]),rep(1:azz,each=dd[t]*nSector))),dim= ⌋
↪  c(nfirmmax/nSector*SH,dd[t],nSector,azz))#sample[(mapply(function(x,y)o ⌋
↪  rder(pp[,x,y]),1:dd[t],rep(1:nSector,each=dd[t])))]#dv ordinare
↪  ancora
pi=array(data=mapply(function(x,y,z)sample[,x,y,z][(posizione[,x,y,z])],1:d ⌋
↪  d[t],rep(1:nSector,each=dd[t]),rep(1:azz,each=dd[t]*nSector)),dim=c(nfi ⌋
↪  rmmax/nSector*SH,dd[t],nSector,azz))
pi=array(mapply(function(x,y) pi[,x,y,],1:dd[t],rep(1:nSector,each=dd[t])), ⌋
↪  dim=c(nfirmmax/nSector*SH*azz,dd[t],nSector))
testpi=pi

if (t>2) {
if(any(default[,,t-1]==1)){
```

```
pf[,1:min(dd[t-1],dd[t]),][rep((which((pf[1,1:min(dd[t-1],dd[t]),])%in%(which(default[,,t-1]==1)))*nfirmmax/nSector*SH*azz),each=nfirmmax/nSector*SH*azz)+c((-nfirmmax/nSector*SH*azz+1):0)]=pi[,1:min(dd[t-1],dd[t]),][rep((which((pf[1,1:min(dd[t-1],dd[t]),])%in%(which(default[,,t-1]==1)))*nfirmmax/nSector*SH*azz),each=nfirmmax/nSector*SH*azz)+c((-nfirmmax/nSector*SH*azz+1):0)]#se in default il primo cambio tutta la sequenza
pf[,1:min(dd[t-1],dd[t]),][which(pf[,1:min(dd[t-1],dd[t]),]%in%azdef==TRUE)]=0
}
testpf=pf[,1:min(dd[t-1],dd[t]),]
settoririmastizeri=sapply(1:nSector,function(x)(any(pf[1:(maxestr)[x],1:min(dd[t-1],dd[t]),x]==0)))
if(any(settoririmastizeri=="TRUE")){
zeris=rep(0,nSector-1)
for (i in (settoririmastizeri*cw)[which(settoririmastizeri*cw>0)]){ #a prescindere dai rientri
zeri=as.data.frame(cbind(which(ifelse(pf[1:(maxestr)[i],1:min(dd[t-1],dd[t]),i]==0,1,0)==1,arr.ind=T),i))#(pf[1:min((maxestr)[i],2),1:min(dd[t-1],dd[t]),i]==0,1,0)==1,arr.ind=T),i))
zeris=rbind(zeris,zeri)}
zeris=zeris[2:nrow(zeris),]
testmapply=mapply(function(x,y,z)((testpi[1:maxestr[z],y,z]%ni%testpf[1:maxestr[z],y,z]*testpi[1:maxestr[z],y,z])[which(testpi[1:maxestr[z],y,z]%ni%testpf[1:maxestr[z],y,z]*testpi[1:maxestr[z],y,z]>0)])[which(zeris[zeris$i==z & zeris$col==y,1]==x)],zeris[,1],zeris[,2],zeris[,3])
pf[1:max(maxestr),1:min(dd[t-1],dd[t]),][(zeris[,3]-1)*max(maxestr)*min(dd[t-1],dd[t])+(zeris[,2]-1)*max(maxestr)+zeris[,1]]=testmapply

for (i in ((maxestr<nfirmmax/nSector*SH*azz)*cw)[which((maxestr<nfirmmax/nSector*SH*azz)*cw>0)]){pf[(maxestr[i]+1):(nfirmmax/nSector*SH*azz),1:min(dd[t-1],dd[t]),i]=0}}

cambio=array(rbern(min(dd[t-1],dd[t])*nSector,1-exp(-pmax(((-(p_cons[pi[1,1:min(dd[t-1],dd[t]),],t]+p_newimpresas[pi[1,1:min(dd[t-1],dd[t]),]])+p_cons[pf[1,1:min(dd[t-1],dd[t]),],t])/p_cons[pf[1,1:min(dd[t-1],dd[t]),],t])*pesodeltap,0))),dim=c(min(dd[t-1],dd[t]),nSector))#qunado dd si contrae problema. in t sample più piccolo
cambio[is.na(cambio)]=0
vederecambio=0
vederecambio=c(vederecambio,ifelse(any(cambio==1),1,0))
if(any(cambio==1)){cambiw[1:(length(which(cambio==1))),t]=which(cambio==1,arr.ind=T)[1]}
pi[,1:min(dd[t-1],dd[t]),]=mapply(function(x,y)cambio[x,y]*pi[,x,y]+ abs((cambio[x,y]-1))*pf[,x,y],1:min(dd[t-1],dd[t]),rep(1:nSector,each=min(dd[t-1],dd[t])))
pf=pi
}else{pf=pi}
#pfindagare[1:4,1:40,t]=pi[1:4,1:40,1]
#testcambio=cbind(testcambio,pf[1,1:3,1])
```

```
for (i in 1:lav){
if (sum(Rcons_s[indexf [,,t],t])>0){
stop=0
j=0
while(stop==0){
j= j+1
az=0
deltadd=0
while(deltadd==0){
az = az+1
if (az>1 & Rcons_s[pf[az,i,j],t]==0){}else{
consumorealeperlavoratoren[i,j]=min((potenzialepesaworker[i,t]-sum(spesaperpersonw[i,,t]))/(p_cons[pf[az,i,j],t]+p_newimpresas[pf[az,i,j]]),conswmax[j]-consumorealeperlavoratore[i,j,t])
consumorealeperlavoratored[i,j]=consumorealeperlavoratored[i,j]+consumorealeperlavoratoren[i,j]
consumorealeperlavoratore[i,j,t]=consumorealeperlavoratore[i,j,t]+min(consumorealeperlavoratoren[i,j],Rcons_s[pf[az,i,j],t])
Rcons_d_w[pf[az,i,j],t]=Rcons_d_w[pf[az,i,j],t]+consumorealeperlavoratoren[i,j]
Rcons_w[pf[az,i,j],t]=Rcons_w[pf[az,i,j],t]+min(consumorealeperlavoratoren[i,j],Rcons_s[pf[az,i,j],t])
spesaperpersonw[i,j,t]=spesaperpersonw[i,j,t]+min(consumorealeperlavoratoren[i,j],Rcons_s[pf[az,i,j],t])*(p_cons[pf[az,i,j],t]+p_newimpresas[pf[az,i,j]])#posso fare che se non vai al max non vai ad altri settori
Rcons_s[pf[az,i,j],t]=max(Rcons_s[pf[az,i,j],t]-consumorealeperlavoratoren[i,j],0)
}
if (consumorealeperlavoratore[i,j,t]>=conswmax[j]| (maxestr[j])==az | all(Rcons_s[pf[,i,j],t]<=0)) {deltadd=1}
if(sum(spesaperpersonw[i,,t])>=potenzialepesaworker[i,t] ){
deltadd=1
stop=1}
}
if ( round(consumorealeperlavoratore[i,j,t],1)<conswmax[j] | (j+1)>nSector){stop=1} #settatt[j+1]==0 a sto punto fallo spendere sul secondo (c'è domanda sul primo non coperta), meglio di niente. però crea volatilità
}}}

if(lav<dd[t]){
for (i in (lav+1):dd[t]){
if (sum(Rcons_s[indexf [,,t],t])>0){
stop=0
j=0
while(stop==0){
j= j+1
az=0
deltadd=0
```

```
while(deltadd==0){
az = az+1
if (az>1 & Rcons_s[pf[az,i,j],t]<=0){}else{

#consumorealeperlavoratoren[i,j]=min((potenzialepesaworker[i,t]-sum(spesape⌋
↪  rpersonw[i,,t]))/(p_cons[pf[az,i,j],t]+p_newimpresas[pf[az,i,j]]),consw⌋
↪  max[j]-consumorealeperlavoratore[i,j,t])
#consumorealeperlavoratored[i,j]=consumorealeperlavoratored[i,j]+consumorea⌋
↪  leperlavoratoren[i,j]
#consumorealeperlavoratore[i,j,t]=consumorealeperlavoratore[i,j,t]+min(cons⌋
↪  umorealeperlavoratoren[i,j],Rcons_s[pf[az,i,j],t])

consumorealepercapitalistan[(i-lav),j]=min((potenzialespesa_c[which(potenzi⌋
↪  alespesa_c[,t]>0),t][(i-lav)]-sum(spesaperpersonc[(i-lav),,t]))/(p_cons⌋
↪  [pf[az,i,j],t]+p_newimpresas[pf[az,i,j]]),conscmax[j]-consumorealeperca⌋
↪  pitalista[(i-lav),j,t])
consumorealepercapitalistad[(i-lav),j]=consumorealepercapitalistad[(i-lav),⌋
↪  j]+consumorealepercapitalistan[(i-lav),j]
consumorealepercapitalista[(i-lav),j,t]=consumorealepercapitalista[(i-lav),⌋
↪  j,t]+min(consumorealepercapitalistan[(i-lav),j],Rcons_s[pf[az,i,j],t])
Rcons_d_c[pf[az,i,j],t]=Rcons_d_c[pf[az,i,j],t]+consumorealepercapitalistan⌋
↪  [(i-lav),j]
Rcons_c[pf[az,i,j],t]=Rcons_c[pf[az,i,j],t]+min(consumorealepercapitalistan⌋
↪  [(i-lav),j],Rcons_s[pf[az,i,j],t])
spesaperpersonc[(i-lav),j,t]=spesaperpersonc[(i-lav),j,t]+min(consumorealep⌋
↪  ercapitalistan[(i-lav),j],Rcons_s[pf[az,i,j],t])*(p_cons[pf[az,i,j],t]+⌋
↪  p_newimpresas[pf[az,i,j]])#posso fare che se non vai al max non vai ad
↪  altri settori
Rcons_s[pf[az,i,j],t]=max(Rcons_s[pf[az,i,j],t]-consumorealepercapitalistan⌋
↪  [(i-lav),j],0)
}
if (consumorealepercapitalista[(i-lav),j,t]>=conscmax[j]| (maxestr[j])==az
↪  | all(Rcons_s[pf[,i,j],t]<=0)) {deltadd=1}
if(sum(spesaperpersonc[(i-lav),,t])>=potenzialespesa_c[which(potenzialespes⌋
↪  a_c[,t]>0),t][(i-lav)]){
deltadd=1
stop=1}
}
if ( round(consumorealepercapitalista[(i-lav),j,t],1)<conscmax[j] |
↪  (j+1)>nSector){stop=1}
}
}}}
###########################################################################⌋
↪  ########################################
###########################################################################⌋
↪  ##############################
spperlys[]=0
for(i in 1 :nlayers){
spperlys[1:lld[i,t],,i]= spesaperpersonw[(1+sum(lld[0:(i-1),t])):(sum(lld[0⌋
↪  :(i-1),t])+lld[i,t]),,t]}#spesa per person ha sulle righe spese di
↪  tutti i lavoratori (anche top managers) divisi per colonne (settori)
```

```
spperlyt[1:lld[1,t],t,]=apply(spperlys,3,rowSums)[1:lld[1,t],]
spperlytys[,,t]=apply(spperlys,3,colSums)
v_perworker[,t,] = v_perworker[,t-1,]
v_perworker[1:lld[1,t],t,] = v_perworker[1:lld[1,t],t,] +
↪  yd_perworker[1:lld[1,t],t,] - spperlyt[1:lld[1,t],t,]


######AGGREGATE
↪  VALUES##################################################################
Rcons_tot_d[indexf[,,t],t] = Rcons_d_w[indexf[,,t],t] +
↪  Rcons_d_c[indexf[,,t],t] + Rg_d[indexf[,,t],t]
DeltaRcons_tot_d[indexf[,,t],t]
↪  =(Rcons_tot_d[indexf[,,t],t]-Rcons_tot_d[indexf[,,t],t-1])
Rcons_tot[indexf[,,t],t]=Rcons_w[indexf[,,t],t] + Rcons_c[indexf[,,t],t] +
↪  Rg[indexf[,,t],t]
cons_w[indexf[,,t],t]=Rcons_w[indexf[,,t],t]*p_cons[indexf[,,t],t] #di
↪  nuovo vettore lungo non per settori
cons_c[indexf[,,t],t]=Rcons_c[indexf[,,t],t]*p_cons[indexf[,,t],t]
g[indexf[,,t],t]=  Rg[indexf[,,t],t]*p_cons[indexf[,,t],t]
cons_tot[indexf[,,t],t]=cons_w[indexf[,,t],t]+cons_c[indexf[,,t],t]+g[index⌋
↪  f[,,t],t]
ueff[indexf[,,t],t]=
↪  as.vector(q_cons[indexf[,,t],t]/((Rk[indexf[,,t],t-1]+Rk_inst[,,t][as.v⌋
↪  ector(indexf[,,t])])*ykratio[,,t][as.vector(indexf[,,t])]))
ueff[is.nan(ueff[,t]),t]=0
y[mc,t] = sum(cons_tot[,t]) + sum(y_inv[,,t])
v_w[t] = v_w[t-1] + yd_w[t] - sum(cons_w[,t])
v_c[,t] = v_c[,t-1]
v_c[which(potenzialespesa_c[,t]>0),t] =
↪  v_c[which(potenzialespesa_c[,t]>0),t] +
↪  yd_c[which(potenzialespesa_c[,t]>0),t] -
↪  rowSums(spesaperpersonc[,,t])[1:length(which(potenzialespesa_c[,t]>0))]

#v_c[,t] = v_c[,t-1] + yd_c[,t] - rowSums(spesaperpersonc[,,t])

############ PROFIT AND CASH CAPITAL SECTOR
↪  #############################################
P_f_inv_persector[,,t] = (y_inv[,,t] - RDspesa_inn[,,t])
↪  -(w_inv[,,t]*N_inv[,,t])
P_f_inv[,t] = rowSums(y_inv[,,t] - RDspesa_inn[,,t]) -Wbd_inv[,t]
↪  #s[sett[,t],t]wbd comprende anche R&D
#P_f_inv[,t] = rowSums(ifelse(sommaallocare[,,t]>0,(y_inv[,,t])
↪  -sommaallocare[,,t]/s[,,t],y_inv[,,t]))-Wbd_inv[,t] #s[sett[,t],t]wbd
↪  comprende anche R&D
#P_f_inv[,t] = ifelse(sommaallocare[,,t]>0,rowSums(y_inv[,,t]) -
↪  (Wbd_inv[,t])
↪  -rowSums(sommaallocare[,,t]/s[,,t],na.rm=T),rowSums(y_inv[,,t]) -
↪  (Wbd_inv[,t])) #s[sett[,t],t]wbd comprende anche R&D
UP_f_inv[,t]=ifelse(P_f_inv[,t]>0 &
↪  D_f_inv[,t]>0,pmin(P_f_inv[,t],D_f_inv[,t]),0)
D_f_inv[,t] = D_f_inv[,t] - UP_f_inv[,t]
```

```
NW_inv[,t]= D_f_inv[,t]+inventories_inv[,t]

############ PROFIT AND CASH CONSUMPTION SECTOR
↪  ##############################################
Rinventories_cons[indexf[,,t],t] = Rinventories_cons[indexf[,,t],t-1] +
↪  q_cons[indexf[,,t],t]-Rcons_tot[indexf[,,t],t]
inventories_cons[indexf[,,t],t] =
↪  Rinventories_cons[indexf[,,t],t]*p_cons[indexf[,,t],t] #prezzo non
↪  costo unitario
P_f_cons[indexf[,,t],t] = inventories_cons[indexf[,,t],t] +
↪  cons_tot[indexf[,,t],t] - Wbd_cons[indexf[,,t],t] - da[indexf[,,t],t] -
↪  l_shortperwage_d[indexf[,,t],t]*(r_l_short[t]/2*(u+1)) #interessi
↪  lunghi sono in DA    #INVENTORIES SAREBBERO DA VALORIZZARE AL LORO
↪  COSTO STORICO
D_f_cons[indexf[,,t],t] = D_f_cons[indexf[,,t],t] + cons_tot[indexf[,,t],t]
↪  - servicedebt_long_tot[indexf[,,t],t] -
↪  servicedebt_short_tot[indexf[,,t],t]
aaaaaa=D_f_cons[,t]
if (payratio=="endogeno"){payratio_c[indexf[,,t],t]=
↪  ifelse(D_f_cons[indexf[,,t],t]> Wbd_cons[indexf[,,t],t-1],1,0) }
UP_f_cons[indexf[,,t],t] = ifelse(P_f_cons[indexf[,,t],t]>0 &
↪  D_f_cons[indexf[,,t],t]>0, pmin(P_f_cons[indexf[,,t],t]*payratio_c[inde⌋
↪  xf[,,t],t],D_f_cons[indexf[,,t],t]),0)     #        #questi devo
↪  vedere. devo scaricare cassa dei profitti
D_f_cons[indexf[,,t],t] = D_f_cons[indexf[,,t],t]-UP_f_cons[indexf[,,t],t]
bbbbbb=D_f_cons[,t]

########### DEFAULT
↪  ####################################################################
if (t>25 & (DEFAULT=="YESpiùsevero"|DEFAULT=="YESmenosevero")){#
if (DEFAULT=="YESpiùsevero")
↪  {default[,,t][indexf[,,t]]=ifelse(D_f_cons[indexf[,,t],t-3]<(-1) &
↪  D_f_cons[indexf[,,t],t-2]<(-1) & D_f_cons[indexf[,,t],t-1]<(-1) &
↪  D_f_cons[indexf[,,t],t]<(-1) ,1,0)}# & &
↪  D_f_cons[indexf[,,t],t]<D_f_cons[indexf[,,t],t-1] &
↪  D_f_cons[indexf[,,t],t-1]<D_f_cons[indexf[,,t],t-2]&
↪  D_f_cons[indexf[,,t],t-2]<D_f_cons[indexf[,,t],t-3]
else if ( DEFAULT=="YESmenosevero") {default[,,t][as.vector(indexf[,,t])]=i⌋
↪  felse(D_f_cons[indexf[,,t],t-2]<0 & D_f_cons[indexf[,,t],t-1]<0 &
↪  D_f_cons[indexf[,,t],t]<0 ,1,0)}
if (any(default[,,t]>0)) {
indexf[,,t:(nPeriods+dk)][which(default[,,t]>0)+rep(nfirmmax,length(which(d⌋
↪  efault[,,t]>0))*((nPeriods+dk)-t+1))*rep(c(0:((nPeriods+dk)-t)),each=le⌋
↪  ngth(which(default[,,t]>0)))]=0
Rk_inst[,,(t-min(z,t-1)):(t+dk)][which(default[,,t]>0)+rep(nfirmmax,length(⌋
↪  which(default[,,t]>0))*(min(z,t-1)+dk+1))*rep(c(0:(min(z,t-1)+dk)),each⌋
↪  =length(which(default[,,t]>0)))]=0

settimpattati=as.numeric(names(table(which(default[,,t]>0,arr.ind=TRUE)[,2]⌋
↪  )))
```

```
Rk_instbk[settimpattati,t]=sapply(settimpattati, function(x)
↪  sum(Rk[(x-1)*(nfirmmax/nSector)+which(default[,x,t]>0),t]))
klratio_bk[settimpattati,t]=sapply(settimpattati, function(x)
↪  mediakl[(x-1)*(nfirmmax/nSector)+which(default[,x,t]>0),t]%*%((Rk[(x-1)⌋
↪  *(nfirmmax/nSector)+which(default[,x,t]>0),t])/sum(Rk[(x-1)*(nfirmmax/n⌋
↪  Sector)+which(default[,x,t]>0),t])))

da[which(default[,,t]>0),t:(nPeriods+dk+1)]=0
Rinventories_cons[which(default[,,t]>0),t:(nPeriods+dk+1)]=0
#Rcons_tot_d[which(default[,,t]>0),1:(t-1)]=0 potrebbe servire solo con dk=0
l_short_d[which(default[,,t]>0),t]=l_short_d[which(default[,,t]>0),t]+abs(D⌋
↪  _f_cons[which(default[,,t]>0),t])#+rowSums(interestpayment_short[which(⌋
↪  default[,,t]>0),(t):(nPeriods+u)])
D_f_cons[which(default[,,t]>0),t]=0

if(any(Rk[which(default[,,t]>0),t]>0)){p_invbk[settimpattati,t]=sapply(sett⌋
↪  impattati,
↪  function(x)if(length(which(default[,x,t]==1))>1){rowSums(l_long_d[(x-1)⌋
↪  *(nfirmmax/nSector)+which(default[,x,t]>0),(1:t)]-servicedebt_long_cc[(⌋
↪  x-1)*(nfirmmax/nSector)+which(default[,x,t]>0),(1:t)])%*%((Rk[(x-1)*(nf⌋
↪  irmmax/nSector)+which(default[,x,t]>0),t])/sum(Rk[(x-1)*(nfirmmax/nSect⌋
↪  or)+which(default[,x,t]>0),t]))}else{sum(l_long_d[(x-1)*(nfirmmax/nSect⌋
↪  or)+which(default[,x,t]>0),(1:t)]-servicedebt_long_cc[(x-1)*(nfirmmax/n⌋
↪  Sector)+which(default[,x,t]>0),(1:t)])/Rk[(x-1)*(nfirmmax/nSector)+whic⌋
↪  h(default[,x,t]>0),t]})
}

servicedebt_short_cc[which(default[,,t]>0),(t+1):(nPeriods+dk+1+u)]=0#
↪  questi vanno in avanti da uncommentare
servicedebt_long_cc[which(default[,,t]>0),(t+1):(nPeriods+dk+1+z)]=0
servicedebt_long_tot[which(default[,,t]>0),(t+1):(nPeriods+dk+1+z)]=0
servicedebt_short_tot[which(default[,,t]>0),(t+1):(nPeriods+dk+1+u)]=0
interestpayment_short[which(default[,,t]>0),(t+1):(nPeriods+dk+1+u)]=0
↪  #interessi futuri da considerarsi quale debito ?
interestpayment_long[which(default[,,t]>0),(t+1):(nPeriods+dk+1+z)]=0

#Rk[which(default[,,t]>0),t:(nPeriods+dk+1)]=0
klratio[,,t:(nPeriods+dk)][which(default[,,t]>0)+rep(nfirmmax,length(which(⌋
↪  default[,,t]>0))*((nPeriods+dk)-t+1))*rep(c(0:((nPeriods+dk)-t)),each=l⌋
↪  ength(which(default[,,t]>0)))]=0
#ykratio[,,t:(nPeriods+dk)][which(default[,,t]>0)+rep(nfirmmax,length(which⌋
↪  (default[,,t]>0))*((nPeriods+dk)-t+1))*rep(c(0:((nPeriods+dk)-t)),each=⌋
↪  length(which(default[,,t]>0)))]=0
azdef=which(default[,,t]==1)
#storicoRD_c[which(default[,t]>0),]=0 # per questo nn
}}

stockdebt_long[,t]=rowSums(l_long_d[,1:t]-servicedebt_long_cc[,1:t]+l_long_⌋
↪  d_iniziale[,1:t])
stockdebt_short[,t]= rowSums(l_short_d[,1:t]-servicedebt_short_cc[,1:t])
```

```
nonperformingloan_long[which(default[,,t]>0),t]=stockdebt_long[,t][which(de⌋
↪  fault[,,t]>0)]
nonperformingloan_short[which(default[,,t]>0),t]=
↪  stockdebt_short[,t][which(default[,,t]>0)]

cumulatononperforming[t]=cumulatononperforming[t-1]+sum(nonperformingloan_l⌋
↪  ong[,t]+nonperformingloan_short[,t])-sum(id_lbk[,t])

NW_cons[,t]= -stockdebt_long[,t]-stockdebt_short[,t] +k[,t] +
↪  inventories_cons[,t]+ D_f_cons[,t] #+ advances

#### COMMERCIAL BANK
↪  ###################################################################
D_b[t]=D_b[t-1] + sum(interestpayment_short[,t])+
↪  sum(interestpayment_long[,t])+ r_r[t]*max(riserve[t-1],0) -
↪  (D_w[t-1]+sum(D_c[,t-1]))*r_d[t] - advance[t-1]
advance[t]=abs(min(D_b[t],0))
D_b[t]=D_b[t]+ advance[t]
P_b[t]=sum(interestpayment_short[indexf[,,t-1],t])+
↪  sum(interestpayment_long[indexf[,,t-1],t])+ r_r[t]*max(riserve[t-1],0)
↪  - (D_w[t-1]+sum(D_c[,t-1]))*r_d[t]
if (P_b[t]>0 &D_b[t]>0){
UP_b[t] = min(P_b[t],D_b[t])
D_b[t]=D_b[t]-UP_b[t]
}

l_s[t] = l_s[t-1] +sum(l_long_d_iniziale[,t])+sum(l_short_dinv[,t])-sum(l_s⌋
↪  hort_dinv[,t-1])+ sum(l_long_d[,t]) + sum(l_short_d[,t])-
↪  sum(servicedebt_short_cc[,t]) - sum(servicedebt_long_cc[,t])
↪  -sum(nonperformingloan_long[,t]) -sum(nonperformingloan_short[,t])
if (any(default[,,t]>0)) {
l_long_d[which(default[,,t]>0),1:t]=0
servicedebt_long_cc[which(default[,,t]>0),1:t]=0
l_long_d_iniziale[which(default[,,t]>0),1:t]=0
l_short_d[which(default[,,t]>0),1:t]=0
servicedebt_short_cc[which(default[,,t]>0),1:t]=0
interestpayment_long[which(default[,,t]>0),1:t]=0
interestpayment_long[which(default[,,t]>0),1:t]=0}

########CENTRAL BANK
↪  ###################################################################
P_cb[t]= r_b[t]*b_cb[t-1] - r_r[t]*max(riserve[t-1],0)

#####SUPPLY GOVERNMENT BONDS
↪  ############################################################
tax[t]= tax[t]+(sum(UP_f_cons[,t])+sum(UP_f_inv[,t])+UP_b[t])*theta
Gspesainteressi[t]=r_b[t]*b_s[t-1]
Def[t] = tax[t] + P_cb[t]-Rg[,t]%*%p_cons[,t]- Gspesainteressi[t] -
↪  sussidiati[,t]%*%sussidio[,t] -sussidiati_inv[,t]%*%sussidio_inv[,t]
Defbeforeturning[t]=Def[t]
```

```
wh=(which(v_perworker[,t,]>0))
if(Def[t]>0 & TURNDEFICIT=="YES"){
lg=length(wh)
v_perworker[,t,][wh]=v_perworker[,t,][wh]+Def[t]/(lg+nCapitalistimax)
v_c[,t]=v_c[,t]+Def[t]/(lg+nCapitalistimax)
v_w[,t]=v_w[,t]+(Def[t]/(lg+nCapitalistimax))*lg
Def[t]=0
}

b_s[t]=b_s[t-1]-Def[t]
nricchpositive[,t]=length(which(v_c[,t]>0))+length(which(v_perworker[,t,]>0
 ↪  ))
NWG[t]=-b_s[t]+D_state[t]

#####DEMAND GOVERNEMTN BONDS
 ↪  ###########################################################
if (b_s[t]>0 & t>2 ) {
if (any(v_c[,t]>0)) {for (i in (which(v_c[,t]>0))) {b_dc[i,t] =
 ↪  ifelse(v_c[i,t]>0,min(v_c[i,t]*max(lambda0 + lambda1*r_b[t] -
 ↪  lambda2*(yd_c[i,t]/v_c[i,t]),0),b_s[t]-sum(b_dc[1:(i-1),t])),0)}}
 ↪  #esce negativo per spesa stato negativo
for (i in wh) {  #devo sistemare questo
b_dperworker[,t,][i] = min(v_perworker[,t,][i]*max(lambda0 + lambda1*r_b[t]
 ↪  - lambda2*(yd_perworker[,t,][i]/v_perworker[,t,][i]),0),max(b_s[t]-sum(
 ↪  b_dc[,t])-b_dw[t],0))
b_dw[t] = b_dw[t] + b_dperworker[,t,][i]}}
b_cb[t] = b_s[t] - sum(b_dc[,t]) - b_dw[t]
D_perworker[,t,] = v_perworker[,t,] - b_dperworker[,t,]

#####DEPOSITS
 ↪  ################################################################
D_w[t] = sum(D_perworker[,t,])
D_c[,t] = v_c[,t] - b_dc[,t]
cD_c[,t] = c((UP_f_cons[,t]),(UP_f_inv[,t]),UP_b[t])*(1-theta)  #percentage
 ↪  solo su consumo?  no interest on cD_C
liquidity[mc,t] =  D_w[t] +sum(D_c[,t]) + sum(cD_c[,t]) + sum(D_f_cons[,t])
 ↪  + sum(D_f_inv[,t]) + D_b[t]

#####RESERVES
 ↪  ################################################################
riserve[t]= -l_s[t] -sum(nonperformingloan_long[,2:t])
 ↪  -sum(nonperformingloan_short[,2:t]) + D_w[t] +D_c[t] + sum(cD_c[t]) +
 ↪  sum(D_f_cons[,t]) + sum(D_f_inv[,t]) +D_state[t] +D_b[t]
NWB[t] = -D_w[t]- sum(D_c[,t])- sum(cD_c[,t])-  sum(D_f_cons[,t]) -
 ↪  sum(D_f_inv[,t])- advance[t] - D_state[t] +riserve[t] +l_s[t]

#####CENTRAL BANK
 ↪  ################################################################
```

```
h_s[t] =  h_s[t-1]+ b_cb[t] - b_cb[t-1] + advance[t] - advance[t-1]-
↪  (riserve[t] - riserve[t-1])    #  #MA QUESTO PU?? NN ESSERE ZERO SE
↪  COMPRANO TUTTO HOUSEHOLD I TITOLI. o alemno riserve si dovrebbero
↪  azzerare
redundant[mc,t]=round(l_s[t]+sum(nonperformingloan_long[,2:t])
↪  +sum(nonperformingloan_short[,2:t]) +b_cb[t] -sum(id_lbk) -D_w[t]
↪  -sum(D_c[,t]) -sum(cD_c[,t]) -sum(D_f_cons[,t]) - sum(D_f_inv[,t])
↪  -D_state[t] -D_b[t] +advance[t],5)#-b_cb+b_cb[t]
# round(-riserve+advance+b_cb,5)
NWCB[t]=-riserve[t] - h_s[t] +b_cb[t]

#####GDP AND DEBT TO GDP
↪  ###################################################################
GDP_currentprice[mc,t]= q_cons[,t]%*%p_cons[,t] +
↪  sum(y_inv[,,t])#-Rinventories_cons[,t])

}#chiude il loop per t
pdef=matrix(0,nfirmmax,1)
pdef[1:nfirmmax/nSector,1]=(p_cons[1:nfirmmax/nSector,2])
for(i in 2:nSector){
if (sum(indexcom[,i,2:t])>0 & nfirmmax>nSector){
pdef[((nfirmmax/nSector)*(i-1)+1):(nfirmmax/nSector*i),1]=p_cons[which(inde⌟
↪  xcom[,i,2:t]>0,arr.ind=T)[1,1],which(indexcom[,i,2:t]>0,arr.ind=T)[1,2]⌟
↪  ]}
else if (sum(indexcom[,i,2:t])>0){
pdef[((nfirmmax/nSector)*(i-1)+1):(nfirmmax/nSector*i),1]=p_cons[i,which(p_⌟
↪  cons[i,1:t]>0)[1]]}
}
GDP[mc,1:nPeriods]= t(pdef)%*%q_cons[,1:nPeriods]+ sapply(1:nPeriods,
↪  function(x) sum((q_inv[,,x])*(p_invli[,,2])))#i primi 20 periodi è più
↪  alto
NDP=t(pdef)%*%q_cons[,1:nPeriods]
D_pil[mc,2:nPeriods]= b_s[,2:nPeriods]/GDP_currentprice[mc,2:nPeriods]


#####TO STORE ALL THE MONTECARLO RESULTS IN EACH MULTIVARIATE COMBINATION
↪  #################
rat=(ncomb-1)*MC+mc
#1
kt=1
Storeallmean[rat,2:(nPeriods),kt]=(D_pil[mc,2:(nPeriods)])
#2
kt=kt+1
Storeallmean[rat,,kt]=(GDP[mc,1:(nPeriods)])
#3 NDP
kt=kt+1
Storeallmean[rat,,kt]=NDP
#4
kt=kt+1
Storeallmean[rat,,kt]=(N[mc,1:(nPeriods)])
#5
```

```
kt=kt+1
Storeallmean[rat,,kt]=yd_w[1:nPeriods]
#6
kt=kt+1
Storeallmean[rat,,kt]=colSums(yd_c[,1:nPeriods])
#7
kt=kt+1
Storeallmean[rat,,kt]=redundant[mc,1:nPeriods]#colSums(spperlytys[,1,1:nPer⌋
↪  iods])
#8
kt=kt+1
Storeallmean[rat,,kt]=GDP_currentprice[mc,1:nPeriods]
#9
kt=kt+1
#Storeallmean[rat,,kt]=Defbeforeturning[1,1:nPeriods]
#10
kt=kt+1
#Storeallmean[rat,,kt]=mid40d[,1:nPeriods]
#11
kt=kt+1
#Storeallmean[rat,,kt]=bot50d[,1:nPeriods]
#12
kt=kt+1
#Storeallmean[rat,,kt]=ggiinnii[,1:nPeriods]
#13
kt=kt+1
Storeallmean[rat,,kt]=(sum(N_inv[,,1:(nPeriods)])+N_research_inn[1:(nPeriod⌋
↪  s)])/N[mc,1:(nPeriods)]
#14
kt=kt+1
#Storeallmean[rat,,kt]=sapply(1:nPeriods,function(x)Gini(Rcons_tot[1:nfirmm⌋
↪  ax/nSector,x]))#DA TOGLIERE #per tuti i settori devo trovare una
↪  soluzione
#15=x
#x:(x +nsector-1)
kt=kt+1
for(i in 1:nSector){
Storeallmean[rat,,kt+(i-1)]=sapply(1:nPeriods,function(x)
↪  mean(klratio[,i,x][which(klratio[,i,x]>0)]))}
#(x+nsector):(x+2*nsector-1)
kt=kt+(nSector)
for(i in 1:nSector){
Storeallmean[rat,,kt+(i-1)]= sapply(1:(nPeriods),function(x)
↪  sum(Rcons_tot[((nfirmmax/nSector)*(i-1)+1):((nfirmmax/nSector)*i),x]))}
#(x+2*nsector):(x+3*nsector-1)
kt=kt+(nSector)
for(i in 1:nSector){
Storeallmean[rat,,kt+(i-1)]=sapply(1:(nPeriods),function(x)mean(p_cons[((nf⌋
↪  irmmax/nSector)*(i-1)+1):((nfirmmax/nSector)*i),x][which(p_cons[((nfirm⌋
↪  max/nSector)*(i-1)+1):((nfirmmax/nSector)*i),x]>0)]))}
#(x+3*nsector):(x+4*nsector-1)
```

```
kt=kt+(nSector)#EMPLOYMENT PER FIRM
for (j in 1:nlayers){
for(i in 1:nSector){
Storeallmean[rat,,kt+(i-1)+(j-1)]=sapply(1:(nPeriods),function(x)mean(N_con⌋
↪  s[((nfirmmax/nSector)*(i-1)+1):((nfirmmax/nSector)*i),x,j][which(N_cons⌋
↪  [((nfirmmax/nSector)*(i-1)+1):((nfirmmax/nSector)*i),x,j]>1)]))}}
#(x+4*nsector):(x+5*nsector-1)
kt=kt+(nSector*nlayers)
for (j in 1:nlayers){
for(i in 1:nSector){
Storeallmean[rat,,kt+(i-1)+(j-1)]=sapply(1:nPeriods, function(x) sum(N_cons⌋
↪  [((nfirmmax/nSector)*(i-1)+1):((nfirmmax/nSector)*i),x,j]))}}#labour
↪  share per sector
kt=kt+(nSector*nlayers)
#(x+5*nsector)
Storeallmean[rat,,kt]=id[1,1:nPeriods]
kt=kt+1
#

quant=c(0.01,0.1,0.25,0.5,1)#top 25 , 50 #CONSUMO TOTALE per quantile
↪  distribuzione.
for (i in 10: nPeriods){
df=as.matrix(rbind(consumorealepercapitalista[,,i],
↪  consumorealeperlavoratore[,,i]))
df=cbind(df, rowSums(df))
df=df[which(df[,(nSector+1)]>1.2),]
lengconsumo=length(which(df[,(nSector+1)]>0))
df=df[order(df[,nSector+1],decreasing=TRUE),1:nSector]
pszi=ceiling(lengconsumo*quant)
acc=kt
Storeallmean[rat,i,acc:(acc+(nSector-1))]=sapply(1:nSector,function(x)
↪  sum(df[1:pszi[2],x]))
acc=acc+nSector
Storeallmean[rat,i,acc:(acc+(nSector-1))]=sapply(1:nSector,function(x)
↪  sum(df[(pszi[2]+1):pszi[3],x]))
acc=acc+nSector
Storeallmean[rat,i,acc:(acc+(nSector-1))]=sapply(1:nSector,function(x)
↪  sum(df[(pszi[3]+1):pszi[4],x]))
acc=acc+nSector
Storeallmean[rat,i,acc:(acc+(nSector-1))]=sapply(1:nSector,function(x)
↪  sum(df[(pszi[4]+1):lengconsumo,x]))
acc=acc+nSector
}
kt=kt+nSector*9+1
#(x+5*nsector) +nsector*4+1
kt=59
Storeallmean[rat,3:(nPeriods),kt]=sapply(3:nPeriods,function(x)
↪  sum(((Rcons_tot[,x][indexcom[,,x]]-Rcons_tot[,x-1][indexcom[,,x]])/Rcon⌋
↪  s_tot[,x-1][indexcom[,,x]])*(Rk[indexcom[,,x],x-1]+Rk_inst[,,x][as.vect⌋
↪  or(indexcom[,,x])])*ykratio[,,x][as.vector(indexcom[,,x])]/captot[x]))
Storeallmean[rat,!is.finite(Storeallmean[rat,,kt]),kt]=0
```

```
Storeallmean[rat,,kt]=Storeallmean[rat,,kt]+1
Storeallmean[rat,,kt]=cumprod(Storeallmean[rat,,kt])
kt=60
Storeallmean[rat,2:nPeriods,kt]=sapply(2:nPeriods,function(x)
↪  mean((klratio[,,x][indexcom[,,x]]-klratio[,,2][indexcom[,,x]])/klratio[⌋
↪  ,,2][indexcom[,,x]]))
kt=kt+1
#61
for (i in 2: nPeriods){

#MACRO WEALTH SHARE BETWEEN CLASSES
iwealth=c(v_perworker[,i,1], v_c[,i])
iwealth=iwealth[iwealth>2]
lengiwealth=length(iwealth)
iwealth=sort(iwealth,decreasing = TRUE)
sumiwealth=sum(iwealth)
pszi=ceiling(lengiwealth*quant)
Storeallmean[rat,i,kt]=sum(iwealth[1:pszi[1]])/sumiwealth
kt=kt+1
Storeallmean[rat,i,kt]=sum(iwealth[1:pszi[2]])/sumiwealth
kt=kt+1
Storeallmean[rat,i,kt]=sum(iwealth[(pszi[2]+1):pszi[3]])/sumiwealth
kt=kt+1
Storeallmean[rat,i,kt]=sum(iwealth[(pszi[3]+1):pszi[4]])/sumiwealth
kt=kt+1
Storeallmean[rat,i,kt]=sum(iwealth[(pszi[4]+1):lengiwealth])/sumiwealth
kt=kt+1
Storeallmean[rat,i,kt]=Gini(iwealth)#gini
kt=kt+1

#MACRO INCOME SHARE BETWEEN CLASSES
iincome=c(yd_perworker[1:sum(employpersector[,i]),i,1], yd_c[1:nfirmmax,i])
iincome=iincome[iincome>1]
lengiincome=length(iincome)
iincome=sort(iincome,decreasing = TRUE)
sumiincome=sum(iincome)
pszi=ceiling(lengiincome*quant)
Storeallmean[rat,i,kt]=sum(iincome[1:pszi[1]])/sumiincome
kt=kt+1
Storeallmean[rat,i,kt]=sum(iincome[1:pszi[2]])/sumiincome
kt=kt+1
Storeallmean[rat,i,kt]=sum(iincome[(pszi[2]+1):pszi[3]])/sumiincome
kt=kt+1
Storeallmean[rat,i,kt]=sum(iincome[(pszi[3]+1):pszi[4]])/sumiincome
kt=kt+1
Storeallmean[rat,i,kt]=sum(iincome[(pszi[4]+1):lengiincome])/sumiincome
kt=kt+1
Storeallmean[rat,i,kt]=Gini(iincome)#gini
kt=kt+1

#INCOME  per settore  profitti contro wage
```

```
for (j in 1 : nSector){
if (sum(N_cons[((nfirmmax/nSector)*(j-1)+1):((nfirmmax/nSector)*j),i,1])>5){
#iincome=c(yd_perworker[(1+min((j-1),1)*sum(employpersector[1:(j-1),i])):em
↪  ploypersector[j,i],i,1],
↪  yd_perworker[(dvlavk[,t]+min((j-1),1)*sum(ceiling(N_inv[,1:(j-1),t]))):
↪  (dvlavk[,t]+sum(ceiling(N_inv[,1:j,t]))-1),i,1],yd_c[(1+(nfirmmax/nSect
↪  or*(j-1))):((nfirmmax/nSector)*j),i],
↪  P_f_inv_persector[,j,i])
iincome=c(yd_perworker[(1+min((j-1),1)*sum(employpersector[1:(j-1),i])):sum
↪  (employpersector[1:j,i]),i,1],
↪  yd_c[(1+(nfirmmax/nSector*(j-1))):((nfirmmax/nSector)*j),i])#,
↪  P_f_inv_persector[,j,i])
#if(dvlavk[j,i]>0){iincome=c(iincome, yd_perworker[dvlavk[j,i]:(dvlavk[j,i]
↪  +sum(ceiling(N_inv[,j,i]))-1),i,1])}
iincome=iincome[iincome>0]
lengiincome=length(iincome)
iincome=sort(iincome,decreasing = TRUE)
sumiincome=sum(iincome)
pszi=ceiling(lengiincome*quant)
acc=kt+6*(j-1)
Storeallmean[rat,i,acc]=sum(iincome[1:pszi[1]])/sumiincome
acc=acc+1
Storeallmean[rat,i,acc]=sum(iincome[1:pszi[2]])/sumiincome
acc=acc+1
Storeallmean[rat,i,acc]=sum(iincome[(pszi[2]+1):pszi[3]])/sumiincome
acc=acc+1
Storeallmean[rat,i,acc]=sum(iincome[(pszi[3]+1):pszi[4]])/sumiincome
acc=acc+1
Storeallmean[rat,i,acc]=sum(iincome[(pszi[4]+1):lengiincome])/sumiincome
acc=acc+1
#MKT CONCENTRATION
Storeallmean[rat,i,acc]=Gini(Rcons_tot[(1+(nfirmmax/nSector)*(j-1)):(nfirmm
↪  ax/nSector*j),i])
acc=acc+1
}}
kt=kt-12
}

#saveRDS(Storeallmean[rat,,],
↪  file=paste0("./output/",ncomb,"MC",mc,"comb.rds"))
}#chiude il loop per montecarlo ncomb.

ratt= (MC*(ncomb-1)+1):(MC*(ncomb-1)+MC)
if (PARALLEL=="YES") {c(Storeallmean[ratt,,])}

}#chiude il parallel

if (PARALLEL=="YES") {
numCores <- detectCores()-1
cl <- makeCluster(min((numCores)-1,MC*ncombination))
```

```
clusterEvalQ(cl,c(library(Rlab),library(dplyr),
↪  library(Rsolnp),library(robustbase),library(future),library(DescTools)))
clusterExport(cl,c("perimit","esppr","parametromaccheronico_inv","deltacamb⌋
↪  ioinv","Storeallmean","spill","tau_suimm","coefftec","SUSSIDISUL","minn⌋
↪  umemplo","maxnumemplo","ind_cw","tsh","SUSSIDI","FUNZIONE","TURNDEFICIT⌋
↪  ","prs","PRSHOCK","percentsus","cw","payratio_c","nfirmmax","RDD","laye⌋
↪  rsmult","nlayers","ind_c","Spillover","payratio","EQ","PARALLEL","annin⌋
↪  d","geso","gesoper","gmediamobile","gendoper","Sectorlux","nSectorwage"⌋
↪  ,"PHILIP","ds","assetbk","POP","parametri","prop","adjex","payratio_c",⌋
↪  "consumo","monopolio","leverage_l","leverage_s","risorse","all","allr",⌋
↪  "b","inv","entry","ACCELERATORE","nfirmmaxinv","nfirmmax","SHH","SHinv"⌋
↪  ,"pesodeltap","conc","capmaxgexp","ncombination","conoscenza","y",
↪  "GDP","GDP_currentprice","liquidity","redundant","D_pil","TMBS","N","pa⌋
↪  rametro.frame","ff","residuosaturazione","conswmax","conscmax","r_l_lon⌋
↪  g", "r_l_short","r_b","r_d","r_r","risultati","risultati_c","RD",
↪  "nSector_attivi","time","nlavoratorimax","u","z","dk","MC","nSector","n⌋
↪  Periods", "propensensi", "lambda0", "lambda1", "lambda2","theta","c",
↪  "beta", "prr_inv", "mu", "ut","%ni%"))
res=parSapply(cl,1:(ncombination),ff)
stopCluster(cl)

res=as.data.frame(cbind(as.vector(res), rep(1:MC),rep(1:nPeriods,
↪  each=MC),rep(1:100, each=MC*nPeriods),rep(1:ncombination,
↪  each=MC*nPeriods*100)))
for(y in 1:100){
for (j in 1:(ncombination)){   #quando lavorano sia mc che ncomb
for(i in 1:(MC)){
Storeallmean[((j-1)*MC+i),,y]=subset(res,V2==i & V4==y & V5==j)[,1]
}}}
}
```

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