Does Inequality Hamper Innovation and Growth? An AB-SFC Analysis

Alessandro Caiani[*]
Marche Polytechnic University

Alberto Russo
Marche Polytechnic University

Mauro Gallegati
Marche Polytechnic University

Abstract

We propose to analyze the relationship between inequality and economic development by means of an Agent Based-Stock Flow Consistent model where workers have been differentiated into four classes competing on segmented labor markets, and where firms' demand for each type of workers is affected by their hierarchical organization. In order to account for the impact of income and wealth distribution on consumption patterns, worker classes have diversified average propensities to consume and save. Finally, firms in the capital sector invest in R&D, thus possibly coming to produce more productive vintages of machineries which affect the evolution of labor productivity in the consumption sector. The model is calibrated using realistic values for the income and wealth distribution across different income groups and their average propensities to consume.

Results of the simulation experiments suggest that more progressive tax schemes and measures which sustain the dynamics of wages of low and middle level workers concur to foster economic development and to reduce inequality. However, the latter seem to be more effective under both respects. Therefore, the model results are broadly in line with the literature suggesting the prevalence of wage-led growth regimes in closed economic systems.

In the conclusions we discuss current limitations and future development of the present research.

Keywords: Innovation, Inequality, Agent Based Macroeconomics, Stock Flow Consistent Models.
JEL Codes

[*]Corresponding author: a.caiani@univpm.it

1 Introduction

Over the last thirty years inequality has kept rising, both in terms of the personal income and wealth distribution (OECD, 2011; Piketty, 2014), and of the functional distribution between profits and wages (Karanassou and Sala, 2010). The debate on the causes of this rising inequality is still far from a conclusion. Similarly, also the discussion on its consequences on the performance and stability of our economic systems is ongoing. In the present work, we investigate the inequality-growth nexus by proposing an Agent Based-Stock Flow Consistent macroeconomic model to assess the impact of different distributive regimes on innovation dynamics and economic development. The model has the same structure of that presented in Caiani et al. (2016). The economy is then composed of a household sector providing labor force to productive units and consuming; a capital sector producing heterogeneous investment goods out of labor; a consumption sector producing homogeneous final goods out of labor and capital; a banking sector holding deposits by households and firms and providing loans to the latter, and, finally, a public sector composed of a central bank and a general government. To address our research question three major modifications were made to the original model:

1. The household sector has been split up into four heterogeneous classes of workers competing on segmented labor markets, one for each type. Workers of each class are employed in a different tier of the firms' hierarchical structure, whose design is inspired by the framework proposed in Ciarli et al. (2010). In defining the initial setup of our simulations we assume that different types of workers, being employed on different levels of the firms' hierarchy, also represent different income groups, as explained in section 4.

2. In order to assess the impact of income and wealth distribution on demand patterns, we refer to empirical data to determine the average propensity to consume and save out of income for each income group. Given that the average propensity to save shows a strong positive relationship with income levels (Dynan et al., 2004), redistributive policies across income groups can exert significant effects on saving and consumption, thereby impacting also on the overall macroeconomic dynamics. To investigate this aspect we propose two experiments: in the first one we consider a redistribution through the introduction of a progressive tax system. In the second one, we analyze how wages downward rigidity, i.e. a proxy for the level of labor protection on the labor markets, affects the distribution of income and wealth across social groups.

3. Finally, we introduce endogenous innovation dynamics: capital firms hire researchers to perform R&D, possibly coming to produce more productive vintages of machinery, when successful. These product innovations in the capital sector, in turn, allow consumption firms to increase the productivity of labor (i.e. to attain process innovations) as they invest in new, more productive, vintages.

Simulation results suggest that the economy described in our model tends to exhibit several features of a wage-led growth regime. Indeed, a redistribution from high income to low income groups through progressive taxation and a stronger downward rigidity of low and middle tiers workers' wages help to reduce inequality and have beneficial effects on the long-term performance of the system, tough the latter is more effective.

The relationship between innovation and inequality has been largely debated in the empirical literature. Weinhold and Nair-Reichert (2009) analyze a large sample of countries in the period 1994-2000 finding that a larger income share of the middle class (staying for a more equitable distribution) positively affects innovation. As for the US, Jacobs (2016) finds that rising inequality results in a decline of innovative dynamism, with different implications for the bottom, middle, and top income earners: for example they find that children born from wealthy parents are far more likely than poor children to obtain a patent in life, that the stagnation of real incomes has dampened entrepreneurship by preventing many individuals from starting new enterprises, and that the increasing fraction of top earners employed in finance has promoted a short-term view with negative consequences for production activities and innovation. Acemoglu et al. (2012) argue that a country, to be innovative, needs to adopt a "cut-throat" form of capitalism, like the US, in order to have the right incentives to be at the frontier of technological development; by contrast, in countries characterized by a "cuddly" form of capitalism, more equality and redistribution tend to hamper innovation. Yet, some countries, such as the Scandinavian ones, are quite successful in combining efficiency and equality. Hopkin et al. (2014) finds that the alleged technological primacy of the US, compared to more egalitarian societies, is circumscribed to total patent filing, which is affected by the 'patent trolling' phenomenon. When better suited indexes of countries' innovative performance are employed, the result is reverted. The empirical evidence seems to suggest that more egalitarian societies can indeed achieve good innovative performances building upon well-designed institutions and an active role by the state in promoting innovation: according to Mazzucato (2013), in order to boost innovation while preserving social inclusion, the state should not limit its intervention to public funding of universities and research centers, but should play active role in the very creation of new markets and their regulation.

Nonetheless, the role of the state in steering the economy has been considerably downsized over the last three decades. In addition, labor markets deregulation and the fall of the unionization rate have been a common trait in the recent history of many developed countries. These phenomena have been identified by many as two of the main causes of the wage share's decline and the concomitant rise of incomes at the top, together with financial deregulation and top income tax rates cuts (Jaumotte and Buitron, 2015). Indeed, the lowest growth of real wages is found to be in those countries having more flexible labor markets, weak labor unions, and limited social welfare (Vergeer and Kleinknecht, 2010). While real wages and labor productivity had evolved along similar patterns for the three decades after WWII, their paths started to diverge since the 1970s onward, as real wages stagnated or even decreased, whereas labor productivity continued to grow, thereby opening a huge gap between productivity levels and the typical worker's wage. As a matter of example, in the US productivity levels and hourly compensation had increased by 96% and 91.3% respectively during the period 1948-1973, while the correspondent rates for the period 1974-2014 were 72.2% and 9.2% (Bivens and Mishel, 2015). This implied a change of the income functional distribution in favor of capital which prompted wealth accumulation at the top.

Changes in the distributive regime within a given institutional framework can have relevant implications for the macroeconomic dynamics. According to the Keynesian tradition, changing the distribution in favor of the rich may reduce aggregate demand due to the lower propensity to consume which characterizes top income groups. Though credit may allow to temporarily overcome the deficiency of aggregate demand originated by the stagnation of wages of lower income groups, the ensuing increasing indebtedness enhances the financial fragility of the system. Therefore, the expansion of finance in a context of high income and wealth polarization, can only postpone, and possibly amplify, the crisis due to the rise of inequality. Though there is no conclusive empirical evidence of a direct link between inequality and crisis episodes, inequality can eventually result in a large crisis through the rise of indebtedness, as found by Perugini et al. (2016). This mechanism has been described by Kumhof et al. (2015) and Russo et al. (2016), in a Dynamic Stochastic General Equilibrium (DSGE) framework and using an Agent Based Modeling (ABM) approach, respectively.

A distributive regime that favors capital over labor can have opposite effects: on the one hand, the increase of the profit share may boost investment and thus economic growth; on the other hand, the decline of the wage share may lower consumption and thus economic growth with possible effects also on labor productivity dynamics. Which one of the two effects prevails depends on macroeconomic and institutional conditions. This question led to a resurgence of the debate between wage-led (trickle-up) and profit-led (trickle-down) growth regimes (see Lavoie and Stockhammer (2012) and Stiglitz (2015)).[1] The settlement of the dispute requires to assess the impact of different distributive regimes on the evolution of the demand and supply sides of the economy. As for the demand side, a wage-led growth strategy rests on the positive effect of wage share increases on consumption, which in turn stimulates investment to keep up with rising demand. On the supply side, the expansion of investment and consumption may increase productivity levels, according to the Kaldor-Verdoon effect (see, for instance, McCombie and Thirlwall (1994) and McCombie (2002)). On the contrary, investment is profit-led if a wage increase discourages productivity-enhancing capital investment and a decrease of labor productivity follows. Based on data of G-20 countries, Onaran and Galanis (2012) find that the domestic demand regime tends to be wage-led in all economies.[2] This is an important result in the perspective of the closed-economy model we propose in this paper. Moreover, "higher employment protection and more extensive labor market regulation are associated with higher labor productivity growth" (Storm and Naastepad, 2012). Indeed, "unregulated markets, weak employment protection, low taxes, high earnings inequalities, and weak unions are not at all necessary to sustain high rates of labor productivity growth; in actual fact, they are detrimental to technological dynamism" (Storm and Naastepad, 2012, p. 108). This is confirmed by Vergeer and Kleinknecht (2014) who find that weak wage growth and a smaller wage share significantly reduce labor productivity growth.

[1]As highlighted by Lavoie and Stockhammer (2012), the benefits of a wage-led growth strategy have been resurrected and formalized by several authors in the field of post-Keynesian and Kaleckian economics starting from the seminal contributions of Rowthorn (1981), Taylor (1983), and Dutt (1987).

[2]In an open economy context, total demand may be profit-led due to the prevailing effect of net export over domestic demand. For instance, global demand remains wage-led for European countries and the US, while it becomes profit-led for China (Onaran and Galanis, 2012).

Though the impact of the functional distribution of income on macroeconomic dynamics is topical, we should not neglect the dramatic increase of inequality in the personal income distribution.

On the empirical ground, much evidence have been brought suggesting that the dramatic increase of inequality is mainly to be related to the rise of top labor incomes (Atkinson et al., 2011).[3] Albeit there are differences between countries, top income inequality increased in all countries for which data are available, as shown by Jones and Kim (2014) employing data from the World Top Income Database on the shares of national income going to the top 1% over the period 1950-2008. Though a vast literature has stressed the role of skill-biased technical change in explaining the increase in labor income inequality since the 1970s (see, for instance, Katz and Murphy (1992), Acemoglu (1998), Acemoglu (2002), Acemoglu (2007), and Goldin and Katz (2008)),[4] some recent contributions focus on institutional factors, such as the decline of top tax rates, and on the role played by financial rents in shaping inequality dynamics (see, for instance, Philippon and Reshef (2009), Kaplan and Rauh (2010), Bivens and Mishel (2013) and Piketty et al. (2014)). Therefore, the increase in top income inequality should be related more to financial deregulation, tax laws and regulations in favor of the rich, rather than to technological factors and other explanations based on the alleged greater productivity of top income earners (Stiglitz, 2012).

Within the AB modeling literature, Ciarli et al. (2010) introduce a multi-layer organizational structure according to which firms are characterized by hierarchical tiers (i.e. the proportion of workers and executives) that affect the pay structure and the distribution of personal income. Furthermore, firms produce goods of diversified quality, and lower and higher classes have diversified tolerance for low quality and high prices. Their model gives rise to a first "demand-led" phase during which productivity is stable and a virtuous circle between employment, wages and firms' investment emerges; and a second "cumulative causation" phase, where productivity and product varieties increase and the distribution of wages becomes more skewed: inequality increases till the growth of income reaches a threshold, after which inequality stabilizes and then falls according to a sort of Kutznets curve.

The focus on the functional distribution of income between capitalists and workers is at the core of Napoletano et al. (2012): based on the "Keynes+Schumpeter" (KS) model (Dosi et al., 2010), they study how the interplay between firms' investment behavior and income functional distribution shapes macroeconomic dynamics, both in the short and long run. They find that a steady growth with low unemployment needs a balanced distribution between profits and wages and that wage flexibility is able to restore growth only under a (very unlikely) profit-led scenario, thereby casting serious doubts on the efficacy of labor flexibility in boosting economic growth.[5] Similarly, Dosi et al. (2013) show that unequal economies are exposed to more severe business cycle fluctuations, higher unemployment rates, and higher probability of crises. Finally, Dosi et al. (2016) presents an agent based model that investigates the effects of a "fordist" and a post-fordist "competitive" labor governance regimes, finding that more rigid labor markets and labor relations are conducive to coordination successes with higher and smoother growth.

The ABM approach thus seems to provide a natural framework to investigate the determinants of the evolution of both the personal and functional distribution of income and wealth, and its impact on the performance of the economic system. Hence, we aim at giving a contribution to the debate on the nexus between inequality and growth by proposing an Agent Based-Stock Flow Consistent Macroeconomic Model to assess the impact of different distributive regimes on innovation dynamics and economic development.

The remainder of the paper is organized as follows: section 2 sketches out the general structure of the economy and the sequence of events occurring in each simulation round. Section 3 provides a detailed characterization of agents' behavior. The features of the simulations setup are then presented in section 4. The results obtained in the baseline scenario and a summary of the validation exercise performed are reported in section 5. Section 6 presents the results of the computational experiment aimed at assessing the effects of progressive tax systems. Similarly, section 7 analyzes the result of the experiments conducted on wages downward rigidity. Section 8 concludes and set the future lines of this research.

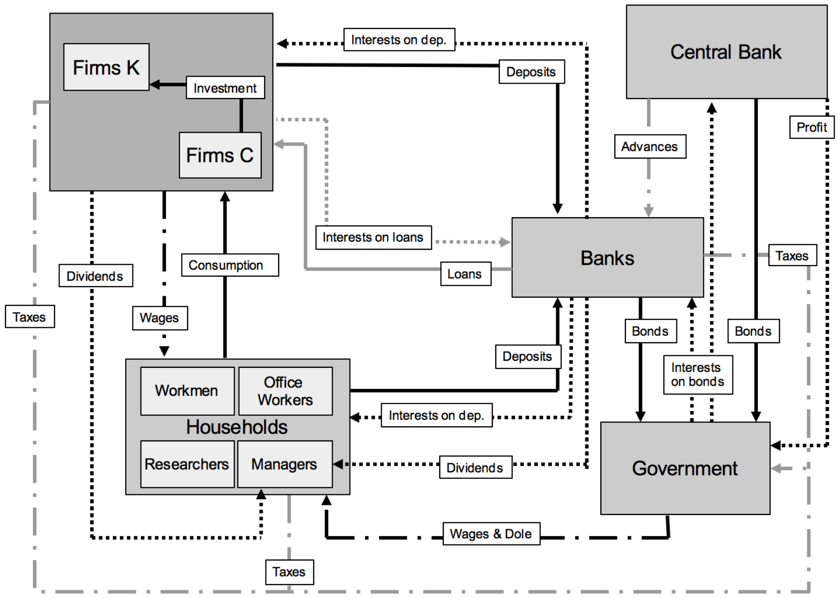

Figure 1: Flow Diagram of the model. Arrows point from paying sectors to receiving sectors.

2 The model

In a nutshell, our model[6] can be conceived as a combination of three major contributions in the AB literature. The core is represented by the AB-SFC "benchmark" model presented in Caiani et al. (2016). This bulk is then augmented by two additional blocks: first, R&D and innovation in the capital sector are shaped following the long-lasting evolutionary tradition building upon the Nelson and Winter's seminal models, and it thus resembles - though being simpler[7] - the innovation process described in the Keynes+Schumpeter family of models (Dosi et al. (2010) and later works). Second, the introduction of a hierarchical organization encompassing different tiers of workers - thereby affecting the distribution of income and wealth - is inspired by the models descending from Ciarli et al. (2010). Compared to these latter contributions, our model is simpler in that we maintain the number of tiers constant throughout the simulations, rather than allowing them to grow with the firm's size. Conversely, labor market interactions are more complex in that workers' wages in the different tiers endogenously emerge as the result of workers' competition process on segmented labor markets, rather than being mechanically determined as a multiple of the minimum wage.

The economy described by the flow diagram of figure 1 is composed of:

- A collection Φ_H of households selling their labor to firms in exchange for wages, consuming, paying taxes to government, and saving in the form of banks' deposits. Households are distinguished according to their function and income level into workmen ("blue-collars"), researchers and office workers ("white collars"), and top managers ("executives"). Managers are the owners of firms and banks, receiving dividends from them proportionally to their net worth and possibly participating to losses with their personal wealth in the case of a default.

- Two collections of firms: consumption (Φ_C) and capital (Φ_K) firms. Consumption firms produce a homogeneous consumption good using labor and capital goods manufactured by capital firms. Capital firms produce heterogeneous vintages of capital goods characterized by the binary $\{\mu_{kt}, l_k\}$,

[3]This is even more evident if we include "business income" (as profits from sole proprietorships, partnerships and S-corporations) in the labor income category (Jones and Kim, 2014).

[4]Moreover, inequality may rise due to the impact of general purpose technologies, by favoring workers that are able to adapt faster than others (Aghion and Howitt, 1997).

[5]Fana et al. (2015), based on empirical assessment of the effects of the recent Italian reform of the labor market, the so called "Jobs Act", comes to similar conclusions.

[6]The source code can be found at: https://github.com/S120/InequalityInnovation

[7]Indeed, for simplicity reasons we abstract from innovation processes affecting labor productivity employed in the capital good sector.

indicating respectively capital productivity and the capital-labor ratio, the latter assumed to be constant. Capital firms hire researchers to perform R&D with the objective of increasing the productivity of the capital good they produce. Firms can apply for loans to banks in order to finance production and investment. Retained profits are held in the form of banks' deposits.

- A collection Φ_B of banks, collecting deposits from households and firms, granting loans to firms, and buying bonds issued by the Government. Mandatory capital and liquidity ratios constraints apply. Banks can ask for cash advances to the Central Bank in order to restore the mandatory liquidity ratio.
- A Government sector, which hires a constant share of the workforce as public workers and pays unemployment benefits to households. The government holds an account at the Central Bank, collects taxes, and issues bonds to cover public deficits.
- A Central Bank, which issues legal currency, holds banks' reserve accounts and the government account, accommodates banks' demand for cash advances at a fixed discount rate, and possibly buys residual government bonds which have not been purchased by banks.

During each period of the simulation agents interact on five markets:

- A consumption goods market: households interact with consumption firms.
- A capital goods market: consumption firms interact with capital firms.
- Segmented labor markets: one for each type of households.
- A credit market: firms interact with banks.
- A deposit market: households and firms interact with banks.

Agents on the demand and supply sides of each market interact through a common matching protocol: 'demand' agents are allowed to observe the prices or the interest rates of a random subset of suppliers, whose size depends on a parameter χ reflecting the degree of imperfect information. Agents switch from the old partner to the best potential partner selected in this random subset with a probability Pr_s defined, following Delli Gatti et al. (2010); Riccetti et al. (2015); Caiani et al. (2016), as a non linear function of the percentage difference in their prices p_{old} and p_{new}. For loans and deposits, the interest rate is used instead. For capital goods, which are also differentiated for the productivity entailed by the vintage to which they belong, a synthetic measure of attractiveness, based on the price and productivity levels, is employed (see section 3.1.3). The shape of this function is governed by the "intensity of choice" parameter $\epsilon > 0$: higher values of ϵ imply a higher probability of switching.[8]

It can happen that some supplier exhausts its inventories available for sale, leaving customers with a positive residual demand. In this case, customers can turn to the other potential suppliers originally sampled, ordered according to their price, their interest, or their attractiveness index. Market interactions are 'closed' when all demanders have completely satisfied their demand, when there are no suppliers willing or able to satisfy their demand, or if demanders run out of deposits to pay for demanded goods.

2.1 Sequence of events

In each period of the simulation, the following sequence of events takes place:

1. *Production planning*: consumption and capital firms compute their desired output level.

[8]For the consumption and credit markets, where the price and the interest rate express a disbursement from the demander, the probability of switching to the new partner is decreasing with the difference between p_{old} and p_{new}:

$$Pr_s = \begin{cases} 1 - e^{\epsilon(p_{new} - p_{old})/(p_{new})} & \text{if } p_{new} < p_{old} \\ 0 & \text{otherwise} \end{cases} \tag{2.1}$$

The same specification is employed for capital goods, though with the prices being replaced by the synthetic indexes of attractiveness associated to each vintage. On the deposit market, where interest rates generates an income for the depositor, the probability of switching is instead:

$$Pr_s = \begin{cases} 1 - e^{\epsilon(p_{old} - p_{new})/(p_{old})} & \text{if } p_{new} > p_{old} \\ 0 & \text{otherwise,} \end{cases} \tag{2.2}$$

2. Firms' labor demand: firms assess the number of workmen, researchers, office workers, and managers needed.

3. Prices, interest, and wages: consumption and capital firms set the price of their output; banks determine the interest rate on loans and deposits. Workers of all types adaptively revise their reservation wages.

4. Investment in capital accumulation: consumption firms determine their desired rate of capacity growth.

5. Capital good market (1): consumption firms compare the productivities and prices of capital goods advertised by eligible suppliers, choose their preferred capital supplier, and place their orders so to attain their desired capacity growth.

6. Credit demand: firms assess their need for external credit. When positive, they select the bank to apply for a loan.

7. Credit supply: banks evaluate loan requests and supply credit accordingly.

8. Labor markets: unemployed households interact with the government and firms on the corresponding labor market: first, the labor market for workmen opens, then the market for office workers, afterwards the market for researchers, and finally, that for top managers.

9. Production: capital and consumption firms produce their output.

10. R&D Activity: capital firms perform R&D. In case of success, the productivity gain is embedded in capital goods produced from the following period onward.

11. Capital goods market (2): consumption firms receive capital units ordered from their suppliers. New machineries are employed in the production process starting from the next period.

12. Consumption goods market: households interact with consumption firms and consume.

13. Interest, bonds, and loans repayment: firms pay interests on loans and repay a (constant) share of each loan principal. The government repays bonds and interest to bonds' holders. Banks pay interests on deposits. Cash advances and related interests, when present, are repaid.

14. Wages and dole: wages are paid. Unemployed workers receive a dole from the government.

15. Taxes: taxes on profits of firms and banks, and taxes on income and wealth of households are paid to the government.

16. Dividends: dividends are distributed to firms' and banks' owners.

17. Deposit market interaction: households and firms select their deposit bank.

18. Bond purchases: banks and the Central Bank purchase newly issued bonds.

19. Cash Advances: the Central Bank accommodates cash advances requests by private banks.

In each period of the simulation, firms may default when they run out of liquidity to honor their commitments (e.g. wages, debt service, taxes) while banks default if their net wealth turns negative. The effects of firms' and banks' defaults are treated in section 3.3.

3 Agents' behavior

This section details the behavior of each type of agent. We employ the following notation in the equations. The subscript t indicates the period of the simulation to which the variable value refers. When generically referring to a firm, regardless its type, we employ the x subscript. Consumption firms' variables have a c subscript, capital firms' a k, banks' a b, generic households' a h, while workmen, office workers, researchers, and managers are identified by their initial letter, respectively w, o, r, m. Capital vintages are indexed by j. Expected variables are marked by a e superscript, while the desired or target levels of a variable are indicated by D, to distinguish them from their realization.

3.1 Firms' behavior

3.1.1 Production planning and labor demand

The desired output of firm x in period t (y^D_{xt}) depends on the firm's sales expectations s^e_{xt}.[9] We assume that firms want to hold a certain amount of real inventories, expressed by a share ν of expected real sales,

[9] All agents share the same simple adaptive scheme to compute expectations for a generic variable z:

$$z^e_t = z^e_{t-1} + \lambda(z_{t-1} - z^e_{t-1}) \tag{3.1}$$

as a buffer against unexpected demand swings (Steindl, 1952) and to avoid frustrating customers with supply constraints (Lavoie, 1992).

$$y^D_{xt} = s^e_{xt}(1+\nu) - inv_{xt-1} \text{ with } x = \{c,k\} \tag{3.2}$$

Firms are characterized by a simplified hierarchical structure of workers and executives: at the lowest tier of the pyramid there are workmen who are responsible for carrying out the production process. At the middle level, office workers (i.e. middle management) supervise workmen and are responsible for carrying out the "top floor" entrepreneurial strategies. These strategies are defined at the top of the hierarchy by the executive management, composed of "top" managers who are also assumed to be the owners of firms and banks.

Indeed, following Ciarli et al. (2010) and previous empirical and theoretical contributions on which they build upon (Simon (1957), Lydall (1959), Waldman (1984), Abowd et al. (1999), Prescott (2003)), we assume that firms are organized in distinct hierarchies of labor, where only low-tier workers enter the production process directly whereas workers in higher layers of the hierarchy are required to 'manage' the firm. In addition, capital firms hire researchers to perform R&D activities, which are assimilated to middle level workers in terms of their initial income and wealth endowments, though competing on their own segmented labor market.

This hierarchical organization indirectly affects the distribution of earnings and income in two fundamental ways: first, initial differentiated wages for each tier of workers are exogenously set in order to reflect a certain degree of inequality in the economy. Second, wages evolve endogenously during the simulation on the base of a decentralized matching process between firms and households on the different labor markets: the labor market for workmen, for office workers, for researchers, and for executives. Hence, both the functional and personal distribution of income and wealth evolve endogenously as a result of this process. For simplicity reasons we assume that there is no social mobility across classes of households and that the hierarchical structure of firms does not evolve over the simulation time-span.

The demand for low tier workers fundamentally depends on the productivity of workmen employed by firms and on their desired output level y^D_{xt}. Firms in the capital-good industry produce their output out of labor only. Capital firms' demand for workmen at time t, N^D_{kwt}, thus depends on y^D_{kt} and the labor productivity in that sector μ_N, which we assume to be constant and exogenous:

$$N^D_{kwt} = y^D_{kt}/\mu_N \tag{3.3}$$

By contrast, consumption firms employ labor in conjunction with different capital vintages purchased from capital firms. We indicate the collection of capital vintages composing consumption firm's c capital stock at time t by K_{ct}. Therefore, consumption firms' demand for labor depends on the productivities of the different vintages of capital employed in the production process. Assuming a constant capital-labor ratio $\overline{l_k}$ across capital vintages, the productivity of workers employing the vintage j can then be expressed as $\mu_{Nj} = \mu_j \overline{l_k}$, being μ_j the productivity associated to the capital vintage j. In order to minimize their unitary costs of production, consumption good producers rank the vintages in their current capital stock according to their productivity level, and employ them in the production process starting from the most productive vintages. Given y^D_{ct} - the desired output of firm c - the target rates of utilization u^D_{cjt} for each batch of capital k_{cj} (where j denotes the type of vintage and c the consumption firm) can then be derived from equation 3.4:

$$y^D_{ct} = \sum_{j \in K_{ct}} u^D_{cjt} k_{cj} \mu_j \tag{3.4}$$

Indeed, after having assigned an increasing index $j = 1, 2, 3$ etc. to the firm's capital vintages, ordered from the most to the least productive, we have that:

$$u^D_{cjt} = \begin{cases} 1 & \text{if } \sum_{i=1}^{j-1} u^D_{cit} k_{ci} \mu_j + k_{cj}\mu_j \leq y^D_{ct} \\ \frac{y^D_{ct} - \sum_{i=1}^{j-1} u^D_{cit} k_{ci}\mu_i}{k_{cj}\mu_j} & \text{if } \sum_{i=1}^{j-1} u^D_{cit} k_{ci}\mu_i \leq y^D_{ct} \text{ and } \sum_{i=1}^{j-1} u^D_{cit} k_{ci}\mu_i + k_{cj}\mu_j > y^D_{ct} \\ 0 & \text{if } \sum_{i=1}^{j-1} u^D_{cit} k_{ci}\mu_i \geq y^D_{ct} \end{cases} \tag{3.5}$$

The required number of workmen can then be calculated as:

$$N^D_{cwt} = \sum_{j \in K_{ct}} u^D_{cjt} \frac{k_{cj}}{\overline{l_k}} \tag{3.6}$$

Since the demand for workmen must be an integer, N^D_{kwt} and N^D_{cwt} are then rounded to the next larger integer (i.e. the minimum amount of workers required to attain the planned level of production).

In addition to workmen, firms need office workers to supervise and coordinate them and "executives" to manage firms' activity. Similarly to Ciarli et al. (2010), we assume that the proportions between different tiers of employees are fixed, though in our model the number of hierarchical tiers is given, rather than depending on the firms' size. Knowing $N^D_{xwt}, x = \{c, k\}$ we can compute the demand for office workers (N^D_{xot}), top managers (N^D_{xmt}), and - in the case of capital firms - researchers (N^D_{xrt}), as follows:

$$N^D_{xht} = N^D_{xwt}\frac{share_w}{share_h} \text{ with } h = \{o, r, m\} \tag{3.7}$$

$$share_w + share_o + share_r + share_m = 1 \tag{3.8}$$

where N^D_{xht} is the demand for workers of the generic type h and $share_w/share_h$ is the ratio between the (fixed) shares of workmen and type-h employees. Therefore, the requirement of workers of type h is expressed as a fraction of the firm' demand for workmen. Ultimately, capital firms' productive capacity is constrained by first-tier workers and their productivity only, whereas consumption firms' capacity may also be constrained by the stock of capital. Higher tiers workers on the contrary do not produce anything directly, but are nonetheless required to supervise workmen and to manage the firm, thereby concurring with their wages to increase firms' variable costs.

Employees in excess, when present, are randomly sampled from the pool of the firm's employees and fired. We also assume a positive turnover of employees, expressed as a share ϑ of firm's employees. The turnover applies indifferently on the different tiers. In other words, a share ϑ of workers is randomly sampled from the complete list of employees and fired at the beginning of each simulation period, before the labor markets open. The demand for each type of workers is adapted accordingly.

3.1.2 Pricing

Prices of goods are set as a non-negative markup mu_{xt} over expected unit labor costs:

$$p_{xt} = (1 + mu_{xt})\frac{W^e_{xt}N^D_{xt}}{y^D_{xt}} \tag{3.9}$$

where $N^D_{xt} = N^D_{xwt} + N^D_{xot} + N^D_{xrt} + N^D_{xmt}$ is firm's total labor demand and W^e_{xt} is the expected average wage of the firm's employees.

The mark up is endogenously revised from period to period following a simple adaptive rule. When a firm ends up having more inventories than desired (see section 3.1.1), or if the rate of capacity utilization of a consumption firm is below the desired level, the markup is reduced in order to increase the attractiveness of the firm's products:

$$mu_{xt} = \begin{cases} mu_{xt-1}(1 + FN_1) & \text{if } \frac{inv_{xt-1}}{s_{it-1}} \leq \nu \text{ and } u_{ct-1} \geq \overline{u} \\ mu_{xt-1}(1 - FN_1) & \text{if } \frac{inv_{xt-1}}{s_{it-1}} > \nu \text{ or } u_{ct-1} < \overline{u} \end{cases} \tag{3.10}$$

where FN_1 is a random number picked from a Folded Normal distribution with parameters ($\mu_{FN_1}, \sigma^2_{FN_1}$).

3.1.3 Investment

Investment is structured as in Caiani et al. (2016). In each period, consumption firms invest in order to attain a desired rate of growth of their productive capacity g^D_{ct}. This latter is defined as a function of their planned rate of capacity utilization u^D_{ct} (depending on y^D_{ct}) and their past-period rate of return, defined as in equation 3.12.

$$g^D_{ct} = \gamma_1\frac{r_{ct-1} - \overline{r}}{\overline{r}} + \gamma_2\frac{u^D_{ct} - \overline{u}}{\overline{u}} \tag{3.11}$$

$$r_{ct} = \frac{OCF_{ct}}{\sum_{j \in K_{ct-1}}(k_{cj}p_j)(1 - \frac{age_{jt-1}}{\kappa})} \tag{3.12}$$

Here, $\overline{u}$ and $\overline{r}$ denote firms' 'normal' rates of capacity utilization and profit respectively, both assumed to be constant and equal across firms. Equation 3.12 provides a broad measure of the firm's profit rate: by OCF_{ct} we indicate the firm's "net operating cash flows" (see section 3.1.5), that is the net cash inflows generated by the firm's activity. The denominator of equation 3.12 expresses the previous period value of the firm's capital stock, being age_{jt-1} the age in period $t-1$ of the batch of capital goods k_{cj} belonging to the collection K_{ct-1} of firm c, and p_j the original purchasing price.

Consumption firms are able to interact with a limited number of capital suppliers. In order to compare them, consumption firms follow a simple algorithm according to which capital vintage j is preferred to capital vintage i if:

$$\kappa(uc^e_{it} - uc^e_{jt}) > p_{jt} - p_{it} \rightarrow (uc^e_{it}\kappa + p_{it}) > (uc^e_{jt}\kappa + p_{jt}) \tag{3.13}$$

$$\text{where } uc^e_{zt} = \frac{W^e_{xt}}{(\mu_{zt}\overline{l_k}share_w)} \text{ ,with } z = \{i, j\} \tag{3.14}$$

where uc^e_i and uc^e_j indicate the expected unit labor costs associated with the two vintages[10], κ represents the technical life-span of capital goods, assumed to be constant and equal across vintages, and p_{jt}, p_{it} and μ_{it}, μ_{it} are respectively the prices and productivity levels of the two vintages. This rule is employed recursively by consumption firms in order to obtain a complete ordering of the capital vintages proposed by the potential suppliers, from the best to the worst.

The polynomials $(uc^e_{jt}\kappa + p_{jt})$ thus provides the synthetic measure of attractiveness associated to each capital vintage employed to calculate the probability of switching supplier, according to equation 2.1.

Having planned their desired capacity (i.e. having determined g^D_{ct}) and having chosen the capital vintage to buy, consumption firms assess their desired investment i^D_{ct} as the number of capital units required to replace obsolete capital and to fill the possible gap between current and desired capacity.[11] Nominal desired investment I^D_{ct} can then be computed by multiplying i^D_{ct} for the price p_{jt} asked by the selected supplier j.

3.1.4 R&D activity

Firms operating in the capital-good industry aim at increasing their market share and their profits by improving the technology embedded in their output through R&D investment. Capital firms' investment in R&D coincides with wages paid to researchers.[12]

Following the well established Evolutionary tradition (Nelson and Winter, 1977, 1982; Winter, 1984; Dosi et al., 2010; Caiani, 2017) we model firms' innovative research activity as a two-step stochastic process. First, a Bernoulli experiment is done to determine whether R&D activity has been successful. Innovator's k probability of success Pr^{inn}_{tk} is increasing with the number of workers hired to carry out research activity:

$$Pr^{inn}_{tk} = 1 - e^{-\xi^{inn} N_{krt}} \tag{3.15}$$

where $xi^{inn} > 0$. If successful, a productivity gain $\Delta_{\mu_{jt}}$ is sampled from a Folded Normal distribution FN_3 with parameters $(\mu_{FN_3}, \sigma^2_{FN_3})$.

The new productivity level, $\mu_{jt+1} = \mu_{jt}(1+\Delta_{\mu_{jt}})$, is then embedded in the output of the firm starting from the next period.[13]

In addition, capital firms also perform R&D imitative activity that possibly allows them to copy the technology of some competitors. The probability of success in imitating Pr^{imi}_{tk} is defined, similarly to innovation, as:

$$Pr^{imi}_{tk} = 1 - e^{-\xi^{imi} N_{krt}} \tag{3.16}$$

with $\xi^{imi} > 0$. In case of success, capital firms can imitate the technology of the most productive vintage within a batch of N^{imi} randomly sampled competitors.

[10] Notice that $\overline{l_k}$ indicates the ratio between capital units and workmen required to employ them in the production process. The overall capital-labor ratio, accounting for office workers and managers as well, can then be approximated by $\overline{l_k}share_w$ which is multiplied in the denominator of equation 3.14 to obtain the value of labor productivity associated with a certain vintage.

[11] Conversely, if $g^D_{ct} < 0$ implying that current capacity is greater than desired, they may abstain from investing or replace only partially capital units reaching obsolescence.

[12] As the number of researchers that capital firms want to hire is a constant share of workmen required for production, R&D investment eventually depends upon planned production levels, which are a function of expected real sales.

[13] For tractability reasons, we assume that also the stock of unsold inventories is updated at the new productivity level.

3.1.5 Firms' profits and finance

Consumption firms' pre-tax profits are the sum of revenues from sales, interests received, and the nominal variation of inventories,[14] minus wages, interests paid on loans, and capital amortization:

$$\pi_{ct} = s_{ct}p_{ct} + i^d_{bt-1}D_{ct-1} + (inv_{ct}uc_{ct} - inv_{ct-1}uc_{ct-1}) \dots$$
$$\dots - \sum_{n \in N_{ct}} w_{nt} - \sum_{j=t-\eta}^{t-1} i^l_j L_{cj} \frac{\eta - [(t-1)-j]}{\eta} - \sum_{j \in K_{ct-1}} (k_{cj}p_k)\frac{1}{\kappa} \tag{3.17}$$

where i^d_{bt-1} is the interest rate on past period deposits D_{ct-1} held at bank b, uc_c are unit costs of production, N_{ct} is the complete list of employees, w_{nt} is the wage paid to worker n, i^l_j is the interest rate on loan L_{cj} obtained in period $j = t-\eta, ..., t-1$, p_j is the price paid for the batch of real capital goods k_{cj} belonging to the firm's collection of capital goods K_{ct-1}, and η and κ are the duration of loans and capital respectively, assumed to be equal. Capital firms' profits only differ in that they do not display capital amortization.

Taxes are then computed on gross profits as: $T_{xt} = Max\{\tau_{\pi t}\pi_{xt}, 0\}$, $\tau_{\pi t}$ being the corporate profits tax rate at time t (see section 3.5). Dividends to managers are then computed as a constant share ρ_x of firms' after-tax profits: $Div_{xt} = Max\{0, \rho_x \pi_{xt}(1-\tau_{\pi t})\}$.

In addition to profits, we also define firms' net 'operating cash flows' OCF_{xt} as after-tax profits plus capital amortization costs (for consumption firms), minus the variation of inventories and principal repayments. As the name suggests, OCF_{xt} gives a more precise measure of the net cash inflows generated by the firm, compared to the accounting definition of profits (see Caiani et al. (2016) for the details).

Firms' demand for external finance L^D_{xt} is based on the slightly modified "pecking-order" mechanism explained in Caiani et al. (2016): although firms usually prefer internal funding to (expensive) external financing, they also want to maintain a certain level of deposits - expressed as a share σ of the expected wages disbursement - for precautionary reasons.[15]

3.2 Banks' behavior

3.2.1 Credit Supply

The behavior of banks resembles, without any relevant modification, that presented in Caiani et al. (2016) to which we refer for the details. On the credit market firms interact with several banks, selecting the best partner, and possibly obtaining multi-period loans.[16] As a consequence, firms generally have a collection of heterogeneous loans with different banks.

Banks' interest rates on loans depend on a comparison between bank's current capital ratio $CR_{bt} = NW_{bt}/L^{Tot}_{bt}$ - where NW_{bt} is the bank's net worth and L^{Tot}_{bt} are bank's outstanding loans - and a common target CR^T_t,[17] determined for simplicity reasons as the past-period average of the sector. When banks are more capitalized than desired, they offer an interest rate lower than their competitors' average, thus trying to expand further their balance sheet by attracting more customers on the credit market. In the opposite case, firms want to reduce their exposure: a higher interest rate has the twofold effect of making bank's loans less attractive while increasing banks' profit margin. Formally:

$$i^l_{bt} = \begin{cases} \bar{i}^l_{bt-1}(1+FN_2) & \text{if } CR_{bt} < CR^T_t \\ \bar{i}^l_{bt-1}(1-FN_2) & \text{otherwise,} \end{cases} \tag{3.19}$$

where $\bar{i}^l_{bt-1} = \frac{\sum_{b \in \Phi_B} i^l_{bt-1}}{size_{\Phi_B}}$ is the market average interest rate in the previous period and FN_2 is a draw from a Folded Normal Distribution $(\mu_{FN_2}, \sigma^2_{FN_2})$.

[14] In accordance with standard accounting rules, firms' inventories are evaluated at the firms' current unit cost of production. As a consequence, the value of inventories may vary due to variation of either their quantity or of their productive costs.

[15] Formally, consumption firms' credit demand can be expressed as:

$$L^D_{ct} = I^D_{ct} + Div^e_{ct} + \sigma W^e_{ct} N^D_{ct} - OCF^e_{ct} \tag{3.18}$$

where Div^e_{ct} is the expected disbursement for dividends (based on expected profits) and I^D is desired nominal investment. The equation of credit demand for capital firms can be obtained from equation (3.18) by simply omitting I^D.

[16] Loans last for $\eta = 20$ periods (i.e. 5 years): in each period firms repay a constant share $(1/\eta)$ of the principal.

[17] Yet, banks' capital ratio has a mandatory lower bound (6%).

A case-by-case credit rationing mechanism starts with banks evaluating applicants' single-period probability of default, under the hypothesis that the loan requested is granted. We define the 'debt service' variable as the first tranche of payment associated to this hypothetical loan: $ds^{L^d} = (i^l_{bt} + \frac{1}{\eta})L^d$. The probability of a default in each of the 20 periods ahead is then computed using a logistic function of the percentage difference between borrowers' OCF_{xt} and ds^{L^d}:

$$pr^D_x = \frac{1}{1 + \exp(\frac{OCF_{xt} - \varsigma_x ds^{L^d}}{ds^{L^d}})}, \tag{3.20}$$

ς_c and ς_k are two parameters expressing banks' risk aversion in lending to capital and consumption firms. The higher ς the more banks are risk averse (i.e. the higher the probability of default for given OCF and ds).[18]

The expected return of a credit project also depends on firms' collateral: consumption firms' collateral is represented by their stock of capital. In the case of a default by a consumption firm, each bank then expects to be able to recover a share $\delta_c \leq 1$ of the outstanding loans to the defaulted firm c through fire sales of its capital. δ_c is equal for all lenders and given by the ratio between firm's capital discounted value (see section 3.3) and firm's outstanding debt, being revenues from fire sales distributed across creditors proportionally to their exposure. δ_k is equal to zero, given that capital firms have no collateral. Knowing $L^d, i^l_{bt}, pr^D_x, \delta_x$, banks compute the overall expected return of a credit project by summing the payoffs arising from each possible outcome of the decision to grant the loan, each one weighted for its probability of occurrence.

Banks are willing to satisfy agents' demand for credit whenever the expected return is greater than, or equal to, zero. Otherwise, the bank may still be willing to provide some credit, if there exists an amount L^{D*} for which the expected return is non-negative.

3.2.2 Deposits and bonds market

Banks hold deposits of households and firms.

Given the fact that banks must satisfy a mandatory liquidity ratio of 8% and since deposits represent a source of reserves much cheaper than Central Bank cash advances (that is, $i^d_{bt} << \bar{i}^a_{cb}$) banks compete with each other on the deposit market.[19] As in the case of the capital ratio, we assume that banks have, besides the mandatory lower bound, a common liquidity target LR^T_t defined as the sector average in the last period.

When the liquidity ratio is below the target banks set their interest on deposits as a stochastic premium over the average interest rate in order to attract customers, and vice-versa when banks have plenty of liquidity:

$$i^d_{bt} = \begin{cases} \bar{i}^d_{bt-1}(1 - FN_2) & \text{if } LR_{bt} \geq LR^T_t \\ \bar{i}^d_{bt-1}(1 + FN_2) & \text{otherwise,} \end{cases} \tag{3.21}$$

where FN_2 being drawn from a Folded Normal Distribution $(\mu_{FN_2}, \sigma^2_{FN_2})$.

Finally, we assume that banks use their reserves in excess of their target (after repayment of previous bonds by the government) to buy government bonds. Remaining bonds are assumed to be purchased by the Central Bank. Finally, commercial banks pay taxes on profits and distribute dividends following the same rules of firms.

3.3 Firms' and banks' bankruptcy

Firms may go bankrupt when they run out of liquidity to honor their commitments (e.g. wages, debt service) while banks default if their net wealth turns negative. We assume defaulted firms and banks to be bailed in by their owners (i.e. the managers), thus maintaining the number of firms and banks constant.[20]

A bankruptcy by a firm implies that wages paid to workers are reduced or not paid at all, since deposits are insufficient to cover the expenses. In addition, it generates a non-performing loans for her

[18] The values of these parameters (see table 1) were set so that, at initial conditions, the probability of defaulting associated to capital and consumption firms (respectively pr^D_{c0} and pr^D_{k0}) are both equal to 1%.

[19] Whenever the liquidity ratio falls below the mandatory threshold banks apply for cash advances to the Central Bank (see 3.5).

[20] However, the 1-to-1 replacement hypothesis, quite common in the AB literature, does not imply that there is no industry dynamics since it does not prevent firms from differentiating from each other. On the contrary, firms tend to be highly heterogeneous, and the distribution of firm size, both in terms of productive capacity and real sales, displays fat tails.

creditors, who see their net wealth shrinking. In the case of capital firms, the loss is totally borne by banks as capital firms have no collateral. In the case of a consumption firm, we assume that its ownership passes temporarily to creditors which try to recover part of their outstanding loans through fire sales of the firm's physical capital to the class of "managers", who collectively own firms and banks proportionally to their individual net-worth.

The financial value of assets sold through fire sales is lowered by a share ι, representing a devaluation factor which makes it convenient for owners to repurchase machineries from creditors. When the discounted value of capital is greater or equal to the firm's bad debt, the loss caused by the bankruptcy falls completely on managers' shoulders. However, in general the loss is split between households and banks which are thus able to recover only a fraction of their loans. The disbursement for the repurchase of machineries from creditors is distributed across individual owners proportionally to their net wealth, as for dividends (section 3.4). Finally, if the net-worth of the firm is still below 25% of the firms' average net-worth in the industry, the owners make an additional deposit transfer to statisfy this minimum entry requirement. As for the fire-sales procedure of consumption firms' capital, each owner contributes to the recapitalization proportionally to his net-worth.

Banks default whenever their net-worth turns negative. We assume that owners bear the loss associated to the default. Owners intervene to restore a positive net-worth up to the point the capital ratio of the bailed-in bank is equal to the average one. The individual disbursement of owners is proportional to their net worth.

3.4 Households' behavior

All types of workers follow a similar adaptive heuristic to set their reservation wage: if over the year (i.e. four periods) they have been unemployed for more than t_u quarters, they reduce their reservation wage by a stochastic amount, and vice-versa. Therefore, the higher the level of unemployment, the greater the probability that agents revise downwardly their reservation wages:

$$w_i^{d,t} = \begin{cases} w_{ht-1}^D(1 - FN_1) & \text{if } \sum_{n=1}^4 u_{ht-n} > t_u \\ w_{ht-1}^D(1 + FN_1) & \text{if } \sum_{n=1}^4 u_{ht-n} \leq t_u \end{cases} \tag{3.22}$$

where $h = w, o, r, m$, $t_u = 2$, and $u_{ht} = 1$ if h is unemployed in t, and 0 otherwise. Therefore, we focus our attention on the role of labor market conditions on the four segmented labor markets in driving wage dynamics and wage differentials, though many other factors may be called upon, such as, for example, human capital, skills, and reputation. In particular, our mechanism tries to capture the impact of unemployment on workers bargaining power and wage claims (Carlin and Soskice, 1990). Yet, within our model there is another important source of differentiation in the overall compensation of workers. Indeed, executives also receive dividends as a remuneration of their participation in firms' and banks' equity. In fact, also in the case of large publicly listed firms, where the management is generally separated from the ownership, the compensation of managers often includes stock options, bonuses, and other contractual conditions allowing executives to participate to firms' profits and capital gains, just as traditional owners. As noticed by A.B. (2007), and remarked by Ciarli et al. (2010), wage differentials are not sufficient to explain the skewness in earnings distribution, while Frydman and Jenter (2010) shows that these remuneration mechanisms represent an important component of executives' overall compensation in the recent decades. We try to mimic these factors, which are not exclusively connected to labor market relations, by including dividends in the compensation of executives.

Workers consume with fixed propensities $\alpha_h, h = w, o, r, m$ out of expected real disposable income. These propensities are differentiated as higher income groups consume a lower share of their expected income. Because workers set their real demand before interacting with consumption firms, they formulate expectations on consumption goods prices p_{ht}^e. In addition, individual consumption displays a certain degree of downward rigidity in that consumers' demand cannot fall under a share β of past-period real consumption[21]:

$$c_{ht}^D = Max\left\{\alpha_h \frac{NI_{ht}}{p_{ht}^e}, \beta c_{ht-1}\right\} \text{ with } h = w, o, r, m \tag{3.23}$$

where NI_{ht} stands for the net income of household h at period t.

[21] Obviously consumption by households can still be financially constrained, so that c_{ht}^D might end up being unfeasible.

The idea of differentiated saving and consumption propensities according to income levels obviously stems from the Keynesian tradition.[22] The opposite Neoclassical view, embodied by the *permanent income hypothesis* instead takes that aggregate saving and consumption behaviors are not affected by the distribution of income, as consumption can be smoothed through lending and borrowing, despite the volatility of transitory income. This vision however has not been supported by evidence. On the contrary, the *relative income hypothesis* originally proposed by Duesenberry (1949) states that the households' saving rate is not linked to the absolute level of income but is positively associated with both the household's positioning in the distribution of income (in particular, with respect to her reference group) and the relation of the households current to past income (see also van Treeck (2014) on this latter aspect). The first aspect sets the basis for the well known "keeping up with Joneses" phenomenon according to which agents of different income groups tend to imitate consumption habits of superior classes, as well as to maintain the pattern of consumption of agents belonging to their same income group, even when their income drops. This habits persistence motivates our inclusion of a persistence parameter in households' consumption function.

The gross nominal income of workmen, researchers, and office workers is composed of wages and interests received on previous period deposits $w_{ht} + i^d_{bt-1} D_{ht-1}$, whereas executives workers also receive dividends from banks and firms Div_{mt}. Unemployed workers, regardless their type, receive a tax-exempt dole from the government which is defined as a share ω of the average wage of workmen only.

In the baseline of the model, we assume that households pay taxes on their income and wealth being subjected to two flat tax rates τ_{it}, τ_{wt}. Notice that, under this scenario, the income (wealth) tax load of each group, as well as the share of total taxes on income (wealth) each group pays, is proportional to the share of income the group earns (wealth it owns).

3.5 Government and Central Bank's behavior

Government behavior largely resembles that presented in Caiani et al. (2016): the public sector hires a constant share of households[23] and pays unemployment benefits (d_t) to unemployed people (U_t). However, some novelty aspects have been introduced: first, the government hires different types of workers with the same proportions characterizing consumption firms. Second, while in the original version of the model the state collected taxes only on income and profits, here we assume that the government charges taxes on households' wealth as well. Third, profits, income, and wealth tax rates $\tau_{\pi t}, \tau_{it}, \tau_{wt}$ follow an adaptive revision rule of the initial tax rates $\tau_{\pi 0}, \tau_{i0}, \tau_{w0}$ depending on the past variation of the debt/GDP ratio and the past level of the deficit/GDP ratio. Formally:

$$\tau_{it} = \tau_{i0} * rev_t \tag{3.24}$$

$$\tau_{wt} = \tau_{w0} * rev_t \tag{3.25}$$

$$\tau_{\pi t} = \tau_{\pi 0} * rev_t \tag{3.26}$$

where,

$$rev_t = \begin{cases} rev_{t-1} + \upsilon & \text{if } \frac{def_{gt-1}}{GDP_{t-1}} > def^1 \text{ or } \Delta \frac{debt_{gt-1}}{GDP_{t-1}} > 0 \\ rev_{t-1} - \upsilon & \text{if } \frac{def_{gt-1}}{GDP_{t-1}} < def^0 \text{ and } \Delta \frac{debt_{gt-1}}{GDP_{t-1}} \leq 0 \\ rev_{t-1} & \text{otherwise} \end{cases} \tag{3.27}$$

where def^0, def^1 are a lower and upper threshold parameters.

After having collected taxes on income and wealth from households, and taxes on profits from firms and banks, the state issues bonds b_t at a fixed price $\overline{p}^b$ and with fixed interest $\overline{i}^b$. Bonds last 1 period for simplicity reasons:

$$\overline{p}^b \Delta b_t = def_{gt} = T_t + \pi_{CBt} - \sum_{n \in N_{gt}} w_n - U_t d_t - \overline{i}^b \overline{p}^b b_{t-1}, \tag{3.28}$$

where $T_t = T_{Ht} + T_{Ct} + T_{Kt} + T_{Bt}$ are total taxes, π_{CBt} are Central Bank profits, N_{gt} is the collection of public workers.

The Central Bank buys bonds not purchased by commercial banks and accommodates banks' request for cash advances. Cash advances are assumed to be repaid after one period and their constant interest

[22] See section 4 for the details regarding the empirical evidence employed to calibrate these parameters.
[23] Public servants are also subject to a turnover ϑ.

rate represents the upper bound for interest on deposits offered by banks to customers. For simplicity reasons, we assume the Central Bank pays no interest on private banks' reserves accounts. Finally, Central Bank earns a profit equal to the flow of interest coming from bonds and cash advances: $\pi_{CBt} = \bar{i}^b B_{t-1} + \bar{i}^a_{CB} CA_{cbt}$. Central Bank's profits are distributed to the government.

4 Simulations Setup

In order to calibrate the initial conditions and parameters of the model we relied on the baseline configuration of the "parent" model presented in Caiani et al. (2016). In particular, the aggregate values of initial stocks and flows are computed according to the exact same procedure, though some values may differ as a consequence of the lower number of households employed in the present work (4000 instead of 8000). For the details regarding the calibration procedure we hence refer to that paper, which provides the full set of equations employed to set initial conditions and an extended discussion of some of the main challenges posed by the calibration of AB macro model in a Stock Flow Consistent (Godley and Lavoie, 2007) manner.

Here we remind that, as in the original calibration, we start from a symmetric initial characterization of agents belonging to the same classes. In particular, agents of a same class start equal regarding the type, number and amount of stocks they hold (e.g. machineries, consumption goods, deposits, loans), and the number of relations they have with other agents. For example, debt-credit relations linking firms to banks on the credit market are drawn randomly, albeit we ensure that each bank starts with the same number of loans, for the same amount, with similar ages and time to maturity, with the same number of customers. Conversely, firms start with the same number and amount of loans, having the same ages and time to maturity, and being supplied by the same number of banks.

Although the bulk of the baseline set up has undergone only minor amendments with respect to the previous version, some integrations is required as a consequence of the variations introduced in the model. These integrations are mainly related to the decomposition of the (previously aggregated) household sector in four subgroups.

We assume that different types of workers also represent different percentiles of income so that the size of each class and the share of income she earns are strictly connected. More precisely, we assumed that workmen, i.e. less specialized-low tier employees, correspond to the lowest 60 percentiles which collectively earn 30% of pre-tax total income. Office workers and researchers, who have equal initial personal income, can be conceived as the middle class. Together, they account for 30% of the total population and earn 40% of total gross income. Finally, executives represent the richest 10% of the population and collectively earn 30% of the gross income. In this way we aim at embedding in the model a realistic initial distribution of income: our setup is placed somewhere in the middle between advanced countries traditionally characterized by high inequality and advanced countries with low inequality.[24]

This configuration is then embedded in the model by properly tuning initial wages of each class of workers in order to attain the desired share of income. We indicate by w_0 the overall workers' average wage, its value being equal to initial wages in the Caiani et al. (2016) model. In order to keep firms' labor costs unaltered (compared to the "parent model" with a single type of workers), and taking into account the fact that managers also receive dividends (Div_{m0}) from firms and banks, we setup initial wages as follows[25]:

$$GI_0 = w_0 N_H + Div_{m0} = \underbrace{w_{w0} N_W}_{SI_{w0} GI_0} + \underbrace{w_{o0} N_O}_{SI_{o0} GI_0} + \underbrace{w_{r0} N_R}_{SI_{r0} GI_0} + \underbrace{w_{m0} N_M + Div_{m0}}_{SI_{m0} GI_0} \tag{4.1}$$

where GI_0 is total gross income, $SI_{w0}, SI_{o0}, SI_{r0}, SI_{m0}$ are the initial shares of income earned by each group, N_W, N_O, N_R, N_M are the total number of workmen, office workers, researchers, and mangers, and N_H indicates their sum.

Since office workers and researchers can be both considered as middle tier workers, we consider them as a unique group having a common initial wage. By indicating with $SP_h = N_h/N_H$ the share of the

[24] As a matter of example, in the US which are traditionally characterized by a significant level of inequality, the bottom 60% of households in the US earns a share of 29% of gross before-tax income, the next 30 percentiles earn approximately 35% of income, and the top 10% earns aproximately 36% of gross income. (Source: supplemental data of the US Congressional Budget Office's report "The Distribution of Household Income and Federal Taxes, 2011", 2014, available at https://www.cbo.gov/publication/49440).

[25] In order not to complicate too much the procedure and without lack of generality, we do not consider interests paid to households by banks, which constitute a negligible portion of households' gross income.

population which belongs to group $h = W, O, R, M$, we then obtain from equation 4.1:

$$SI_{m0}(w_0 N_H + Div_{m0}) = w_{m0} N_M + Div_{m0} \rightarrow w_{m0} = \frac{SI_{m0}}{SP_m} w_0 + \frac{Div_{m0}}{N_M}(SI_{m0} - 1) \tag{4.2}$$

$$SI_{w0}(w_0 N_H + Div_{m0}) = w_{w0} N_W \rightarrow w_{w0} = \frac{SI_{w0}}{SP_w} w_0 + SI_{w0} \frac{Div_{m0}}{N_W} \tag{4.3}$$

$$(SI_{o0} + SI_{r0})(w_0 N_H + Div_{m0}) = w_{or0}(N_O + N_R) \rightarrow w_{or0} = \frac{SI_{o0} + SI_{r0}}{SP_o + SP_r} w_0 + \frac{Div_{m0}}{N_O + N_R} \tag{4.4}$$

where w_{w0}, w_{or0}, w_{m0} are initial wages of workmen, office workers and researchers, and managers respectively. By SP_w, SP_o, SP_r, SP_m we indicates the share of the total population represented by each group (fixed).

Although wealth inequality is well known to be more pronounced than income inequality, we chose instead to employ the same distribution of income to setup initial shares of wealth held by each group (in the form of deposits), and see whether a realistic distribution of wealth emerges endogenously during the simulation as a consequence of agents' income dynamics and consumption/saving behaviors.

Total deposits held by households are then simply distributed across different types of workers according to these wealth shares.

In order to assess the impact of income inequality on consumption and demand patterns we also take into account the well known empirical fact that richer people tend to save a higher portion of their income with respect to poorer people. The same intuition was at the base of Keynes' fundamental psychological law of consumption which states that the marginal propensity to consume is between 0 and 1, implying that further increases in income levels increase consumption less than proportionally. Accordingly, we assume that the average propensity to consume of workmen α_w is equal to 95% whereas that of office workers and researchers ($\alpha_o = \alpha_r$) is lower and equal to 85%, and that of managers is equal to 75%.[26]

We assume that consumption firms' hierarchical structure reflects the subdivision of workers in different classes observed in the society. This means that the ratio between workers employed in different tiers, e.g. workmen and office workers, is equal to the ratio between the dimensions of the two populations. More formally, $share_w, share_o, share_m$ in equation 3.7 are respectively equal to SP_w, SP_o, SP_m. A similar assumption applies to capital good producers, although these latter also hire researchers to perform R&D activity. In this case we assume that $share_o$ and $share_r$ are both equal to 0.15, thereby summing up to 30%.

We then set the total number of households, the size of each workers group, and the number of employees in the capital and consumption sectors[27] so that all populations start with a rate of unemployment approximately equal to 8%, net of integer rounding of required workers' units. We then compute the value of labor productivity in the capital sector which allows to produce the initial desired level of output given the initial number of workmen employed. Similarly we set the initial productivity of capital goods (assumed to be equal across capital producers), and the technical ratio between capital units and workmen, at the level consistent with initial desired output, given the initial stock of capital available to manufacturers of consumption goods and the number of workmen initially employed in the sector. Desired output and real capital stocks in turn have been calculated following the procedure explained in Caiani et al. (2016).[28]

Table 1 in the appendix provides an overview of the parameters values employed in the simulations.

Simulation were then run for 1000 periods, each period representing a quarter, performing 25 Monte Carlo repetitions for each scenario.

[26]These values are reasonably similar to empirical ones: Dynan et al. (2004) reports that the lowest quintile has a propensity to save equal to 0.14%, the second 0.09%, the middle quintile equal to 11%, the fourth 17%, and the top quintile equal to 23.6%. Yet, the average saving rate increases significantly for top percentiles as the top 5% and 1% of households saves 37.2% and 51.2% of their net income. This suggests that our average propensities to consume may slightly overestimate the empirical equivalent for high-income earners. This is required to avoid putting excessive depressive pressure on our artificial system where savings mostly remain idle, whereas in reality they can circulate again, for example as inter-generational transfers, or being invested in real estates, or in financial assets.

[27]In this respect we keep the same proportions between sectors employed in Caiani et al. (2016). Workers employed in each sector are then equally distributed across firms.

[28]Notice that since only workmen are directly employed in the production process, whereas other types of workers are in charge of different functions (supervision and basic management, R&D, strategic management), labor productivity in the capital good sector and the capital-workmen ratio are both significantly higher than the correspondent values in the previous version of the model.

5 Baseline results, an overview

5.1 Validation

After having run our simulation experiments we first proceeded to the empirical validation of the model results.

This procedure yields very similar qualitative and quantitative results compared to the original model, suggesting that also the current version provides a good approximation of the properties displayed by real world data and matches a huge variety of micro and macroeconomic stylized facts. On the macro level, artificial time series volatility resembles the relative volatility of main real aggregates[29] and their auto and cross correlation structure, the only difference in this respect being represented by consumption which is still positively correlated to real GDP but appears to be lagged by two quarters, rather than coincident. This can probably be explained by the inclusion of a persistence factor in agents' consumption function (eq. 3.23). On the other hand, this characteristic of the model allows to match a more important stylized facts for the purpose of the paper: the greater-than-one average propensity to consume observed at the low end of the income distribution (see Fisher et al. (2015)): in our model this can be explained by the fact that workers who lost their jobs adapt their demand for consumption goods only gradually, using deposits as a buffer stock to fund consumption, so that their average propensity to consume can be greater than one, possibly for several periods, as observed in reality.

In accordance with the empirical evidence on prices dynamics over the business cycles, inflation tends to be pro-cyclical and lagging whereas mark-ups are counter-cyclical and lagging (Bils, 1987; Rotemberg and Woodford, 1999). In addition, the model is fairly in line with the stylized facts highlighted in Klenow and Kryvtsov (2005) concerning the frequency of price changes and the relative frequency of price-decreases and increases. Also changes in inventories and inventories/sales ratio are in accordance with available empirical evidence (Bils and Kahn, 2000), the former being pro-cyclical and the latter counter-cyclical. As in the original model banks leverage tends to be moderately pro-cyclical (Nuño and Thomas, 2013) while firms' total debt (Lown and Morgan, 2006; Leary, 2009) and firms' leverage are pro-cyclical.

Finally, real GDP growth rates have the typical tent-shaped leptokurtic distribution (Fagiolo et al., 2008).

At the micro level, we observe that our artificial firms are highly and persistently heterogeneous regarding their dimension, market shares and productivity levels. This differences are generated by selection processes occurring in both capital and labor markets, which are enhanced by the process of Schumpeterian competition triggered by innovation. In accordance with the empirical evidence, firms' investment appear to be lumpy rather than smoothed over time. In addition, all the properties extensively discussed in Caiani et al. (2016) related to firms' size distribution, banks' credit, credit degree, and bad debt distributions continue to hold also for the model presented here. All distributions are right-skewed and characterized by excessive kurtosis and fat tails.

Finally, the model produces plausible outcomes for both income and wealth distributions, as measured by the Lorenz Curve and the Gini Index. Though income and wealth have the same initial distribution, the model highlights that wealth inequality ends up being significantly more marked than income inequality.

Properties highlighted in this section are robust across all the configurations analyzed in the paper.

5.2 Baseline dynamics

Before focusing our attention on the relationship between inequality and economic growth, in the present section we provide an overview of the model dynamics in the baseline scenario. For this sake, panel 2 displays a selection of relevant economic variables. Variables values refer to the time span 500:1000 of a single simulation.[30]

Figures on the top line show that the model generates exponential real growth of both real GDP and consumption. Real consumption grows as a consequence of two phenomena: on the supply side, the incremental innovation process taking place in the capital good sector, allows to produce ever-increasing quantities of goods thanks to the higher capital productivity of new vintages which increases labor productivity in the consumption sector; on the demand side, the trend of wages grows faster than that of productivity and prices, so that the greater production of consumption firms can generally find an outlet in

[29] With investment and unemployment volatility being significantly more volatile than real GDP, and consumption being slightly less volatile than output.

[30] In all the experiments performed in the paper, the transition takes approximately 200 periods before the system converges to a quasi-steady trend.

the market thanks to the increasing real aggregate demand. The number of units of capital purchased by consumption firms instead fluctuates around a broadly steady level. The fact that real capital units do not show the persistent increasing trend displayed by real output and real consumption units is not surprising, given our assumption that labor productivity in the capital good sector is constant. Conversely, the fact that they do not decline testifies that real demand for consumption goods and firms' desired production levels grow with similar trends, so that the capital and labor-saving effects of technological change are offset by firms' desire to increase their productive capacity.[31]

Unemployment fluctuates around approximately 15% for most of the time span displayed. This value is fairly high compared to the baseline of the 'parent' version of the model where unemployment fluctuated around 8%. This can be easily explained by the fact that the average propensity to consume of the household sector as a whole is significantly lower compared to the original version, as a consequence of the lower propensity of middle and high income workers. The lower demand in turn tends to depress the economy. While one may be prone to ascribe higher unemployment to the inclusion of innovation in the model, which may exert a labor-saving effect, a set of pilot simulations especially performed to test this hypothesis seems to reject it for values of the innovation parameters in a neighborhood of the selected ones.

The slightly increasing trend of unemployment in the last part of the simulation seems to be due to increased inequality, which causes a greater share of income to go in the hands of low-propensity-to-consume agents thereby slowing down demand growth for consumption goods, compared to their supply.

The three figures also highlight that economic development unfolds through a succession of economic cycles. The darker and lighter gray areas highlight, by way of example, one of them. Economic upturns and downturns are the combined effect of both real and financial factors: an initial increase of investment caused by a spur of consumption firms' profit rates (see the periods before the darker gray area in the bottom-center figure of panel 2) triggers a process of expansion which allows employment, demand, and production to grow together. Higher demand causes firms' capacity utilization rates to increase (bottom-left figure in panel 2) while the greater impulse to innovation caused by rising output allows firms to maintain and even increase their profit margins (bottom-center figure in panel 2), notwithstanding wages faster increase due to lower unemployment. On the contrary, wages recovery after the previous economic slowdown allows firms' higher production to translate into higher sales. Altogether this stimulates further increases in investment and a parallel increase in loans: in fact, firms are more prone to apply for loans as a consequence of higher wages, and banks are more willing to grant credit due to higher operating cash flows of applicants. Consumption firms' leverage then increases (bottom-right figure in 2). However, further increases of workers' wages, in particular of middle and top tiers (see section 7) and augmented outlays to service the debt start squeezing firms' profit margins. The possible over-investment of some firms and the progressive replacement of old capital batches with new more productive vintages, on the other hand, tend to reduce both labor and capital requirements. As a consequence, the investment upturn is reversed though it takes some time before the cycle is reverted for unemployment and consumption as well. In the meanwhile, firms which had undergone excessive debt and investment, being exposed to this worsened economic scenario, start defaulting causing further drops in demand and employment. The economy undergoes a period of contraction (top line figures 2) and de-leveraging, as displayed by the lighter gray area in the bottom-right figure of panel 2. This phase continues till the debt and capital in excess are absorbed and the adjustments of wages, unit costs, and prices allow firms to recover some profitability. On the other hand, the slowdown of firms' productive capacity growth puts a brake to the fall of capacity utilization rates caused by the recession. Investment can then recover, possibly setting the stage for a new expansionary phase.

6 Policy Experiment: testing different tax regimes

6.1 Implementing a progressive tax scheme on income and wealth

Empirical evidence suggests that income and wealth inequality exert an impact on innovation and output dynamics, possibly hampering economic growth. The same seems to happen in our model where we account for the fact that different income groups are generally characterized by different propensities to consume and save, so that the distribution of income and wealth starts to exert an impact on aggregate

[31] Yet real investment, computed as nominal investment divided by average consumption goods price, is increasing as a consequence of the higher inflation of capital goods prices. This in turn can be attributed to the fact that more productive capital goods reduce unit labor costs of consumption firms, on which the markup is applied, thereby dampening inflation. On the contrary, this does not happen for capital firms given their workmen's constant productivity.

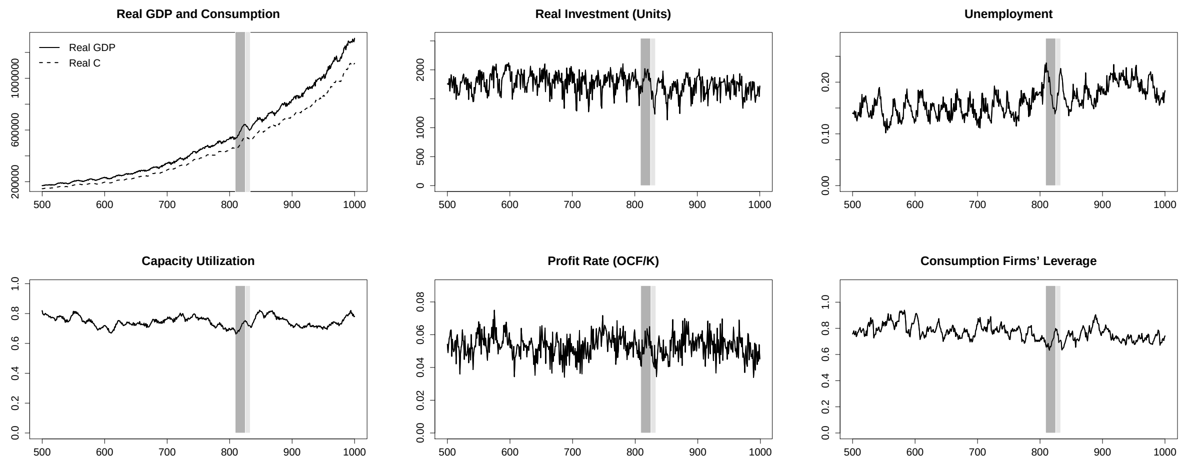

Figure 2: **Baseline Run 1** Top, Left: real GDP. Top, Center: real units of capital goods purchased. Top, Right: global unemployment. Bottom, Left: consumption firms' average capacity utilization rate. Bottom, Center: consumption firms' average rate of profit computed as OCF/capital financial value. Bottom, Right: consumption firms' average leverage

demand. To investigate this possibility we employ the model to evaluate the impact of alternative tax regimes characterized by different degrees of progressiveness. In particular, we focus on their efficacy in redistributing income across different social groups and on the impact exerted by this redistribution on the performance of the economy.

Under a flat tax rates regime, each subgroup of the household sector contributes to total taxes on income (or wealth) for a portion equal to the share of income earned (share of wealth owned), irrespective of the number of agents belonging to that group; that is, irrespective of agents' personal income levels.

The condition to realize a redistribution of income (wealth) through a progressive tax system instead, requires that people having income (wealth) above the average contribute to total tax payments more than proportionally to their income (wealth) share, and vice-versa. The ratio between the share of income SI_{Ht} earned (wealth SW_{Ht} owned) by each group of workers and the share of population they represent (SP_h) can then be employed to compare the group's average per capita income with the overall average income of the economy, as shown hereunder:

$$\frac{SI_{ht}}{SP_h} = \frac{GI_{ht}/GI_t}{N_h/N_T} = \frac{GI_{ht}/N_h}{GI_{Ht}/N_T} \tag{6.1}$$

$$\frac{SW_{ht}}{SP_h} = \frac{GW_{ht}/GI_t}{N_h/N_T} = \frac{GW_{ht}/N_h}{GI_{Ht}/N_T} \tag{6.2}$$

In order to isolate the effects arising from the redistribution of income from the effects originating from a possible variation of the total tax load of workers, we designed our artificial progressive tax regime in a way such to realize a "tax shift" between workers' classes. That is, we design it so to operate a redistribution of the total tax burden between workers' groups, leaving unaltered the total tax load of the household sector. This latter is given by total taxable income (wealth) of households multiplied by the current 'benchmark' tax rate τ_{it} (τ_{wt}, computed by the government as explained in section 3.5). This is not to say that a redistribution of income operated through our tax shift experiment does not exert an impact on public finance as well. On the contrary, since different groups have different propensities to save and consume, the tax shift is likely to affect aggregate demand patterns, thereby influencing public finance in different ways: for example, through a variation of taxable income, and then tax revenues, or through a variation of public spending for unemployment doles, or still indirectly, given that variations of nominal GDP affect deficit-to-GDP and debt-to-GDP ratios.

If instead the tax rates in the progressive tax regimes were designed so that the total tax load of households would be eventually modified, it would be far more difficult to assess in an unambiguous way how much of the effects observed were to relate to the redistribution of income, and how much to the fiscal contraction (or expansion) which implicitly accompanied it.

Therefore, in each period of the simulations, the government first determines the overall income and wealth tax burden of households as $TI_t = GI_t\tau_{it}$ and $TW_t = NW_t\tau_{wt}$ respectively, and then redistributes it across workers' groups.

Keeping in mind that with a flat tax rate this amount is distributed according to households sectors' shares of income SI_{Ht} (wealth SW_{Ht}) we can employ the ratio in equation 6.1 to define the following correction factors of the tax-burden for each group h:

$$correction^{i}_{ht} = SI_{ht}\left(\frac{SI_{ht}}{SP_h}\right)^{\theta} \quad \text{with } \theta \geq 0 \tag{6.3}$$

$$correction^{w}_{ht} = SW_{ht}\left(\frac{SW_{ht}}{SP_h}\right)^{\theta} \quad \text{with } \theta \geq 0 \tag{6.4}$$

where the first equation refers to income taxes, and the second to taxes on wealth.

These correction factors are then normalized in order to compute the shares of total taxes to be charged on each class of households:

$$tax\ burden^{i}_{ht} = \frac{correction^{i}_{ht}}{correction^{i}_{wt} + correction^{i}_{rt} + correction^{i}_{ot} + correction^{i}_{mt}} \tag{6.5}$$

$$tax\ burden^{w}_{ht} = \frac{correction^{w}_{ht}}{correction^{w}_{wt} + correction^{w}_{rt} + correction^{w}_{ot} + correction^{w}_{mt}} \tag{6.6}$$

$$\tag{6.7}$$

Finally, knowing total taxes and the share to be paid by each group, we derive the correspondent tax rates on income and wealth for each workers' class:

$$TI_{ht} = \underbrace{(GI_t\tau_{it})}_{TI_t} tax\ burden^{i}_{ht} = \underbrace{(GI_t SI_{ht})}_{GIht} \tau_{iht} \rightarrow \tau_{iht} = \frac{\tau_{it}\, tax\ burden^{i}_{ht}}{SI_{ht}} \tag{6.8}$$

Office workers and researchers, who starts with the same levels of personal income and wealth, are treated together and are then subject to the same tax rates.

Two things must be noticed about the procedure just explained. First, the greater the parameter θ the more pronounced the redistribution through taxes.[32]

Second, for $\theta = 0$ $tax\ burden^{i}_{ht} = SI_{ht}$ and $tax\ burden^{w}_{ht} = SW_{ht}$ so that the progressive tax scheme reduces to the original flat tax rates scheme, being $\tau_{iht} = \tau_{it}$ and $\tau_{wht} = \tau_{wt}$.

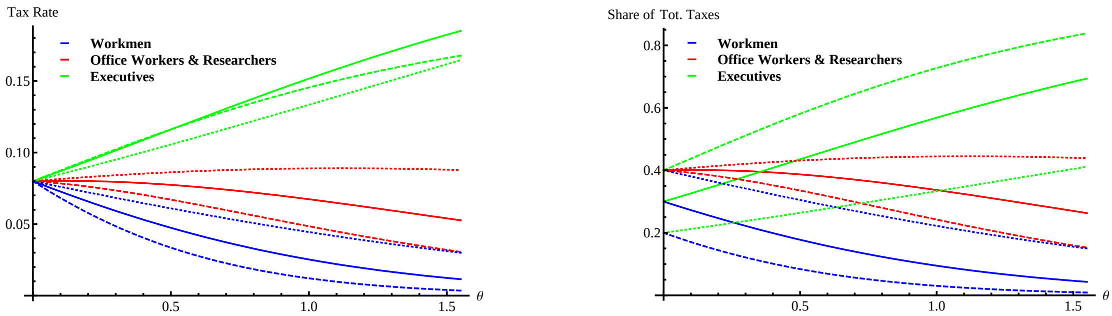

Figure 3: **Impact of θ on Groups' Tax Rates (left) and Tax Burdens (right):** Continuous lines correspond to an income distribution equal to that employed to setup our simulations: $SI_w = 0.3$, $SI_{o\&r} = 0.4$, $SI_m = 0.3$. The dotted lines correspond to a hypothetical configuration with: $SI_w = 0.4$, $SI_{o\&r} = 0.4$, $SI_m = 0.2$. Finally the dashed lines correspond to a hypothetical configuration with: $SI_w = 0.2$, $SI_{o\&r} = 0.4$, $SI_m = 0.4$. Population shares are kept equal across the three cases and correspond to the value employed in the simulations (see table 1 in the appendix).

Figure 3 graphically displays, for explanatory purpose, how the parameter θ affects the tax burden (expressed by the share of total taxes paid) and the tax rate of each group of workers, for given income distributions. We consider three different configurations of income: the initial one employed in our simulations (continuous lines); a more equal configuration with $SI_w = 0.4$, $SI_{o\&r} = 0.4$, and $SI_m = 0.2$ (dotted lines); and a more unequal configuration with $SI_w = 0.2$, $SI_{o\&r} = 0.4$, and $SI_m = 0.4$ (dashed lines). The left figure shows that for $\theta = 0$ all tax rates are equal to the benchmark one fixed by the government, so that, in the right figure, the share of taxes charged on each group is equal to the share of income it earns. Instead, greater values of θ redistribute a greater share of the tax load on richer people.

[32] Indeed, for positive values of θ, the higher the average income of a group compared to the global average (i.e. the higher $\frac{SI_{ht}}{SP_h}$), the higher the share of taxes paid by that group ($tax\ burden^{i}_{ht}$) will be. The same occurs for taxes on wealth.

However, the figure also shows that, while a higher $\frac{SI_{ht}}{SP_h}$ always corresponds to a higher *tax burden*$^i_{ht}$, the tax rate can be either higher or lower for given values of θ, as one can observe by looking at the dashed and continuous green lines for the tax rates of executives. Identical considerations apply to taxes on wealth.

For this experiment we tested 7 different values of θ ranging from 0 to 1.5 with an increment of 0.25 between subsequent scenarios. Figures 4,5,6 display a collection of plots highlighting differences between tax regimes tested in the experiment. For graphic reasons and to allow an intuitive interpretation of results the trend and cycle components of artificial time series have been separated using the Hodrick-Prescott filter and Monte Carlo average trends have been employed in the figures. All time series displayed refer to the time span 500:1000. Lighter lines refer to greater values of the parameter θ.

For a quantitative assessment of results, table 2 in the appendix provides a summary of results obtained under each tax system, accompanied by the outcome of the tests for difference between data populations generated in the baseline and in each alternative scenario.

The results of our experiments suggest that introducing a progressive tax system improves the dynamics of the system: real GDP, real consumption, investment (panel 4 top line) are significantly higher than in the flat-tax rate baseline for every $\theta > 0$ scenario. The same occurs to labor productivity (second line-center), with the only exception of the $\theta = 0.25$ scenario (i.e. the most moderate progressive scheme) which displays a pattern very close to the baseline one. Conversely, despite the greater productivity of capital goods in most “progressive” scenarios, the fact that demand and output increase more than proportionally, causes unemployment to be lower on average under all scenarios with $\theta > 0$. The enhanced dynamics of wages due to lower unemployment and higher demand in turn causes average inflation to rise slightly with higher values of θ, though always remaining at moderate levels (center-right figure in 4). Finally, also public finance seems to benefit from the improved system dynamics as the debt to GDP ratio (bottom-left in panel 4) tends to decrease under more progressive scenarios. Figures in panel 5 highlight a very important aspect of these experiments: real consumption seems to increase as a consequence of a transfer of purchasing power and consumption from top managers to workmen and office workers. While the share of financially constrained consumption of the former tends to increase for greater values of θ, as a consequence of the increase in their tax rates, the financial constraint of the latter is significantly lessened (top line plots in figure 5). As a result, the consumption of lower income groups markedly increases, boosting real output growth. On the contrary, top managers’ real consumption is unaltered in most scenarios or even decreases in the most progressive tax regime, where the overall growth of output is not sufficient to offset their tighter financial constraint.

On the firms’ side, investment increases as a consequence of greater profits margins due to higher demand and enhanced innovation dynamics, while the growth of investment tends to counteract rising output keeping average capacity utilization rates at similar levels. The overall effect of investment and profit dynamics is that firms’ finance appears to be not significantly affected by the change in the tax system. Indeed, the trends of firms’ credit gap under the seven different scenarios, which eventually depend on firms’ demand for credit and firms’ operating cash flows, tend to overlap (center and right figures in the bottom line of 4).

Finally, figure 6 displays the Lorenz Curves and Gini Indexes associated to income and wealth in the 7 experiments performed. These plots show several important features of the model: first, the baseline is characterized by very high level of inequality for both income and wealth, the latter being considerably more pronounced than the former. Second, inequality in income and wealth tends to decrease moving towards more progressive tax schemes. Third, despite the reduction of inequality from scenario to scenario, all experiments are characterized by a rising trend in income and wealth polarization. Growing inequality in the distribution of income seems to be mainly due to the different pace at which wages of different groups grow. These imbalances in wages patterns of growth in turn originate from the fact that the four labor markets of the model are characterized by different degrees of competition, notwithstanding their identical structure and despite different types of workers employ the same routines to set their reservation wage. The main reason for this lies in the hierarchical structure of firms: given proportions across different tiers of workers, large variations of workmen employment are required to induce a unit variation of firms’ demand for office workers and researchers, and even larger variations are necessary to induce a unitary change in top managers’ employment. This implies that higher tiers workers’ employment is relatively more stable compared to lower ones’, boosting a faster growth of wages. Indeed, the greater stability of employment in higher tiers implies that, even when average unemployment rates across classes are at par, the overall turnover of workers in the higher tiers will be lower than in the bottom tiers: people employed in the higher tiers tend to be employed for longer timespan so that wages upward revisions in these classes are more frequent compared to those of lower tiers where workers

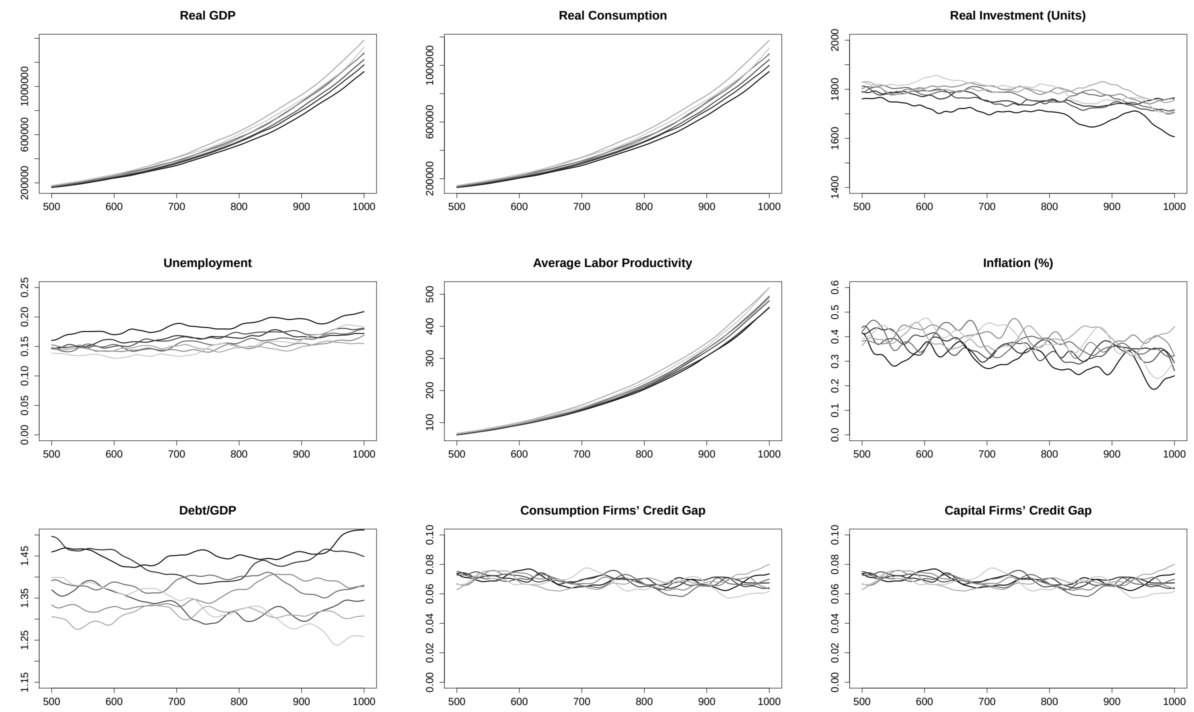

Figure 4: **Different Tax Schemes:** Lighter gray lines correspond to higher values of θ. Top, Left: Real GDP. Top, Center: Real Consumption. Top, Right: Real Investment. Growth rates of prices have been computed using average market prices (weighted for firms' market shares). Center, Left: Unemployment. Center, Center: Consumption Firms' Average Labor Productivity (weighted for consumption firms' output shares). Center, Right: Inflation. The growth rates of prices have been computed using average market prices (weighted for firms' market shares). Bottom, Left: Government Debt/GDP ratio. Bottom, Center: Consumption Firms' Credit Gap as: Credit Demanded/Credit Received. Bottom, Right: Capital Firms' Credit Gap

are more likely to experience temporary periods of unemployment, during which they may decrease their reservation wage.

Figure 5: **Different Tax Schemes:** Lighter gray lines correspond to higher values of θ. Top Left, Center, Right: Workmen's, Office Workers&Researchers', and Top Managers' Shares of Financially Constrained Consumption. Bottom Left, Center, Right: Workmen's, Office Workers&Researchers', and Top Managers' Real Consumption.

In addition to the previous properties, figures from 4 to 6 all highlight another important aspect: while the gains of a more progressive tax scheme appear to be evident for low values of θ, these gain tends to reduce, or even fade out, for further increases of the "progressiveness" parameter when θ is already high. Table 2 in the appendix, for example, shows that final real GDP in the $\theta = 1.25$ case is 30.59% higher than in the baseline, whereas it is only 25.95% greater in the $\theta = 1.5$ case.[33] Similarly, the Gini index calculated on income is 9.07% lower in the former case, while it is only 8.33% lower in the latter.[34] Even though this apparent non-monotonicity may be partially due to stochastic factors, possibly fading out with a higher number of Monte Carlo repetitions, there is a more fundamental explanation for the decreasing gains across scenarios with higher values of θ. When the tax rate charged on lowest income households is already very low, further decreases of the tax rate do not significantly increase disposable income available for consumption, and thus they are less effective in increasing demand. This also implies that when the incomes of high and low income workers' classes proceed at very different paces, cutting taxes to poor people may not be sufficient to revert the increasing inequality trend.[35]

All in all, the evidence provided by our experiments suggests that progressive taxation is an effective tool to attenuate income and wealth inequality and to foster prolonged real economic development. In particular, our results seem to provide some ground for the thesis according to which tax system reforms more favorable to high income households[36] may be called into question as one of the factors which have contributed to feed the long-lasting wave of rising inequality observed in many advanced countries. However, our experiments also suggest that ex-post reditribution of income through progressive taxation may be insufficient, alone, to stop and reverse this tendency.

This motivates a quest for alternative measures which aims at tackling inequality directly in the wages determination sphere, that is on the labor markets.

[33] In addition, figure 4 shows that the average trends for the $\theta = 0.75$ and $\theta = 1.0$ cases tend to overlap, whereas the latter is slightly lower if we consider the average deviation from the baseline in table 2.

[34] To be thorough, this does not happen for wealth inequality measures which are consistently decreasing from scenario to scenario.

[35] However, the property observed may be partly connected also to the peculiar configuration of our experiments, where the tax rates of different workers' groups were computed so to maintain the overall tax load on households unaltered compared to the flat tax rate system. As already discussed, the functions adopted for this sake (eq. 6.8) imply that $tax\ burden^i_{ht}$ is an increasing function of $\frac{SI_{ht}}{SP_h}$, while τ_{iht} may be also decreasing if the rise of $tax\ burden^i_{ht}$ determined by eq. 6.3 and 6.5 is less than proportional to the rise of income share held by group h. Therefore, an increase in income polarization, though determining an increase of the tax burden for high-income groups and a correspondent decrease for low-income agents, may be accompanied by a reduction of tax rates for all groups, which softens the redistributive efficacy of the tax scheme.

[36] Among these we mention the progressive reduction of top statutory personal income tax rate and top marginal tax rates for employees occurred since the '80s. In some countries, such as the US, this drop has been of the order of more than 20% (from 70% in 1981 to 47% after 2007) according to OECD data.

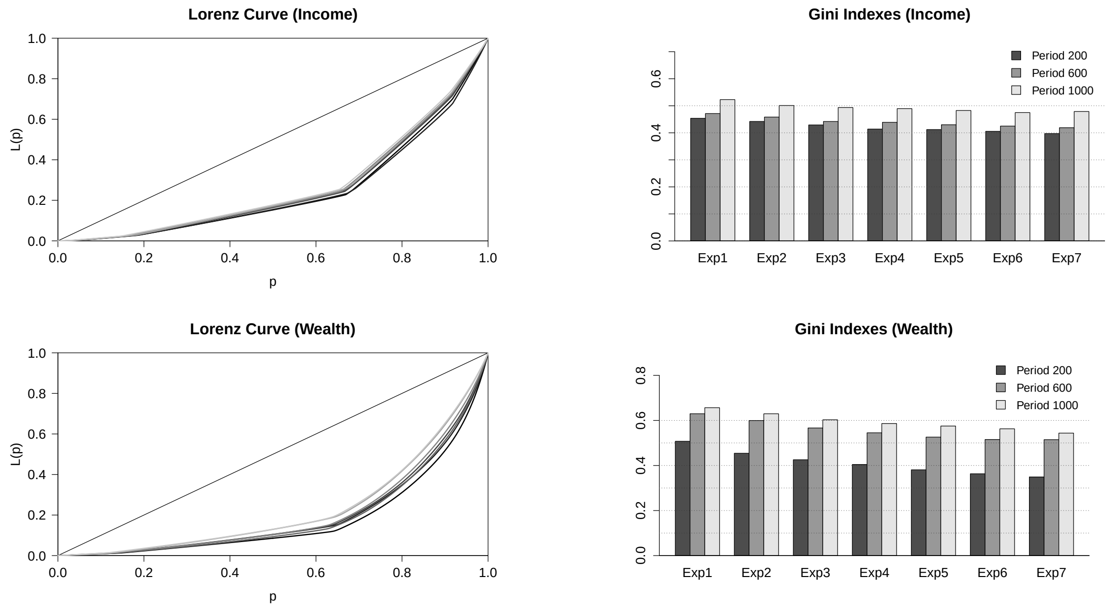

Figure 6: **Different Tax Schemes:** Lighter gray lines correspond to higher values of θ. Top, Left: Lorenz Curve (Income) at period 1000. Top, Right: Gini indexes (Income) at different simulation time steps. Bottom, Left: Lorenz Curve (Wealth) at period 1000. Bottom, Right: Gini indexes (Wealth) at different simulation time steps.

7 Labor Market Experiments

The objective of this section is to analyze the impact on inequality and economic development of different degrees of downward rigidity of wages. For this sake we test four different values of the parameter t_u defining the number of periods of unemployment required before workers reduce their reservation wage, which in the baseline was set equal to two (see equation 3.22). Higher values of t_u thus make wages downward revisions less frequent, while making upward revisions more likely. This parameter can be assumed to represent a proxy of the degree of labor protection and workers' coordination in the labor markets. Indeed, many of the policy and regulatory tools aimed at increasing the degree of labor protection share the goal of supporting - though through different mechanisms - the growth of wages, in particular with respect to profits. Examples are collective bargaining, which enhances workers' coordination in pushing their wage claims, or minimum wage laws, which soften the wage competition process among workers.

Admittedly, here we do not aim to model the specific mechanism by which this types of interventions operate. Rather, we employ the parameter t_u to assess how the final outcome of these policies on workers' wage claims affects the macroeconomic performance and the distribution of income and wealth.

Indeed, one may argue that an excessive growth of wages may squeeze profits and reduce investment whereas keeping wages low might free resources for investment and boost output growth and employment, with positive cascade effects on workers as well. Conversely, low wages can depress aggregate demand, reducing investment opportunities, whereas a wage-led growth can foster a virtuous circle of rising demand and investment, whose positive effects might eventually trickle up to profits. Testing these alternative hypothesis is the main aim of the present section.

To accomplish this task we perform two different sets of experiments. In the first case, we change the value of the parameter t_u for all types of workers in the range 1:4, with a unitary increment between each scenario. In the second set of experiments we exclude from the parameter sweep the class of executives. This distinction is motivated by the fact that managers, though being formally employees, are substantially different from other types of workers in that, being the owners of firms and banks, they earn a profit, and represent by far the richest group in the economy. Table 3 presents a summary of the results obtained in the two experiments. Here, $t = 2$ represents the baseline case.

7.1 Adjusting wages downward rigidity of all types of workers

In the first set of experiment the parameter t_u is progressively increased for all types of workers. For space reasons, we omit the plots related to this scenario. A summary of results is reported in the first four columns of table 3 in the appendix.

Results suggest that variations from the baseline of main real aggregates are relatively low and do not show any clear-cut monotonic tendency across scenarios[37]: the maximum variations of real GDP is less than 2.3%, 1.6% for real consumption, and approximately equal to 4% for real investment. Similar arguments apply to labor productivity and unemployment, which do not display a clear-cut tendency across scenarios. As far as inequality is concerned, only wealth inequality shows a monotonic inverse relationship between values of the Gini indexes and values of t_u. Income inequality, on the contrary, decreases for higher values of t_u, but it is slightly lower for $t_u = 1$ as well. Variations are nonetheless narrow and statistically significant only for the last scenario ($t_u = 4$). Furthermore, simulations performed in all the scenarios investigated continue to display the increasing pattern of inequality already observed in the previous experiments.

Not surprisingly, higher (lower) values of t_u instead produce significant variations in nominal variables, causing higher (lower) levels of inflation. Interestingly, higher inflation is also connected to significant lower values of the Debt/GDP ratio of the public sector.[38]

To summarize, results of this first batch of experiments suggest that measures which indiscriminately sustain the growth of wages of all types of workers do not produce significant variation of main real aggregates, nor they help to tackle income and wealth inequality in an effective way, while they allow to limit the public debt burden by stimulating inflation, which still remains at moderate levels though.

7.2 Adjusting wages downward rigidity of middle and low tiers workers'

In order to account for the fact that executives, i.e. top managers, cannot be assimilated to other types of workers for the reasons explained above, we performed a second test in which managers are excluded from the parameter sweep on t_u.

Figures 7, 8, 9 provide a graphical overview of the main results obtained in this second experiment. The last three columns of table 3 in the appendix provides the usual quantitative summary of results.

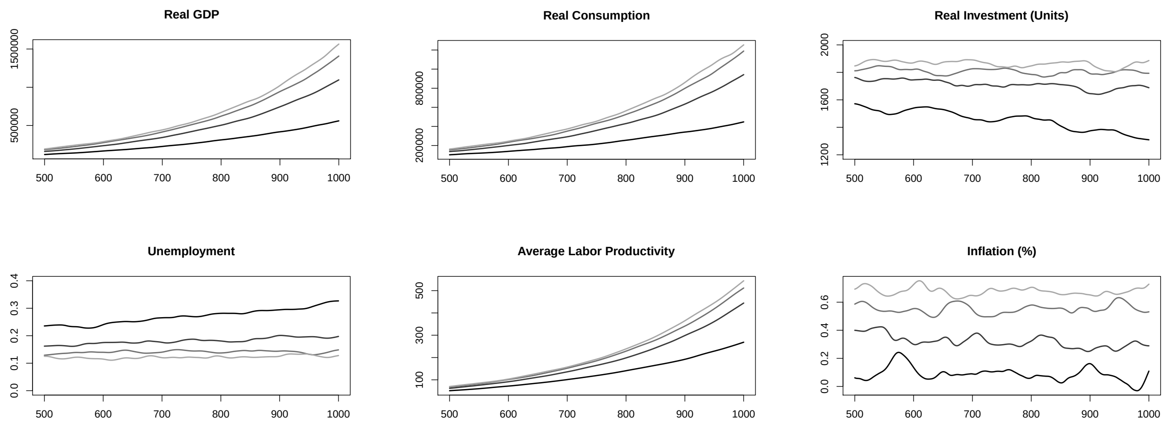

Figure 7: **Labor Market Experiment - Low-Middle Tiers Workers Only:** Lighter gray lines correspond to higher values of t. Top, Left: Real GDP. Top, Center: Real Consumption. Top, Right: Real Investment. Growth rates of prices have been computed using average market prices (weighted for firms' market shares). Bottom, Left: Unemployment. Bottom, Center: Consumption Firms' Average Labor Productivity (weighted for consumption firms' output shares). Bottom, Right: Inflation. The growth rates of prices have been computed using average market prices (weighted for firms' market shares).

Results of the simulation show that variations of t_u for low and middle tiers workers only exert a huge impact on both the real and nominal sides of the economy, displaying a clear-cut tendency across different scenarios.

[37]Still, summary results for the tests on the difference between populations, reported in the $p < 0.05$ and $p < 0.10$ lines of table 3, highlight that significant statistical differences between time series in the baseline and the corresponding time series (i.e. obtained with the same pseudo random number generator seed) in the alternative scenarios do exist. However, the low variations of average values observed suggest that the same value of the parameter can affect the dynamics of these variables in opposite directions, depending on stochastic effects.

[38]Given the almost negligible impact on unemployment and real aggregates, these variations are probably due to nominal factors, in particular to the higher inflation. This in fact increases tax revenues, while reducing the debt burden, and interests payments on past debt especially.

A reduction of t_u, which increases the downward pressure on wages of workmen, office workers, and researchers, determines a significant drop in main real economic aggregates, which translates into pathological levels of unemployment. Real GDP and real consumption in the $t_u = 1$ scenario are almost half the value they reached in the baseline configuration, while investment is more than 20% lower. As a consequence, average unemployment is around 36.5%, that is 76% higher than in the baseline.

High unemployment and the depressed dynamics of wages of workers in the lower tiers, in turn, cause inflation to be close to zero, or even below, for long time-spans of the simulations despite the fact that labor productivity, which dampens inflation by reducing unit labor costs, is 35% lower. Public finance is affected as well by the depressed economic context: the debt-to-GDP ratio is 45% higher than in the baseline as a consequence of the greater counter-cyclical expenditure for unemployment benefits and of the reduction in tax reveneus due to low nominal GDP levels. In turn, the possible upward revisions of tax rates which follow the spike in debt-to-GDP and deficit-to-GDP ratios eventually depresses further aggregate demand.

This scenario is also associated with markedly higher levels of inequality in both income and wealth distribution, as figure 9 shows. Inequality dynamics is the key to understand the drop of main real aggregates: low consumption is a direct consequence of the loss of purchasing power by lower income-higher propensity to consume workers in favor of higher income-lower propensity to consume managers. Lower demand in turn depresses investment, both as a consequence of falling capacity utilization rates (which eventually stabilizes, as obsolete machineries are not replaced and excess capacity is absorbed) and of reduced profit margins: even if firms' costs decrease, the lower demand by middle and low level workers reduces revenues more than proportionally. Finally, lower output and higher unemployment also hamper innovation activity, thereby dampening labor productivity dynamics.

Figure 8: **Labor Market Experiment - Low-Middle Tiers Workers Only:** Lighter gray lines correspond to higher values of t. Top, Left: Government Debt/GDP ratio. Top, Center: Consumption Firms' Credit Gap as: Credit Demanded/Credit Received. Top, Right: Capital Firms' Credit Gap. Bottom, Left, Center, and Right: Workmen, Office Workers&Researchers, and Top Managers' Real Consumption.

This situation is completely reverted in the two scenarios characterized by greater downward rigidity ($t_u = 3$ and $t_u = 4$) of low and middle workers' wages. In these experiments real output (+29% and +39%), real consumption (+29% and +39%), and real investment (+7% and +13%) are boosted by the shift of income and wealth distribution in favor of lower income earners, thereby reducing also average unemployment levels (-20% and -30%).

Figure 8 highlights that the shift in the distribution of income and wealth also implies a redistribution of real consumption across different income groups, with overall positive systemic effects: in fact, the rise of workmen and middle level workers' real consumption more than compensates the fall of executives' caused by the reduction of their real income.

Higher nominal demand in turn stimulates inflation, which is almost double in the third scenario and 1.4 times higher in the last one.[39] Unemployment is lower and inflation is higher notwithstanding the accelerated path of average labor productivity in the consumption sector which is 18% and 22% higher in the last two experiments. In addition, the improvement of public finance already observed in the last two

[39]Still, inflation is mild even in this last case, being characterized by an average quarterly rate of approximately 0.79% which corresponds to an annual rate slighlty above 3%.

scenarios of the previous experiment, is now reinforced (top left of figure 8): besides the positive effect of inflation in reducing the debt burden, as already discussed in the previous subsection, the concomitant reduction of government's countercyclical outlays for unemployment doles further improves the situation. This in turn allows to alleviate the tax burden of the economy by reducing tax rates on income, wealth and profits.

Finally, also in this case firms' finance does not seem to be significantly affected by changes in the values of t_u: plots on the top line of figure 8 show that consumption and capital firms' credit gap trends tend to overlap across scenarios.

While the economy emerging from these two latter scenarios seems to be more efficient, it is also more equal. The Gini Indexes computed on income and wealth are consistently decreasing across scenarios. Accordingly, the Lorenz Curves clearly move towards the line of perfect equality as we pass from scenario 1 to 2, and from scenario 2 to scenarios 3 and 4, though the Lorenz curves for wealth of these latter two cases intersect, possibly suggesting that workmen may be relatively better off in the last scenario, whereas office workers and researchers may be better off in the previous one.

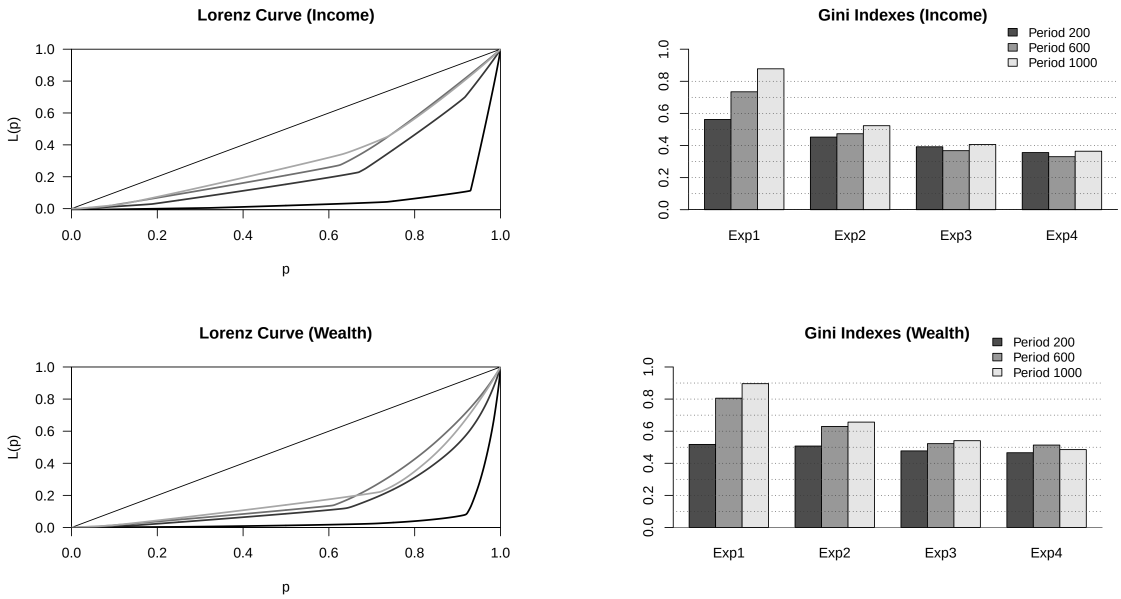

Figure 9: **Labor Market Experiment - Low-Middle Tiers Workers Only:** Lighter gray lines correspond to higher values of t. Top, Left: Lorenz Curve (Income) at period 1000. Top, Right: Gini indexes (Income) at different simulation time steps. Bottom, Left: Lorenz Curve (Wealth) at period 1000. Bottom, Right: Gini indexes (Wealth) at different simulation time steps.

8 Final considerations and future investigations

While the experiments on the tax regimes suggested that more progressive tax systems can dampen income and wealth inequality, results of the last labor market experiment suggests that this result can be significantly improved when inequality is tackled directly on the labor market, rather than through an ex-post redistribution of income. Furthermore, results also show that increasing the downward rigidity of wages of low and middle tiers workers allows to dampen significantly, or even to stop, the rising trend of inequality observed in all previous experiments.

In conclusion, our results seem to suggest that institutional, policy, and regulatory measures which have the effect of reducing the downward pressure on wages of low and middle income workers and to sustain their growth, can be effective in boosting economic development, improving both demand and supply conditions. These measures seem to be also more effective in reducing inequality compared to ex-post redistributions realized through taxation.

Conversely, the properties of the economy in the scenario where low and middle workers are more likely to reduce their reservation wages ($t_u = 1$) seem to provide some ground for the thesis according to which labor market reforms aiming at increasing wages flexibility and the progressive demise of collective bargaining might have played a crucial role in causing the long-lasting polarization of income and wealth observed in many advanced countries since the beginning of the eighties.

The results of our experiments thus seem to provide evidence in favor of the prevalence of a wage-led growth regime. Nonetheless, some caution is advisable, given the simplified nature of the economy depicted in the model and the germinal stage of our analysis. Several aspects of the model presented here need to be deepened and further investigated.

Among these, two are particularly relevant in our opinion and will be the object of our future investigation. First, the robustness of results presented in the paper should be assessed also in relation to different configurations of firms' desired growth (i.e. investment) function parameters. Indeed, the way firms look at profits and demand when taking their investment decisions (i.e. the sensitivity of investment with respect to the weights γ_1 and γ_2 of the profit and capacity utilization rates in equation 3.11) can play a decisive role in leading to either a wage-led or a profit-led growth regime.

Second, different characterization of technological change can greatly affect the dynamics of the system presented in the paper, possibly enhancing, flattening, or even reverting the results discussed above. Testing different configurations of the parameters characterizing the R&D activity by firms - in particular those determining the magnitude and variability of productivity gains by capital firms - is thus necessary to check the robustness of our findings.

In addition, also the effects of a combination of the fiscal and labor market measures tested here are yet to be assessed.

In order to provide a more comprehensive analysis of the inequality-economic development nexus, we are also planning some amendments to the structure of the model. In particular, the introduction of international trade seems to be topical, given the impact of wages on countries' international competitiveness, and conversely, the influence exerted by international trade on countries' income levels. The inclusion of credit to households, which would open the possibility of a profit led-debt driven growth regime, represents another interesting possible integration of the model.

As a final remark on the current limitations of our analysis, even though the model produces realistic results for the distribution of income and wealth *across* income groups, it does not allow for high income and wealth dispersion *within* each income group, that is between agents' belonging to the same class.[40] A smoother and more realistic distribution of personal income and wealth, which was somehow beyond the objectives of the present work, might nonetheless be achieved by increasing the number of hierarchical layers of firms, possibly allowing them to grow endogenously with firms' dimension along the line traced, for example, by Ciarli et al. (2010).

[40]The only exception is represented by the class of managers, given the multiplicative effect embedded in the dividend distribution procedure, which allows richer managers' to increase the share of dividends received from firms and banks.

Compliance with Ethical Standards:

Funding: this research has benefited from funding of the Institute for New Economic Thinking (INET) and from the European 7th Framework Program under the project “Mathematics of Multilevel Anticipatory Complex Systems (MatheMACS)’, Project Reference: 318723.

Conflict of Interests: The authors declare that they have no conflict of interest.

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A Calibration

Table 1: Parameters

Symbol	Description	Baseline	Experiment
g_{SS}: pre-SS	Nominal rate of growth in the SS	0.0075	same
λ: free	Adaptive expectations parameter	0.25	same
N_W, N_O, N_R, N_M: pre-SS	Number of workmen, office workers, researchers, top managers	2400, 1119, 81, 400	same
$size_{\Phi_C}$: pre-SS	Number of consumption firms	100	same
$size_{\Phi_K}$: pre-SS	Number of capital firms	10	same
$size_{\Phi_B}$: pre-SS	Number of banks	10	same
$share_{cw} = share_{kw}$: free	Share of Workmen in C and K firms	0.6	same
$share_{co}$: free	Share of office workers in C firms	0.3	same
$share_{ko}$: free	Share of office workers in K firms	0.15	same
$share_{kr}$: free	Share of researchers in K firms	0.15	same
$share_{cr}$: free	Share of researchers in C firms	0.0	same
$share_{cm} = share_{km}$:free	Share of managers in C and K firms	0.10	same
SI_{w0}: free	Workmen's initial share of gross income	0.3	same
$SI_{o0} + SI_{r0}$: free	Office workers' and researchers' initial share of gross income	0.4	same
SI_{m0}: free	Top managers' initial share of gross income	0.3	same
SW_{w0}: free	Workmen's initial share of pre-tax wealth	0.3	same
$SW_{m0} + SW_{r0}$: free	Office workers' and researchers' initial share of pre-tax wealth	0.4	same
SW_{m0}: free	Top managers' initial share of pre-tax wealth	0.3	same
$\alpha_w, \alpha_o = \alpha_r, \alpha_m$: free	Workmen, office workers&researchers, and managers' average propensity to consume out of income	0.95, 0.85, 0.75	same
β: free	Real consumption persistence parameter	0.9	same
u_0: pre-SS	Initial unemployment (both global and for each workers' group)	0.08	same
μ_N: SS-given	Productivity of labor in K sector	6.67	same
$\{\mu_k, l_k\}$: pre-SS, SS-given	Initial productivity and (constant) capital/workmen ratio of K	$\{1, 20\}$	same
$\chi_c = \chi_k$: free	Number of potential partners on C and K goods mkts	3 , 5	same
$\chi_d = \chi_l$: free	Number of potential partners on deposit-credit mkts	3	same
$\chi_w, \chi_{o,\chi_r,\chi_m}$: free	Number of potential partners on workmen, office workers, researchers, and managers' labor mkts (for each vacancy)	10	same
$\epsilon^c = \epsilon^d = \epsilon^l$: free	Intensity of choice in deposit-credit and consumption goods mkts	4.62	same
ϵ^k: free	Intensity of choice in capital goods mkt	13.86	same
ν: pre-SS	Firms' inventories target share	0.1	same
ϑ: free	Labor turnover ratio	0.05	same
μ_{c0}, μ_{k0}: pre-SS	Initial mark-up on ULC for C and K firms	0.32, 0.05	same
$(\mu_{FN_1}, \sigma_{FN_1})$: free	Folded Normal 1 Distribution parameters	(0, 0.015) $\mathbf{E}(FN_1) \approx 0.012$	same
t_u: free	Quarters of unemployment in reservation wage revision	2	1 : 1: 4
N_{gt}: pre-SS	Number of public servants (constant)	680	same
$\tau_{\pi 0}, \tau_{i0}, \tau_{w0}$: pre-SS	Profits, income, and wealth initial tax rates	0.18, 0.08, 0.05	same
θ: free	Tax system progressiveness parameter	0	0.0 : 0.25 : 1.5
def^1, def^0: free	Upper and lower deficit threshold in the tax rate revision rule	0.05, 0.02	same
υ: free	Adjustment parameter in the tax rate revision rule	0.05	same
η, κ: pre-SS	Loans and capital goods duration	20, 20	same
$\overline{r}$: SS-given	Target profit rate (Investment function)	0.04345	same
$\overline{u}$: SS-given	Target capacity utilization (C firms' investment and price functions)	0.8	same
γ_1, γ_2: free	Profit and capacity utilization rates weight (Investment function)	0.015, 0.015	same
ξ^{inn}, ξ^{imi}: free	Innovation and imitation probability of success parameters	0.015, 0.045	same
$(\mu_{FN_3}, \sigma_{FN_3})$: free	Folded Normal 3 Distribution parameters	(0, 0.01) $\mathbf{E}(FN_3) \approx 0.008$	same
σ: pre-SS	Firms' precautionary deposits as share of WB	1	same
$\rho_c = \rho_k$: pre-SS	Firms' profits' share distributed as dividends	0.9	same
ρ_b: pre-SS:	Banks' profit share distributed as dividends	0.6	same
i^l_{b0}, i^d_{b0}: pre-SS	Initial interest rate on loans and deposits	0.0075, 0.0025	same
CR^T_0, LR^T_0: SS-given	Initial banks' target capital and liquidity ratios	0.18, 0.26	same
ς_c, ς_k: free	Banks' risk aversion towards C and K firms	3.9, 21.5	same
$(\mu_{FN_2}, \sigma_{FN_2})$: free	Folded Normal 2 Distribution parameters	(0, 0.015) $\mathbf{E}(FN_2) \approx 0.012$	same
ι: free	Haircut on defaulted firms' capital value	0.5	same
w_{n0}: pre-SS	Initial average wage	5	same
ω: pre-SS	Dole (share of average workmen's wages)	0.4	same
$\overline{i}^a_{cb}$: pre-SS	CB interest rates on advances	0.005	same
$\overline{i}^b$: pre-SS	Bonds interest rate	0.0025	same
$\overline{p}^b$: pre-SS	Bonds price	1	same

B Results Summary Tables

Table 2: Tax Progressiveness Experiments

		Baseline	Scenarios					
Variable	Measure	**Exp 1:** $\theta = 0.00$	Exp 2: $\theta = 0.25$	Exp 3: $\theta = 0.50$	Exp 4: $\theta = 0.75$	Exp 5: $\theta = 1.00$	Exp 6: $\theta = 1.25$	Exp 7: $\theta = 1.50$
Real GDP	MC Average	1122991.89	+0.0963	+0.1305	+0.2093	+0.1746	+0.3059	+0.2595
	$p < 0.05$	-	64	88	72	68	68	60
	$p < 0.10$	-	72	92	76	76	84	72
	Av. Growth Rates	0.0035	+0.0206	+0.0272	+0.0348	+0.0358	+0.0612	+0.0491
	$p < 0.05$ (G.R)	-	60	60	68	56	60	60
	$p < 0.10$ (G.R)	-	72	64	76	64	64	64
	SD (cycle)	0.0175	0.0176	0.0164	0.0161	0.0161	0.0164	0.0165
	SD (across MC)	0.2092	0.1492	0.1987	0.2860	0.2292	0.2287	0.2053
Real Consumption	MC Average	956097.13	+0.0925	+0.1294	+0.2007	+0.1697	0.3055	+0.2550
	$p < 0.05$	-	80	60	96	84	76	84
	$p < 0.10$	-	80	72	96	92	84	88
	Av. Growth Rates	0.0035	+0.0191	+0.0266	+0.0323	+0.0341	+0.0607	+0.0469
	$p < 0.05$ (G.R)	-	72	68	60	64	60	60
	$p < 0.10$ (G.R)	-	72	68	68	72	64	68
	SD (cycle)	0.0135	0.0134	0.0125	0.0119	0.0121	0.0125	0.0125
	SD (across MC)	0.2101	0.1538	0.2037	0.2908	0.2312	0.2291	0.2077
Real Investment	MC Average	1606.85	+0.1091	+0.0768	+0.0691	+0.1063	+0.1045	+0.0761
	$p < 0.05$	-	100	76	88	88	100	96
	$p < 0.10$	-	100	80	92	88	100	96
	SD (cycle)	0.0863	0.0868	0.0841	0.0822	0.0825	0.0850	0.0841
	SD (across MC)	0.0980	0.0850	0.0892	0.0978	0.0676	0.0726	0.0639
Unemployment (%)	MC Average	20.91	-0.1474	-0.1025	-0.1065	-0.1489	-0.2103	-0.0698
	$p < 0.05$	-	88	88	88	88	96	100
	$p < 0.10$	-	88	88	92	92	96	100
	SD (cycle)	0.0862	0.1010	0.0958	0.0989	0.1055	0.1093	0.1106
	SD (across MC)	0.2245	0.2548	0.2152	0.2946	0.2201	0.2602	0.2307
Inflation (%)	MC Average	0.3287	+0.0858	+0.0798	+0.1409	+0.1272	+0.1584	+0.1772
	$p < 0.05$	-	96	72	68	72	74	88
	$p < 0.10$	-	96	76	84	80	84	88
	SD (cycle)	0.4594	0.4562	0.4596	0.4529	0.4573	0.4581	0.4576
	SD (across MC)	0.1963	0.1471	0.1691	0.1530	0.1435	0.1479	0.2101
Labor Productivity (Consumption Sector)	MC Average	459.37	+0.0359	+0.0782	+0.1346	+0.1027	+0.1763	+0.1813
	$p < 0.05$	-	60	56	76	84	68	72
	$p < 0.10$	-	68	60	80	84	76	76
	Av. Growth Rates	0.0037	+0.0033	+0.0139	+0.0186	+0.0178	+0.0351	+0.0358
	$p < 0.05$ (G.R)	-	72	72	64	72	68	68
	$p < 0.10$ (G.R)	-	76	76	68	76	80	72

Table 2: Continued

	SD (cycle)	0.0032	0.0032	0.0032	0.0032	0.0032	0.0032	0.0033
	SD (across MC)	0.1815	0.1459	0.1844	0.2552	0.2204	0.2123	0.1872
Debt/GDP	MC Average	1.51	-0.0328	-0.1018	-0.0781	-0.0778	-0.1254	-0.1560
	$p < 0.05$	-	88	80	100	88	96	96
	$p < 0.10$	-	88	80	100	88	96	100
	SD (cycle)	0.0262	0.0261	0.0261	0.0273	0.0262	0.0264	0.0274
	SD (across MC)	0.1183	0.1010	0.1137	0.1604	0.1460	0.1682	0.1750
Gini-Income	MC Average	0.5227	-0.0412	-0.0553	-0.0631	-0.0763	-0.0907	-0.0833
	$p < 0.05$	-	56	88	96	100	100	100
	$p < 0.10$	-	64	88	100	100	100	100
	SD (cycle)	0.0154	0.0150	0.0142	0.0147	0.0125	0.0122	0.0135
	SD (across MC)	0.0295	0.0300	0.0287	0.0300	0.0260	0.0257	0.0283
Gini-Wealth	MC Average	0.6566	-0.0406	-0.0815	-0.1067	-0.1233	-0.1426	-0.1712
	$p < 0.05$	-	72	100	100	100	100	100
	$p < 0.10$	-	88	100	100	100	100	100
	SD (cycle)	0.0163	0.0134	0.0148	0.0267	0.0207	0.0238	0.0244
	SD (across MC)	0.0249	0.0213	0.0245	0.0455	0.0359	0.0422	0.0449

Table 2: "MC Average" refers to the Monte Carlo average of the correspondent variable in each scenario. In the case of Real Output, Real Investment, Real Consumption, Labor Productivity (Consumption Sector), debt/GDP, and the Gini Indexes, end of simulations values are employed. Inflation and unemployment instead refer to average values over the time-span 500-1000. "Av. Growth Rates" are average growth rates over the time-span 500-1000 (only for Real GDP, Real Conusmption and Labor Productivity which display an increasing trend). For non-baseline scenarios, the average deviations from the baseline are shown instead of the absolute value, in order to better appreciate the variation from scenario to scenario. "$p < 0.05$" and "$p < 0.1$" report the percentage of MC simulations for which we can reject the null hypothesis (respectively at the 5% and 10% levels of significance) that the variable time series (in the time span 500-1000) in the given scenario and the correspondent one in the baseline (i.e. with the same *pseudo random number generator* seed) are two identical populations. In order to perform these checks, the Mann-Whitney-Wilcoxon Test was employed. "$p < 0.05(G.R)$" and "$p < 0.1(G.R)$" display the same statistics for the time series of growth rates. "SD (cycle)" is the MC mean of the average Standard Deviations of the variable cycle component over the time span 500-1000, normalized for the trend component in order to allow a comparison on the same scale. Finally, "SD (across MC)" indicates the Standard Deviation of the values employed to calculate the Monte Carlo Averages, normalized for correspondent average value in order to allow a comparison on the same scale. Since we did not filter the Gini indexes, the rough series were employed instead of the cycle component when computing "SD (cycle)".

Table 3: Labor Market Experiments

		Baseline	Experiment Labor Market - all Workers Scenarios			Experiment Labor Market - no Executives Scenarios		
Variable	Measure	**Exp 2:** $t_u = 2$	Exp 1: $t_u = 1$	Exp 3: $t_u = 3$	Exp 4: $t_u = 4$	Exp 1 : $t_u = 1$	Exp 3: $t_u = 3$	Exp 4:$t_u = 4$
Real GDP	MC Average	1122991.89	-0.0127	+0.0101	+0.0229	-0.4445	+0.2900	+0.3904
	$p < 0.05$	-	80	72	84	92	80	84
	$p < 0.10$	-	84	80	88	100	84	84
	Av. Growth Rates	0.0035	-0.0208	-0.0014	0.0011	-0.2014	+0.0791	+0.1120
	$p < 0.05$ (G.R.)	-	68	64	60	88	68	72
	$p < 0.10$ (G.R.)	-	72	76	72	96	68	76
	SD (cycle)	0.0175	0.0169	0.0174	0.0179	0.0196	0.0172	0.0174

Table 3: Continued

	SD (across MC)	0.2092	0.2356	0.1987	0.1814	0.2423	0.1904	0.1777
Real Consumption	MC Average	956097.13	-0.0105	+0.0040	+0.0158	-0.4587	+0.2868	+0.3750
	$p < 0.05$	-	84	68	80	100	80	80
	$p < 0.10$	-	84	80	88	100	84	80
	Av. Growth Rates	0.0035	0.0210	-0.0030	0.0030	-0.2109	+ 0.0764	+0.1088
	$p < 0.05$ (G.R.)	-	68	64	64	88	68	68
	$p < 0.10$ (G.R.)	-	72	68	64	88	68	72
	SD (cycle)	0.0133	0.0135	0.0138	0.0144	0.0151	0.0137	0.0146
	SD (across MC)	0.2101	0.2433	0.1470	0.1806	0.2494	0.1986	0.1757
Real Investment	MC Average	1606.85	+0.0370	+0.0402	-0.0010	-0.2159	+0.0689	+ 0.1262
	$p < 0.05$	-	96	92	84	100	92	96
	$p < 0.10$	-	96	92	84	100	92	96
	SD (cycle)	0.0863	0.0839	0.0871	0.0886	0.0891	0.0866	0.0867
	SD (across MC)	0.0980	0.0738	0.1212	0.0798	0.1075	0.0814	0.1014
Unemployment (%)	MC Average	20.91	+0.0593	+0.0071	+0.0873	+0.7583	-0.1992	-0.3048
	$p < 0.05$	-	96	96	96	96	92	100
	$p < 0.10$	-	96	96	96	96	92	100
	SD (cycle)	0.0862	0.0798	0.0852	0.0771	0.0525	0.1196	0.1444
	SD (across MC)	0.2245	0.2359	0.2425	0.2083	0.1430	0.3121	0.3741
Inflation (%)	MC Average	0.3287	-0.8495	+0.8112	+1.2428	-0.6490	+0.9736	+1.4009
	$p < 0.05$	-	96	100	100	96	100	100
	$p < 0.10$	-	96	100	100	96	100	100
	SD (cycle)	0.4594	0.4169	0.4137	0.4258	0.5908	0.3857	0.3820
	SD (across MC)	0.1963	1.9049	0.1159	0.0629	0.7226	0.1032	0.0491
Labor Productivity (Consumption Sector)	MC Average	459.37	-0.0315	-0.0194	+0.0107	-0.3525	+0.1811	+0.2233
	$p < 0.05$	-	76	60	72	100	76	72
	$p < 0.10$	-	84	60	80	100	80	76
	Av. Growth Rates	0.0037	-0.0187	- 0.0840	0.0030	-0.1400	+ 0.0413	+0.0608
	$p < 0.05$ (G.R.)	-	80	64	64	84	68	64
	$p < 0.10$ (G.R.)	-	80	68	64	88	68	68
	SD (cycle)	0.0032	0.0033	0.0032	0.0032	0.0033	0.0031	0.0030
	SD (across MC)	0.1815	0.2074	0.1067	0.1584	0.2263	0.1938	0.1824
Debt/GDP	MC Average	1.51	+0.3398	-0.1750	-0.2364	+0.4497	-0.2572	-0.3109
	$p < 0.05$	-	100	100	100	100	96	100
	$p < 0.10$	-	100	100	100	100	100	100
	SD (cycle)	0.0262	0.0260	0.0270	0.0278	0.0344	0.0265	0.0276
	SD (across MC)	0.1183	0.1268	0.1309	0.1562	0.1162	0.1663	0.2130
Gini-Income	MC Average	0.5227	-0.0407	-0.0218	-0.0567	+0.6787	-0.2230	-0.3033
	$p < 0.05$	-	32	20	56	100	100	100
	$p < 0.10$	-	32	28	72	100	100	100
	SD (cycle)	0.0154	0.0197	0.0179	0.0184	0.0143	0.0161	0.0178
	SD (across MC)	0.0295	0.0392	0.0350	0.0373	0.0163	0.0397	0.0487

Table 3: Continued

Gini-Wealth	MC Average	0.6566	+0.0124	-0.0211	-0.0437	+0.3603	-0.1799	-0.1987
	$p < 0.05$	-	4	16	52	100	100	100
	$p < 0.10$	-	20	24	56	100	100	100
	SD (cycle)	0.0163	0.0248	0.0173	0.0200	0.0049	0.0159	0.0412
	SD (across MC)	0.0249	0.0375	0.0271	0.0320	0.0055	0.0361	0.0786

Table 3: Measures presented in the table follow the same conventions adopted in table 2. Experiment 2 ($t_u = 2$), representing the baseline scenario, is common to both experiments.