Are higher wages good for business? An assessment under alternative innovation and investment scenarios

Caiani, Alessandro and Russo, Alberto and Gallegati, Mauro

Università Politecnica delle Marche

31 January 2017

Are higher wages good for business? An assessment under alternative innovation and investment scenarios

Alessandro Caiani*
Marche Polytechnic University

Alberto Russo
Marche Polytechnic University

Mauro Gallegati
Marche Polytechnic University

Abstract

This paper aims at investigating the interplay between inequality, innovation dynamics, and investment behaviors in shaping the long-run patterns of development of a closed economy. By extending the analysis proposed in Caiani et al. (2017) we explore the effects of alternative wage regimes under different investment and technological change scenarios. Experiments results seem to de-emphasize the role of technological progress as a possible source of greater inequality. Overall, simulation results are consistent with the predominance of a wage-led growth regime in most of the scenarios analyzed: a faster growth of low and middle level workers' wages, relative to managers', generally exert beneficial effects on the economy and allows to counteract the labor-saving effects of technological progress. Furthermore, contrary to what is sometimes argued in the academic and political debate, a distribution more favorable to workers does not compromise firms' profitability, but rather strengthen it creating a more favorable macroeconomic environment which encourages further innovations, stimulates investment, and sustains economic growth.

Keywords: Innovation, Investment, Inequality, Agent Based Macroeconomics, Stock Flow Consistent Models.
JEL Codes: O41, E64, E22

1 Introduction

In this paper we aim at investigating the interplay between inequality, innovation dynamics, and investment behaviors in shaping the long-run patterns of development of a closed economy. The present contribution extends the analysis proposed in Caiani et al. (2017) by presenting two experiments designed to explore the effects of alternative wage regimes under different characterizations of the parameters governing firms' investment and the pace of technological progress. Therefore, a first objective of the paper is to provide an extensive robustness check of the policy implications drawn in Caiani et al. (2017) regarding the opportunity of policy interventions fostering a more equal distribution of income and wealth. However, the experiments also allow us to deepen the analysis of the relationship between innovation, inequality, economic growth, firms' profitability, public finance, and economic stability. The insights from our simulation experiments are then commented in light of the relevant theoretical and empirical literature. A particular attention is dedicated to the debate on the predominance of wage-led or profit-led growth regimes. Experiments results seem to de-emphasize the role of technological progress as a source of greater inequality. In fact, the presence of innovation reduces income inequality compared to the case with no technological progress, while different paces of innovation do not alter significantly income and wealth distribution. In all scenarios, inequality remarkably diminishes as the parameter governing the downward rigidity of low and middle level workers is increased. Overall, simulation results are consistent with the predominance of a wage-led growth regime in most of the scenarios analyzed: a faster growth of wages of low and middle level workers, relative to managers', generally exerts beneficial effects on the economy and allows to counteract the labor-saving effects of technological progress. Furthermore, contrary to what is sometimes argued in the academic and political debate, a distribution more favorable to workers does not compromise firms' profitability, but rather strengthens it, creating a more favorable macroeconomic environment which encourages investment in innovative activities and capital accumulation, and sustains economic growth. Moreover, simulation results show that wealth-to-GDP ratios and public debt-to-GDP ratios are higher in the scenarios where workers' wages proceed at lower pace, because these are generally associated to a distribution of income and wealth more favorable to high-propensity-to-save managers (i.e.

*Corresponding author: a.caiani@univpm.it

firms and banks' owners), and less favorable to high-propensity-to-consume workers (i.e. middle-to-low income classes).

Our research line is motivated by the observation that inequality has kept rising in most advanced countries over the last decades, both in functional and inter-personal terms: on the one hand, there has been an increase of the share of national income claimed by capital owners, at the expense of wage earners; on the other hand, many studies (see for example Atkinson et al. (2011); Piketty (2014)) have documented a significant and consistent rise of top labor incomes (Jones and Kim, 2014), while income levels in the middle and low range of the wage distribution have stagnated. Rising inequality, in turn, has been identified by many as one of the deep causes of households' growing indebtedness which eventually led to the Great Recession (see, for instance, Perugini et al. (2016), Kumhof et al. (2015), and Russo et al. (2016)).

Both the debate about the origins of inequality and its consequences for economic growth, economic stability, and technological change are far from reaching a general agreement. Caiani et al. (2017) provides a first overview of the theoretical and empirical debate on the relationship between innovation and inequality. While non-mainstream economists has primarily focused on institutional and policy factors to explain rising inequality[1], within mainstream Economics much more importance has been given to the role of technical progress: Katz and Murphy (1992), Acemoglu (1998), Acemoglu (2002), Acemoglu (2007), and Goldin and Katz (2008), for example, stress the role of skill-biased technical change in driving inequality. Similarly, Aghion and Howitt (1997) show that inequality may rise due to the introduction of general purpose technologies, which favor workers that are able to adapt faster than others. Jones and Kim (2014) instead proposes a Schumpeterian model in which income is Pareto distributed finding a negative relationship between growth and top income inequality. The rationale for this result is that higher inequality tends to reduce growth by making research riskier; by contrast, faster growth boosts creative destruction which lowers inequality. A different result is reached by Aghion et al. (2015) who also employ a Schumpeterian framework with top income inequality. Their finding is that more innovation-led growth should both increase the income of top earners (reflecting innovation rents) and social mobility (which reflects creative destruction). Therefore, there is a positive effect of innovation on top income inequality. At the same time, more innovation implies more creative destruction, with new entrants replacing incumbent firms. Therefore, innovation exerts a positive influence on social mobility. On the contrary, Antonelli and Gehringer (2013) maintain that technological change is a powerful factor in reducing income inequality for two main reasons: i) innovation boosts economic growth, increasing wage levels and thus reducing inequality; ii) innovation enhances market competition, in particular on prices of factors and products, thus dampening the accumulation of rents and resulting in lower income inequality. At the same time, inequality affects the dynamics of technological change: the lower inequality, the higher the incentives to increase human capital, and then the faster is economic growth.

The comeback of inequality in advanced economies also led to a resurgence of the debate on the prevalence of wage-led or profit-led growth regimes. According to advocators of the former, an increase of the wage share would generally exert positive effects on the economy, increasing consumption and improving entrepreneurs expectations, thereby spurring also investment. On the contrary, in a profit-led regime an increase of the profit share would boost investment, more than compensating the possible initial decline of aggregate demand.[2] On a theoretical perspective (see Lavoie and Stockhammer (2012)), the benefits of a wage-led growth strategy have been formalized by several post-Keynesian and Kaleckian authors, since the seminal contributions of Rowthorn (1981), Taylor (1983), and Dutt (1987). 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. In a closed-economy which abstracts from the role of imports and exports, this asks to analyze how income and wealth distribution affects households' patterns of consumption and firms' investment determinants, that is entrepreneurs' 'animal spirits'. These latter not only represent a fundamental component of aggregate demand, but also a fundamental engine of technological change and labor productivity growth.

The role of inequality and its effects on macroeconomic dynamics have been studied also through simulation models. For instance, Napoletano et al. (2012) investigate the role of firms' investment

[1] For example, Piketty et al. (2014) insists on the decline of top incomes tax rates and the concomitant increase in rent seeking behaviors. On a similar ground, Stiglitz (2012) relates the rise in top income inequality to financial deregulation, tax laws reforms, and other regulatory interventios in favor of the rich, while denying the idea that rising top incomes levels would reflect a skill-premium due to the higher productivity of top income earners. Other, as Jaumotte and Buitron (2015) and Vergeer and Kleinknecht (2010) has focused on the fall of unioninzation rates and the deregulation of labor markets to explain the fall of wage-shares observed in many countries.

[2] A similar debate, but on a slightly different perspective which looks at personal, rather than functional, distribution of income, is that between advocators of a trickle-up economy and advocators of a trickle-down effect (Stiglitz, 2015).

behavior and income distribution in shaping short and long-run macroeconomic dynamics within the 'Keynes+Schumpeter' model (Dosi et al., 2010). In particular, they study two alternative scenarios: a first one in which firms only look at past profits when taking their investment decisions, and a second in which investment choices are related to expectations on future consumption. They find that a balance in the income distribution between profits and wages is required in order to reach a steady growth with low unemployment, and that greater wage flexibility is able to foster growth only in the scenario where firms' investment depends on their profits. When investment depends on demand instead, unemployment tends to increase if real wages decrease. Building on the same KS agent-based modeling framework, Dosi et al. (2013) argue that the more the economy is unequal the higher is the probability of large crises. Along similar lines, Dosi et al. (2017) investigate the behavior of two 'archetypes of capitalism', that is two different regimes as for wage determination, firing, labor protection and the sharing of productivity gains. Simulation results show that the more wages are flexible and the more labor is mobile, the higher is the probability to observe systematic coordination failures and large crises. In turn, this greater instability reduces the resources invested in innovative activities and capital accumulation, thereby dampening economic growth.

Agent Based Modeling is a natural way to extend the analysis of inequality from the functional distribution of income to the whole inter-personal distribution of income (and wealth). For instance, 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: based on the labor productivity of capital vintages, firms hire first-tier workers; then, according to a given parameter, they hire a second-tier of managers to supervise first-tier workers; more managers are needed in a third-tier and so on, depending on the size of the firm. Engineers are also employed to carry out R&D activities. At the end, the number of workers depends on labor productivity and on the parameter governing the proportion between each tier. The different tiers are tied to different pays so that they give rise to different income-consumption classes which concur to form total aggregate demand.

In order to analyze the interactions between alternative wage regimes on the one hand, and different investment or innovation regimes on the other hand, we employ the Agent Based-Stock Flow Consistent (AB-SFC) model presented in Caiani et al. (2017), whose core was represented by the AB-SFC 'benchmark' model presented in Caiani et al. (2016). On the top of this framework, we added two important blocks: first, we introduced R&D and innovation in the capital sector, following the long-lasting evolutionary tradition building upon the Nelson and Winter's seminal models (see Dosi et al. (2010) and later works for an application of this approach to macroeconomic analysis). Therefore, technological change in the model is endogenous. Second, following Ciarli et al. (2010) and the empirical and theoretical contributions on which they build upon (Simon (1957), Lydall (1959), Waldman (1984), Abowd et al. (1999), Prescott (2003)), we assumed that firms' employees are organized in distinct hierarchical tiers, where only low-tier workers enter the production process directly, while workers in higher layers of the hierarchy are required to 'manage' the firm and define their competitive strategies (see section 2, point 1) or to perform R&D. More precisely, we considered four tiers of workers: workmen (at the lowest tier), office workers and researchers (in the middle), and managers (on the top of the hierarchy). Within this framework, the wage of workers employed in the different tiers endogenously emerged as the result of workers' competition process on segmented labor markets on which unemployed workers interacted with firms looking for workers to hire in order to carry out their production plans.

The model was then calibrated following the procedure presented in Caiani et al. (2016), slightly integrated for the parts related to the new blocks added to original model. In particular, the model was calibrated with realistic values for the initial income and wealth distribution across different income groups and their average propensities to consume and save, as to account for the fact that richer people tends to consume a lower share of their income. We then provided a minimal empirical validation of the baseline model following the well-established procedure proposed by Dosi et al. (2010) intended to check the model ability to replicate and explain a collection of relevant micro and macroeconomic stylized facts. Finally, we employed the model to investigate the effects of different fiscal regimes and alternative reservation wage revision schemes: we found 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, though the latter resulted to be more effective under both respects.

For this reason, the experiments presented in this work have the same design of the experiments on workers' wages presented in Caiani et al. (2017), as far as the 'policy' side is concerned. However, the four alternative wage regimes considered will be tested under a variety of scenarios, either differentiated for the pace of technological change, or for the characterization of (consumption) firms' investment behavior. The present work represents a continuation of the former, directed first of all at checking in a far more extensive way the robustness of the policy implications drawn in that context. However, we also aim at providing a more detailed analysis of the relationship between innovation, inequality, firms' profitability, economic growth, and economic stability. For this reason, we provide several additional statistics and indicators which help us to shed light on the reciprocal influence between these factors, and to connect our results to the relevant theoretical and empirical literature.

The remainder of the paper is organized as follows. Section 2 briefly describes the structure of the model, agents' behavior, and the sequence of events. Section 3 presents the results of the computational experiments addressed to investigate the relationship between wage and innovation regimes, while the experiments which consider alternative investment and wage regimes are presented in Section 4. Section 5 concludes.

2 The model

Given that the model presented in Caiani et al. (2017) was not amended in order to perform the experiments described in the present work, we make reference to that article for all the details regarding the precise specification of agents' behavioral equations. For explanatory and synthesis reasons, in what follows we just provide a discursive overview of agents' behaviors, their rules of interactions, and the timing of events within each simulation round. Our economy 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 $\{\mu_{kt}, l_k\}$, 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 vintage they produce. Firms can apply for loans to banks in order to finance production and investment when needed. Retained profits are stored in their deposit accounts at banks.

- A collection Φ_B of banks, holding deposits of 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 if reserves are low.

- 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's 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.

Agents make forecasts on the future levels of the variables which are relevant for their behaviors employing a simple adaptive scheme.

Agents on the demand and supply sides of each market (i.e. consumption and capital goods markets, credit and deposit markets, segmented labor markets for each type of worker) the labor markets interact through a common matching protocol: 'demand' agents are allowed to observe the offers of a random subset of suppliers which they rank according to their attractiveness, depending on the price, interest, and productivity (for capital goods) offered. Then, following Delli Gatti et al. (2010); Riccetti et al. (2015); Caiani et al. (2016), they decide whether to stick to the old supplier or switch to the new (best) one with a probability depending on the difference between their attractiveness. When customers are left with a positive residual demand because the chosen supplier has exhausted its supply, they are allowed to turn to the other potential suppliers, following the ranking they made before. 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.

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

1. *Production planning.* At the beginning of each simulation round, consumption and capital firms compute their desired output level. Consumption firms employ labour and capital vintages (with heterogeneous productivities) purchased from capital firms. Capital firms produce machines out of labor only. In addition, capital firms hire researchers to perform R&D activities. The desired output of firms depends on their sales expectations and the level of inventories inherited from previous periods. Moreover, firms want to hold a certain amount of real inventories as a buffer against unexpected demand swings (Steindl, 1952) and to avoid frustrating customers with supply constraints (Lavoie, 1992).

2. *Firms' labor demand.* 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. These latter are assumed to be the owners of firms and banks. Firms assess the number of workmen, researchers, office workers, and managers needed. Similarly to Ciarli et al. (2010), we assume that the proportions between different tiers of employees are fixed so that the demand of each type of workers is a given share of the demand of workmen, net of rounding.

   Consumption firms employ labor in conjunction with different capital vintages purchased from capital firms. Therefore, consumption firms' demand of workmen depends on the productivities of the different vintages of capital employed in the production process. By contrast, firms in the capital-good industry produce their output out of labor only.

   Capital firms' demand for workmen thus depends on desired production and the labor productivity. For capital firms, labor productivity is assumed to be constant and exogenous. In addition, capital firms hire researchers to perform R&D activities. These are assimilated to middle level workers in terms of their initial income and wealth endowments, though competing on their own segmented labor market.

   Ultimately, capital firms' productive capacity is constrained by first-tier workers and their productivity only, whereas consumption firms' capacity may be constrained by their stock of capital as well. 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.

3. *Prices, interest and wages.* Prices of goods are set as a non-negative markup over expected unit labor costs. 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, 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. The opposite happens if inventories are below (or equal to) the desired level, meaning that the firms was able to sell at least as much as she expected, and the rate of capacity utilization is above (or equal to) the normal one.

   Banks' interest rates on loans depend on a comparison between the bank's current capital ratio, namely the ratio between bank's net worth and bank's outstanding loans, and a target level equal to the past-period average of the sector. When banks are more capitalized than desired, they can offer an interest rate lower than their competitors' average so to attract borrowers on the credit market and expand their balance sheet by granting more loans. In the opposite case, banks want to reduce their exposure: a higher interest rate has the twofold effect of making banks' new loans less attractive while also increasing banks' profit margin on them.

   The revision rule of workers' reservation wage plays a crucial role for the analysis performed in this paper, being at the center of the two experiments performed in sections 3 and 4. Workers belonging to any of the four classes adaptively revise their reservation wages depending on their past employment condition: when they have been unemployed for more than t_u quarters over the last year (i.e. four periods) they reduce their reservation wage by a stochastic amount so to increase their probability of being hired. Otherwise, they increase it. Therefore, the higher the level of unemployment and the higher t_u, the greater the probability that agents reduce their reservation wages and the lower the probability that they increase it. Formally:

$$w_i^{d,t} = \begin{cases} w_{ht-1}^D(1 - FN_1) & \text{if } \sum_{n=1}^4 u_{ht-n} > t_u \\ w_{ht-1}^D(1 + FN_1) & \text{if } \sum_{n=1}^4 u_{ht-n} \leq t_u \end{cases} \tag{2.1}$$

where $h = w, o, r, m$ is the index referring to either 'workmen' (w), 'office workers' (o), 'researchers'(r), or 'managers' (m), 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.

4. *Investment in capital accumulation.* 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. This latter is defined as a function of their planned rate of capacity utilization (which, in turn, depends on desired production) and their past-period profit rate. The precise specification of firms' desired capacity growth function can be found in section 4, given its centrality for the experiment presented in section 4.

5. *Capital good market (I).* 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. However, consumption firms are able to interact with a limited number of capital suppliers. In order to rank the alternative vintages proposed by different suppliers, consumption firms employ a simple algorithm which compares not only the prices, but also the expected units costs associated to each vintage, which depend on their productivities. Then, consumption firms compute the number of units required to replace the machineries reaching obsolescence and to fill the possible gap between their current and desired productive capacity, and invest accordingly.

6. *Credit demand.* Firms' demand for external finance 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 for precautionary reasons. Taking this in mind, firms compare their expected financial needs with the available internal funds and compute their credit demand: when positive, they select a lender comparing the interest rates offered by a random subset of banks and apply for a loan.

7. *Credit market.* The behavior of banks resembles, without any relevant modification, that presented in Caiani et al. (2016) to which we refer for the details. In particular, banks are willing to satisfy agents' demand for credit whenever the expected return associated to a loan project is greater than, or equal to, zero. This expected return depends on the rate of interest offered by the bank, on the amount of credit asked, and on the borrower's credit worthiness. This latter is a function of the firm's operational cash flows (OCF), of the outlays associated to the service of its new and old debts, and of its collateral value (i.e. the financial value of capital goods for consumption firms). Credit rationing may apply depending on whether banks decide to grant the whole amount demanded, a share of it, or nothing. The loan creation process leads to an expansion of the banks' balance sheets, as the new loan recorded as an asset is mirrored by a new deposit, a liability for the bank. On the other side, since loans have a multi-period duration, firms will generally have a collection of different loans with different banks on the liability side of their balance sheet.

8. *Labor markets.* Unemployed households interact with private firms and the government on *segmented* labor market, one for each type of household/worker: first, the labor market for workmen opens, then the market for office workers, afterwards the market for researchers, and finally, that for top managers. As far as the government is concerned, we assume that the public sector hires a constant share of households, employing the same proportions characterizing firms to determine its demand for each type of workers.

9. *Production.* Capital and consumption firms produce their output.

10. *R&D Activity.* Firms operating in the capital-good industry invest in R&D to improve the technology embedded in their output, so to possibly improve their market share and profits. This investment coincides with the wages paid to researchers hired for this purpose. The innovative process underlying capital firms' R&D activity is shaped following the well established Evolutionary tradition (Nelson and Winter, 1977, 1982; Winter, 1984; Dosi et al., 2010; Caiani et al., 2017). More details on this process can be found in section 3, given its centrality for the experiment presented in section 3.

    In addition, part of R&D investment by capital firms is dedicated to imitation, by which firms can imitate (when successful) the best technology within a randomly sampled subset of competitors.

11. *Capital goods market (II).* Consumption firms receive capital units ordered from their suppliers, which sum up to their current capital stock, being employable for production starting from the next period.

12. *Consumption goods market.* Households consume with fixed propensities out of expected real disposable income. These propensities are differentiated as higher income groups consume a lower share of their income.[3]In addition, individual consumption displays a certain degree of downward rigidity in that consumers' demand cannot fall under a given share of past-period real consumption, in order to account for the habits persistence observed in real world.[4]

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 pays interest to bondholders. 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. *Profits.* Profits of firms are computed: capital firms' pre-tax profits are the sum of revenues from sales, interests received, and the nominal variation of inventories, minus wages and interests paid on loans. For consumption firms, also the financial amortization of capital is subtracted.

16. *Taxes.* The government collect taxes on profits from firms and banks, and taxes on income and wealth from households. As in the baseline presented in Caiani et al. (2017) we assume that households pay taxes on their income and wealth being subjected to two flat tax rates, one for income and one for wealth. Similarly, also the tax rate on profits is equal across firms and banks. However, these tax rates are multiplied by a scaling factor which adapts in relation to the dynamics of the deficit and debt-to-GDP ratios: this factor is increased if past deficit/GDP was higher than a threshold or if the variation of debt/GDP was positive; it is diminished if past deficit/GDP was lower than the threshold and the variation of debt/GDP was negative (or null); it is kept unaltered otherwise.

17. *Dividends.* Dividends, computed as a constant share of profits (when positive), are distributed to firms' and banks' owners, namely the top managers.

18. *Deposit market.* Households and firms select their deposit bank, comparing the interest rate they offer. Banks must have enough reserves in their accounts at the Central Bank so to satisfy a mandatory liquidity ratio of 8%. Since deposits represent a cheaper source of reserves, compared to Central Bank cash advances, commercial banks compete on the deposit market. Banks increase the interest rate whenever their liquidity ratio is below a target, defined as the sector average liquidity ratio in the last period. In this way they try to attract depositors. Otherwise, they decrease it.

19. *Bond purchases.* Banks use the reserves in excess of their target (after repayment of previous bonds by the government) to purchase newly issued government bonds. We assume the interest rate on bonds and their price to be fixed. Banks use part of their reserves to buy bonds. The Central Bank buys all residual bonds.

20. *Cash Advances.* The Central Bank accommodates cash advances requests made by private banks in order to respect the mandatory reserve ratio. Cash advances are assumed to be repaid after one period

[3]The idea of differentiated saving and consumption propensities according to income levels obviously stems from the Keynesian tradition. Keynes' fundamental psychological law of consumption 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, in Caiani et al. (2017) we assumed 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%. These values are reasonably similar to empirical ones (Dynan et al., 2004).

[4]Obviously consumption by households can still be financially constrained, so that desired consumption might end up being financially unfeasible.

and their constant interest rate represents the upper bound for interest rates on deposits offered by banks. For simplicity reasons, we assume the Central Bank pays no interest on private banks' reserves accounts.

21. *Central Bank's profit.* The Central Bank earns a profit equal to the flow of interest coming from bonds and cash advances. This profit is immediately transferred to the government for simplicity reason.

22. *Bankruptcy.* In each period of the simulation, firms can default if they run out of liquidity to honor their financial commitments (e.g. wages, debt service, taxes), 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, so to maintain the number of firms and banks constant. A bankruptcy by a firm implies that wages paid to workers are reduced or not paid at all, since deposits are insufficient to cover these outlays. In addition, it generates a non-performing loans for its creditors. In the case of capital firms, this loss is totally borne by banks as capital firms do not have any collateral. In the case of a default by a consumption firm, banks can try to recover part of the outstanding credit by making fire sales of the firm's machineries. These capital goods are re-purchased by 'managers' so to allow the firm to restart as a brand new enterprise. Similarly, when a bank defaults, owners intervene with their own financial resources to restore a positive net-worth.

3 Alternative wage and technological regimes

The aim of the first experiment presented in this paper is to examine in depth the relationship between the dynamics of innovation on the one hand, and income and wealth distribution on the other hand. More precisely, we wanted to assess how different distributive regimes, characterized as relatively more (or less) favorable to workers than to managers (i.e. firms' and banks' owners), affect the dynamics of the system under different characterizations of the innovation process.

In the model, capital good producers invest in R&D in order to improve the technology embedded in their output so to attract more customers. The number of researchers hired to perform R&D depends on the their planned level of output, as researchers represent a constant share of workmen hired for production.

Following a well established tradition (Nelson and Winter, 1977, 1982; Winter, 1984; Dosi et al., 2010; Caiani et al., 2017), first the probability of an innovative success for firm k is computed Pr_{tk}^{inn}. In our model, this is an increasing function of the number of researchers hired. When successful, a productivity gain $\Delta_{\mu_{jt}}$ is sampled from a Folded Normal distribution FN_3 with parameters $(\mu_{FN_3}, \sigma^2_{FN_3})$ and the new productivity level, $\mu_{jt+1} = \mu_{jt}(1 + \Delta_{\mu_{jt}})$ is embedded in the capital vintages produced starting from the next period.[5]

For the experiment presented in this section, we consider five scenarios where the average dimension of productivity gains achieved by firms through R&D is progressively increased, starting from a scenario with no innovation at all, where researchers act as normal office (i.e. middle level) workers. These alternative scenarios are characterized as a parameter sweep over $\sigma^2_{FN_3}$, the parameter defining the standard deviation of the Folded Normal distribution from which firms sample the productivity gains associated to an innovation. More precisely, the following values for $\sigma^2_{FN_3}$ are tested: $[0, 0.005, 0.01, 0.015, 0.02]$.

Then, for each innovation scenario, we perform a sensitivity analysis on four values of the parameter t_u for workmen, researchers, and office workers, ranging from 1 to 4 with a unitary increment. Therefore, for this experiment we tested 20 different configurations obtained from the combination of the 5 innovation regimes and the 4 wage regimes. For each configuration we ran 25 Monte Carlo repetitions for a total of 500 simulations. The parameter t_u, as explained in the text, defines the threshold number of periods of unemployment over a year required to induce agents to reduce their reservation wage. Higher values of t_u thus make wages downward revisions less frequent, while making upward revisions more likely. Since the value of t_u for managers is kept constant at 2, i.e. its baseline value, higher values of the parameter for the other classes tend to favor the growth of workers' (i.e. workmen, researchers, and office workers) wages relatively to those of managers, thereby increasing their share of income and wealth. The experiments conducted on parameter t_u thus allow to assess in a simple and intuitive way the effects of policies (e.g. collective bargaining and minimum wage laws) aiming to strengthen workers' wage claims and to support their wage growth, in particular with respect to profits and managers' remuneration. In other words, greater values of t_u are associated to more equal personal income and wealth distributions, and to a

[5]For sake of completeness, we remind that capital firms can also try to imitate the technology of some competitors through imitative R&D, as explained in details in Caiani et al. (2017).

functional distribution more favorable to workers, as we discussed extensively in Caiani et al. (2017). The aim of the experiment is to test how these different distribution regimes, combined with different technological regimes, concur to shape the economic dynamics of the system.

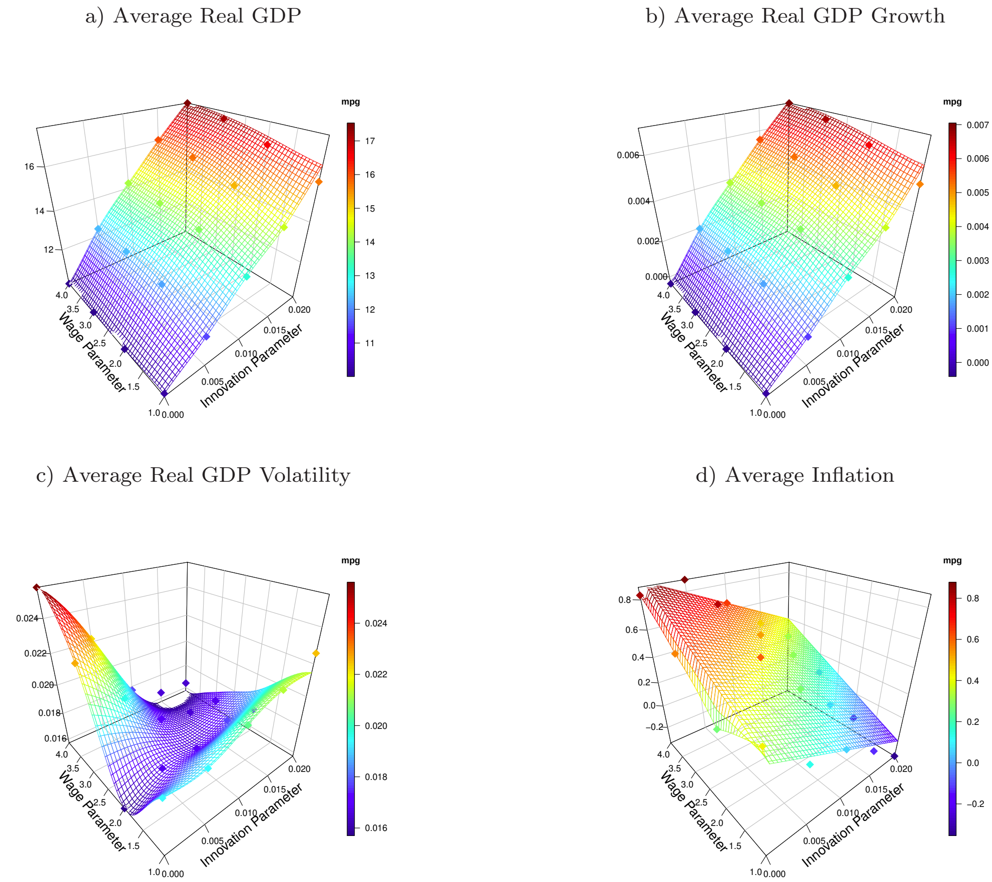

Figure 1: The effects of workers' wage regimes (t_u) and productivity gains characterization ($\sigma^2_{FN_3}$) on the economic performance.

3.1 Results

Figures from 1 to 4 show the average Monte Carlo results for a batch of selected variables, displayed as filled squares, and the surfaces obtained by interpolating these values. In order to draw these surfaces, the Kriging interpolation method was employed. This technique, originally developed in Geostatistics, has been increasingly adopted as a meta-modeling tool in Economics, in order to approximate the behavior of 'big' models analyzed through computer experiments over a given parameter space. In particular, the Kringing method appears to be well suited for the carrying out of the sensitivity analysis of Agent Based models, as extensively advocated by Salle and Yildizoglu (2014), who provide an exhaustive description of the technique and its possible applications in this field of study.

Figure 1-a and 1-b display the Monte Carlo average end-of-simulation levels and average growth rates (over the time span 500:1000) of real GDP in the 20 different scenarios tested. Figure 2-a and 2-c display the average end-of-simulation levels for real consumption and real investment.[6] The figures clearly highlight that innovation is the main driver of economic growth, as real GDP sharply and constantly raises - both in levels and growth rates - as we increase $\sigma^2_{FN_3}$ from its initial value of 0 (i.e. no technological progress case) to 0.02 (i.e. fastest innovation case). Not surprisingly, also real consumption and real investment increase with $\sigma^2_{FN_3}$. Innovation indeed increases the productivity of capital vintages produced by capital firms, and then the productivity of labor, which is employed by consumption firms in fixed

[6]Average end-of-simulation values were computed as the mean of the logarithm of the trend component, obtained by filtering the series with the Hodrick-Prescott filter for quarterly data.

proportions with capital units[7]. This allows to produce more output with the same amount of productive factors.

In the firms' perspective, for given values of wages, innovation allows to decrease unit variable costs of production. Since prices are set as a markup over expected unit variables costs, this should allow to reduce the price and to improve firms' competitiveness without reducing firms' profit margin. However, in general, wages tend to increase over the simulation timespan if unemployment is not chronically high, as employed workers progressively revise upwardly their reservation wage. Technological progress thus allows to mitigate inflation in the measure in which it dampens the growth of unit variable costs of production caused by the raising wage bill. This tends to increase households' purchasing power, enabling them to absorb the additional batches of goods that firms can produce thanks to the enhanced productivity of new vintages.

Indeed, innovation *per se* is not sufficient to ensure a long lasting real output growth. Aggregate real demand should grow first in order to increase firms' sales and improve their sales expectations, so to persuade them to increase production levels and their productive capacity through investment. However, firms' may decide to increase their markup when sales are going well (i.e. if inventories are below the desired level and the rate of capacity utilization is above the 'normal' one) so to increase their profit margin. This tends to increase prices and reduce households' purchasing power. In a systemic perspective, the dynamics of firms' markups depend both on macroeconomic aspects, since the level of aggregate demand affects the level of sales of all firms, and on microeconomic, or industry-specific, factors affecting the competitive pressure faced by firms on the market, such as the market concentration, firms' size distribution, and productivity levels dispersion across producers.[8] Indeed, more concentrated markets, dominated by fewer, larger, and highly productive firms are subject to lower competitive pressure, so that firms' emerging markups are higher on average. Innovation seems to exacerbate firms' 'Schumpeterian' selection process leading to more concentrated market structure.[9]

Furthermore, innovation sustains firms' profits, as highlighted by figure 3-d, by reducing total unit costs of production thanks to the increased productivity of capital goods. Since firms' desired capacity growth rate (see equation 4.1) also depends on the past profit rate, this prevents investment in capital accumulation from falling as a consequence of the capital-saving effect of technological change[10], making firms more willing to expand their productive capacity, while also increasing the internal funding available for this purpose.

However, while real output increases constantly for higher values of $\sigma^2_{FN_3}$, unemployment levels display a more complicated dynamics across the various scenarios tested. When workers' wage growth is very low compared to managers' (i.e. $t_u = 1$), faster technological progress always means higher unemployment. In the other scenarios, a moderate pace of technological progress instead allows to reduce unemployment, whereas further increases of $\sigma^2_{FN_3}$ tend to raise unemployment again, making the labor-saving effect to prevail. This tendency can be counteracted by promoting a faster grow of workers' wages. Distributive regimes which favor workers (i.e. workmen, researchers, and office workers) over capitalists (i.e. managers-equity holders) seem to improve the dynamics of the system in all the positive innovation scenarios tested, allowing aggregate demand to grow with potential output producible thanks to the new capital vintages. If unemployed workers are relatively more reluctant to decrease their reservation wages and employed workers are more confident in increasing their wage claims, workers' purchasing power increases. Since workers are characterized by higher average propensities to consume, compared to managers', households' total demand increases, as testified by figure 2-a which displays households' total real consumption. The enhanced pattern of consumption observed for higher values of t_u, in turn, improves consumption firms' sales expectations, stimulating further capital accumulation, as shown in figure 2-c. In all the scenarios with positive productivity growth, increasing t_u not only improves the dynamics of real output,

[7] Indeed, assuming a constant capital-labor ratio $\overline{l_k}$ across capital vintages, the productivity of workers employing the vintage k can be expressed as $\mu_{Nk} = \mu_k \overline{l_k}$, being μ_k the productivity associated to the capital vintage k.

[8] However, desired markups can be different from realized ones since firms' pricing is based on the expected unit labor costs, which can be different from real ones.

[9] For the consumption good market for example, the Monte Carlo average of the Herfindahl Numbers Equivalent at the end of the simulation is almost monotonically increasing as we increase the pace of innovation. When all firms have equal market shares, the Herfindahl Numbers Equivalent is equal to the number of firms in the industry (100 in our case). Instead, when firms have unequal shares, it gives the number of equal-sized firms in a hypothetical industry characterized by the same degree of concentration as the actual industry, according to the Herfindahl-Hirschman Index. The percentage variation of the index between the two extreme cases $\sigma^2_{FN_3} = 0$ and $\sigma^2_{FN_3} = 0.02$ is -46% for the $t_u = 1$ scenario, -43% for $t_u = 2$, -41% for $t_u = 3$, and -30% for $t_u = 4$, with values ranging between 48 and 20.

[10] Indeed, as capital productivity increases, fewer machineries are needed to produce a given quantity of consumption goods. Capital firms' investment in R&D thus ends up reducing the necessity for their own goods. One may thus wonder what is the incentive leading capital firms to invest in R&D: capital firms are forced by the pressure of their competitors to invest in R&D in order to improve the attractiveness of the vintages they produce.

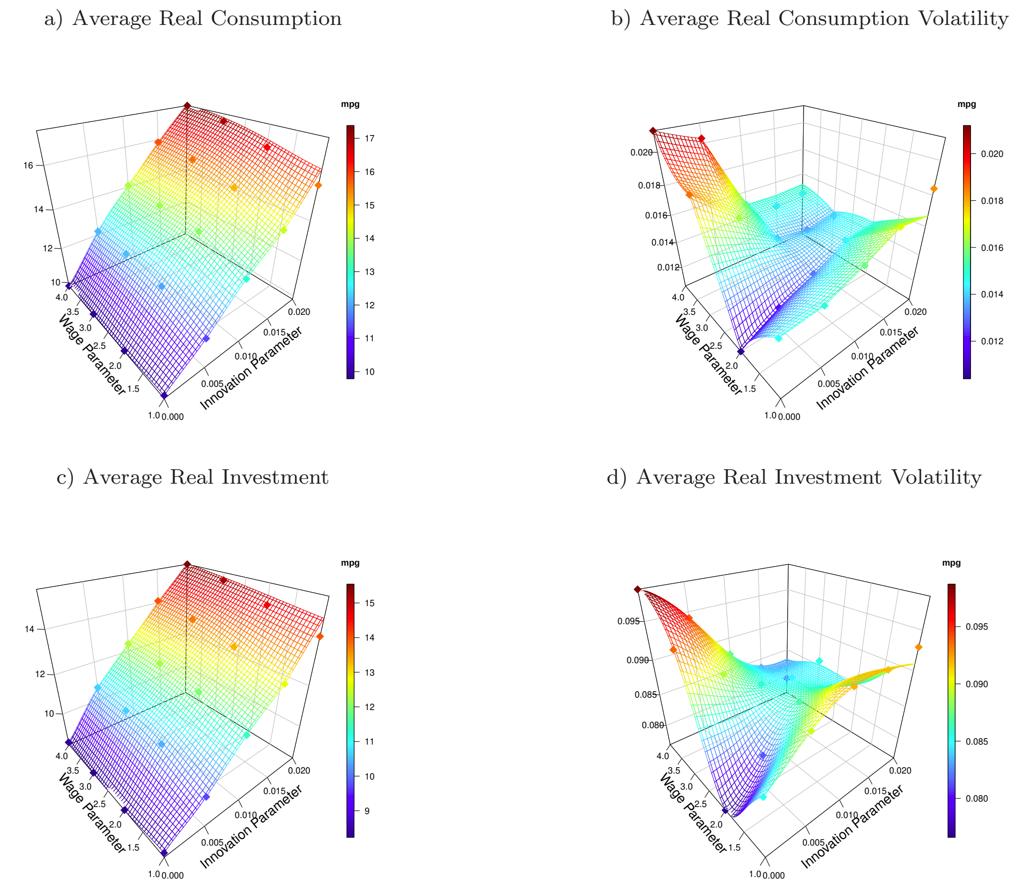

Figure 2: The effects of workers' wage regimes (t_u) and productivity gains characterization ($\sigma^2_{FN_3}$) on the economic performance.

but sharply reduces unemployment levels counteracting the labor-saving effect of technological progress. The reduction of unemployment is even more significant if we consider that the improved patterns of real output, employment, and profits enhance R&D investment, fostering further innovations in capital vintages which eventually increase the dynamics of labor productivity, as shown by figure 3-a and 3-b.

Only in the case with no innovation, where labor productivity growth sticks to zero, an increase of t_u for workers does not seem to produce any positive impact on the dynamics of main economic aggregates. The experiments conducted under this scenario always display a depressed economy where unemployment is pathologically high, irrespective of the value given to t_u.[11] Higher values of t_u in absence of innovation are thus associated to higher inflation (figure 1-d), pushed by the higher unit variable costs of production associated to the (relatively) faster pace of growth of workmen' and office workers' wages [12].

One may be prone to believe that, being workers' wage bill the biggest entry in firms' variable costs of production, regimes which favor workers' wage claims relatively to managers' tend to cause a reduction of firms' profit rates. In a dynamic and systemic perspective, the opposite is true. In the measure in which workers' wages growth stimulate aggregate demand, firms have higher sales expectations and are more

[11] Admittedly, an increase in workers' wages dynamics, relatively to that of managers, seems to exert even slightly negative effects, though the strength of this relationship is hard to assess. Indeed, unemployment in the $t_u = 2, 3, 4$ cases is slightly above the average value in the $t_u = 0$ case, reflecting a lower level of real output. However, unemployment does not increase monotonically with t_u. This negative effect has a very specific motivation: in the depressed economy emerging from the four scenarios with no innovation, defaults (even of large firms) are more frequent. As a consequence, banks' defaults are less infrequent as well. In such a context, switching the distribution of income and wealth towards workers, at the expense of managers-owners, may deprive these latter of the financial resources required to replace consumption firms (i.e. to repurchase capital goods from creditors) and to bail-in and recapitalize banks after their default, in particular if the bankruptcies involve large organizations. New entrants replacing defaulted firms will thus lack the internal funds required to hire workers. If this is the case, new entrants will either end up being financially constrained, thus being prevented from carrying out their production plans, or will resort to credit, thus becoming highly leveraged and more fragile.

[12] Indeed, researchers are assimilated to office workers in this scenario so that funds invested in R&D in the other scenarios with technological change are here employed to pay office workers.

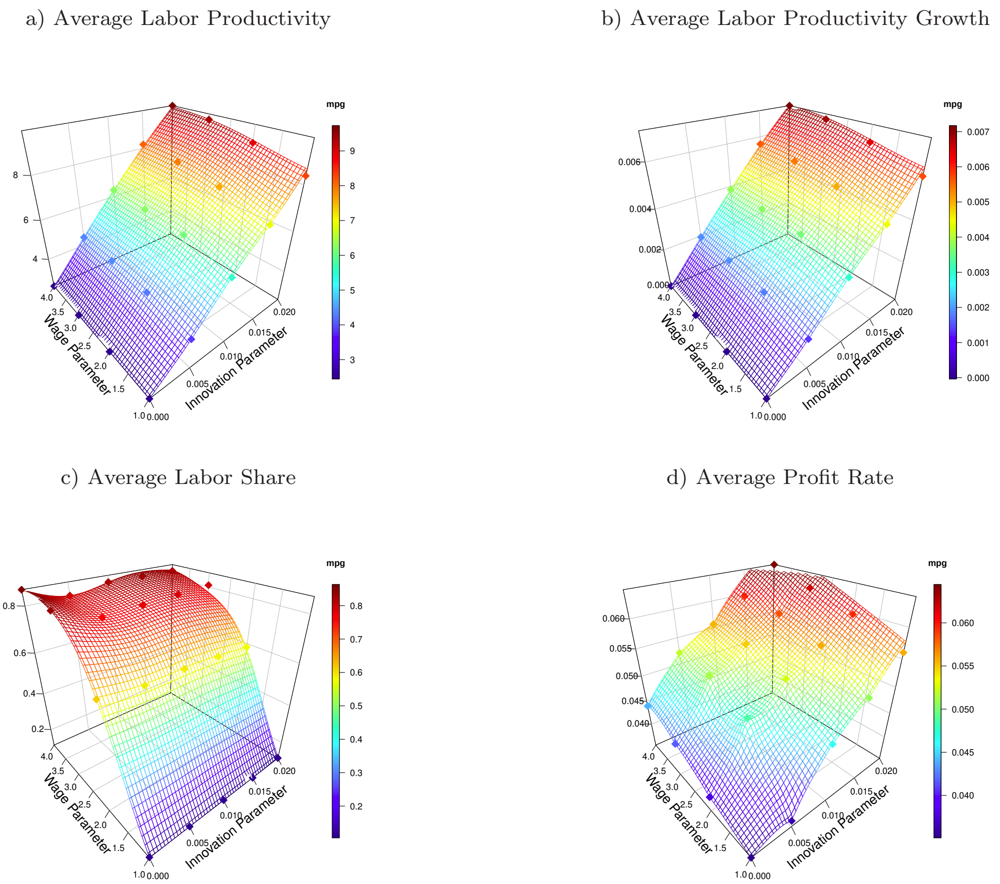

Figure 3: The effects of workers' wage regimes (t_u) and productivity gains characterization ($\sigma^2_{FN_3}$) on the economic performance, functional income distribution, and firms' profitability.

likely to sell greater volumes of goods on the market. This improves total profits, while also implying that firms can exploit their stock of machineries at a level closer to full capacity. The ratio between total profits and the nominal value of firms' capital accumulated through investment, that is the rate of profit, ends up being generally higher for higher values of t_u.

Not surprisingly, part of the enhanced aggregate demand achieved by increasing t_u goes to feed inflation: figure 1-d, which displays the average quarterly growth rate of consumption good prices (in percentage values) on the usual timespan, shows that inflation is positively correlated to t_u. On the contrary, as already discussed, inflation is negatively correlated to technological progress, because greater productivity gains allow to dampen unit variable costs of production.

In order to assess how a different pace of technological progress and different distributive regimes impact on the amplitude of economic cycles, we plot the Monte Carlo average standard deviations[13] of some key economic variables. Interestingly, the volatility of main economic aggregates seems to respond in similar ways to the different combinations of the two parameters $\sigma^2_{FN_3}$ and t_u investigated in this experiment. As depicted in figures 1-c, 2-b and 2-d the volatility of real GDP, real consumption, and real investment all display an eagle ray-shaped surface: when innovation proceeds with longer strides higher values of t_u allow to dampen the volatility of output. When instead potential productivity gains are smaller or totally absent, an initial increase of t_u from 1 to 2 allows to reduce the volatility, whereas further increments of the parameter increase volatility again. The volatility of unemployment is very low when innovation is absent. In this case the economy sticks to very high levels of unemployment with only minor fluctuations. In this configuration increasing t_u seems to slightly increase the volatility but the extent of this variation is narrow. When innovation is moderate (i.e. for the lowest positive values of $\sigma^2_{FN_3}$) instead, favoring workers' wage growth seems to increase significantly the volatility of

[13]More precisely, for each simulation and for each variable we compute the standard deviation over the time span 500:1000 of the cyclical component normalized by the trend component in order to allow a comparison on the same scale. Then we take the averages across the 25 Monte Carlo repetitions performed under each parameter configuration.

unemployment. However, this positive relationship between t_u and the volatility of unemployment seems to be significantly dampened when innovation proceeds at faster pace.[14]

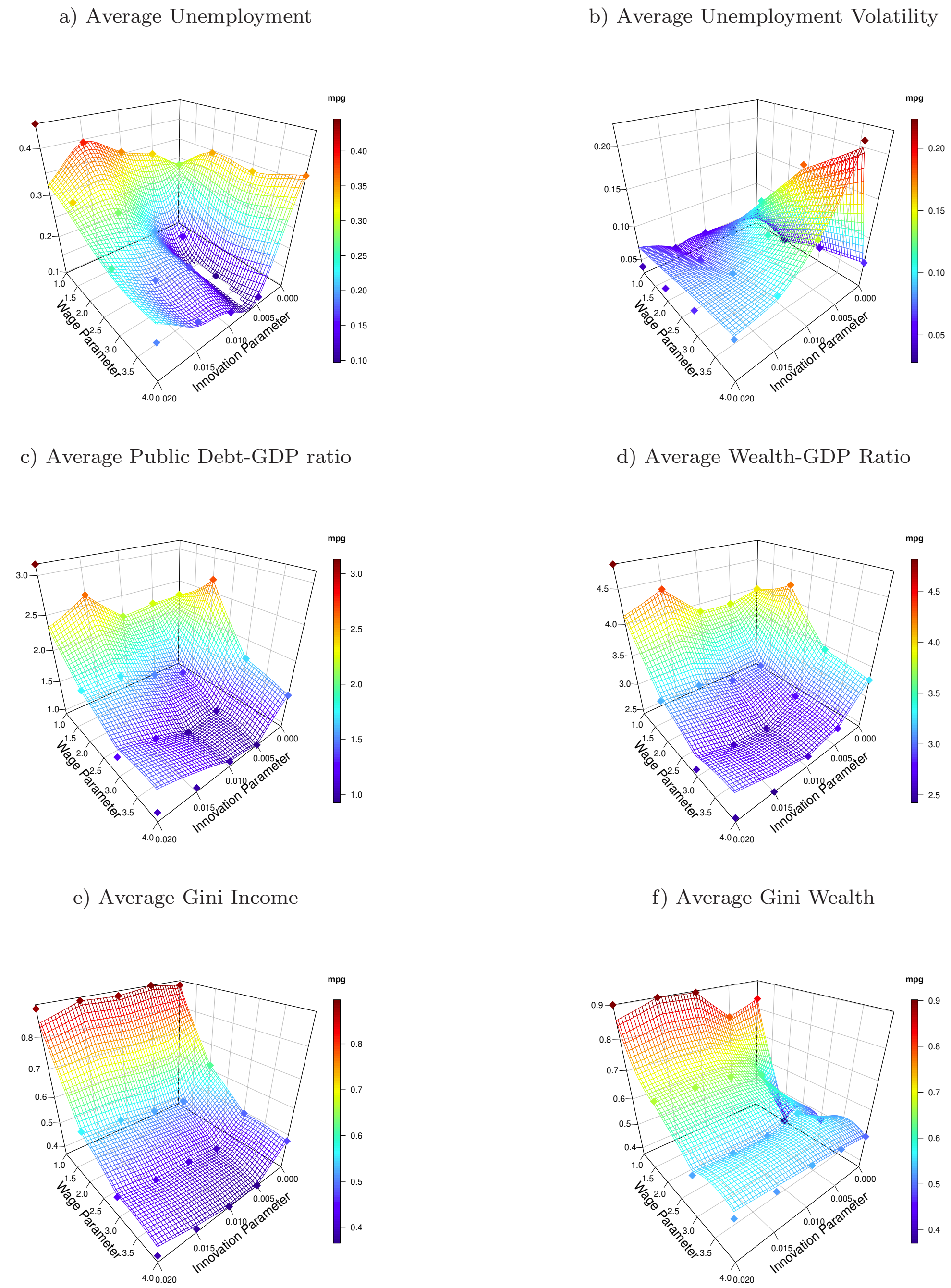

Figure 4: The effects of workers' wage regimes (t_u) and productivity gains characterization ($\sigma^2_{FN_3}$) on the economic performance, public finance, and personal income and wealth distribution.

Figure 4-d displays the ratio between the total net worth of the private sector (i.e. households, banks, and firms) and GDP. The shape of the figure has many similarities with that of Public Debt over GDP. This is not completely surprising, given the structure of our economy: if we abstracted from physical capital and firms' inventories, assuming that there were not real assets in the economy, the two pictures should exactly match, because the net financial wealth of the private sector should be exactly offset by

[14] Furthermore, it must be noticed that the higher values plotted for higher values of t_u does not necessarily imply wider fluctuations of unemployment, that is a higher standard deviation of the cyclical component *per se*. Values plotted indeed can be higher (lower) either as a consequence of a higher (lower) standard deviation, for given values of the trend, or as a consequence of lower (higher) trend values for given standard deviations.

public debt, given the fundamental accounting principle that every financial stock must be a liability for someone and an asset for someone else. The discrepancy between the total value of the private wealth and the value of public debt is then equal to the financial value of physical stocks held by firms (i.e. machineries and inventories of consumption goods), which are the only assets in our artificial economy which do not represent a liability for anyone else. The similar shape of the two graphs in turn implies that the value of these real assets, relative to the net value of the financial stocks held by the private sector, is quite stable across scenarios. Interestingly, wealth-GDP ratios are the highest in the 4 scenarios with no innovation and in the scenarios where wages of workers proceed at lowest pace ($t_u = 1$), whereas being generally decreasing for higher values of t_u.

The decline of the wealth-GDP ratio as we increase t_u can be interpreted as the consequence of the shift in the distribution of income from high-propensity-to-save/low-propensity-to-spend agents towards low-propensity-to-save/high propensity-to-spend agents which favors the growth of income over the accumulation of assets by reducing the average rate of saving. This allows to attain a quasi-equilibrium in which income is relatively higher compared to the stock of wealth. However, as suggested for example by Piketty and Zucman (2014), wealth-income ratios increase or decrease also depending on the rate of growth of national income. Piketty and Zucman (2014) refers to the Harrod-Domar formula with a fixed-coefficients production function – which states that the wealth-income ratio β in the long run is equal to the net-of-depreciation saving rate s divided by the income growth rate g – to explain the rise of wealth-GDP ratios in most advanced economies over the last decades: besides the recovery of asset prices, the Harrod (1939)-Domar (1947) formula identifies in the slowdown of productivity and population growth (absent in our model) two of the driving forces of the observed wealth-GDP ratio upsurge. If we adhere to this interpretation, the higher wealth-income ratios observed for the lower values of t_u, and when technological change is absent, can be partly explained as a consequence of the rise of s due to the distribution more favorable to managers-capitalists, and partly as a consequence of the lower GDP growth which characterizes these configurations, as one can observe in figures 1-b and 1-d. In our model, differently from the Harrod-Domar analysis, s is not given. Indeed, it endogenously evolves according to the evolution of the income distribution between different classes of agents, which is fundamentally affected by the value of t_u, as we have seen.

The differences between these scenarios, as far as inequality is concerned, can be appreciated both in terms of personal and functional income distribution: figure 3.c shows that the labor share, measured as the share of income going to workmen, researchers, and office workers, increases significantly with t_u, whereas it is almost unaffected by technological change.

Similarly, inequality as measured by the Gini indexes of income and wealth (figures 4-e and 4-f), sharply decreases as we sustain workers' wage dynamics compared to managers'. The impact of innovation is again less unambiguous. The cases with positive innovation are generally characterized by a lower income inequality compared to the scenario with no innovation, where the efficacy of distributive policies which favor workers seem to be significantly dampened. However, the differences between the Gini indexes of income in the scenarios with positive technological change are almost negligible compared to the strong differences associated with alternative wage regimes. The same result seems to hold for wealth inequality. However, differently from income inequality, the scenario with no innovation does not display higher wealth inequality.[15]

These results thus seem to de-emphasize the role of technological progress as a possible cause of the greater inequality observed over the last decades in most advanced economies: Aghion et al. (2015), for example, employs a Schumpeterian framework to show that innovation dynamics causes top income inequality: technological innovations allow the entrepreneur to increase his technological advantage over competitors, reducing labor requirements at the expense of workers' share of income, at least temporarily. Our model results do not seem to provide support for this thesis. The labor share indeed is almost unaffected by the pace of technological change.

In addition, the experiments analyzed in this section tend to confirm the robustness of the fundamental indications provided by Caiani et al. (2017) regarding the efficacy of distributive policies which are directly targeted to sustain workers' growth pace relative to top income earners' as a tool to tackle inequality. Conversely, our findings are broadly in line with empirical studies stressing the role of labor market deregulations and the fall of the unionization rates in causing a decline of wage shares and a concomitant rise of incomes at the top (Jaumotte and Buitron, 2015). These studies show that 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). In our model, the parameter t_u can be assumed

[15] Furthermore, in this latter case the impact of t_u is not monotonic, since the Gini index is the lowest for the $t_u = 2$ case, while being quite in line with the other experiments under the alternative wage regimes.

to represent a proxy of the degree of labor protection and workers' coordination in the labor markets, as higher values of t_u make wages downward revisions less frequent, while making upward revisions more likely. The reduction of income and wealth inequality caused by an increase of t_u in turn exerts a positive and consistent effect on the performance of the system, whereas higher inequality tends to slowdown economic growth and technological change. These findings are thus in line with the empirical studies which support the existence of a negative relationship between innovation and inequality (Weinhold and Nair-Reichert, 2009; Jacobs, 2016; Hopkin et al., 2014), while being in contrast with the thesis according to which inequality would be the 'price to pay' to support technological change and real output dynamics, providing the right incentives to invest in innovation-enhancing activities (Acemoglu et al., 2012). Moreover, our results are also in line with Storm and Naastepad (2012), who show that higher employment protection and more extensive labor market regulation are associated with higher labor productivity growth, and with Vergeer and Kleinknecht (2014), who find that weak wage growth and a smaller wage share significantly reduce labor productivity growth. More in general, our contribution seems to confirm the existence of a positive relationship between demand patterns and productivity growth, compatible with the theoretical and empirical literature stemming from the Kaldor-Verdoon growth laws (Kaldor, 1957; Thirlwall, 1983; McCombie, 2002).

4 Alternative investment and wage regimes

Advocators of a profit-led growth regime maintain that an increase in firms' profits would provide incentives to invest more, thereby exerting a positive effect on capital accumulation and growth. This should hence justify the opportunity of a distribution of income favoring capital over labor. Similarly, referring to the personal income distribution, rather than to its functional distribution, it has been argued that distributive configurations more skewed towards top incomes would free resources for investment, thereby increasing the level of activity and favoring the turnover of obsolete machineries. These two visions do not deny that more unequal distributions do exert a negative impact on consumption - at least in the short run - given the falling marginal propensity to consume with respect to income levels (Dynan et al., 2004). Rather, they argue that the beneficial effect related to investment would offset this initial drop, triggering a virtuous circle that would eventually trickle down to the poorest, possibly allowing them to consume more than they would afford in a more equal society.

In the debate about the predominance of wage-led or profit-led growth regimes, as well as in the dispute about the effects of personal income and wealth inequality on the performance of our economies, the crux of the matter thus seems to be how investment responds to possible changes in the distribution of income. If for example firms' investment projects are highly dependent on their sales expectations, then the drop of consumption originated by a change of the distribution in favor of capital and top incomes would eventually depress investment. On the contrary, if firms' look at the return on their past investments to assess the opportunity of future investments, a reduction of unit costs thanks to a distributive regime more favorable to firms and managers may eventually increase profits and stimulate investment, notwithstanding the fall of aggregate demand due to the lower purchasing power of low-propensity-to-save/high-propensity-to-consume agents.

To assess how these different contingencies affect the dynamics of consumption, investment, employment, and other main variables in the present model, we propose an experiment in which the four different wage regimes, already analyzed in previous sections, are combined with alternative configurations of firms' desired capacity growth function, which determines their investment.

In the model, consumption firms invest in order to attain a desired rate of growth of their productive capacity g^D_{ct} which depends on their planned rate of capacity utilization, u^D_{ct},[16] and their past rate of profit, r_{ct-1}, equal to the ratio between the firm's operating cash flows and the financial value of its capital stock.

$$g^D_{ct} = \gamma_1 \frac{u^D_{ct} - \overline{u}}{\overline{u}} + \gamma_2 \frac{r_{ct-1} - \overline{r}}{\overline{r}} \tag{4.1}$$

Here, $\overline{u}$ and $\overline{r}$ denote firms' 'normal' rates of capacity utilization and profit respectively[17], both assumed to be constant and equal across firms.

[16] This planned rate of capacity utilization, in turn, depends on the desired output of the firm given its sales expectation and the stock of unsold inventories inherited from the previous period.

[17] The empirical evidence suggests that normal rates of utilization range between 80 and 90% (Eichner, 1976). For our model we employed the value of 80%. A detailed discussion about empirical and theoretical contributions on this aspect can be found in Lavoie (2015). The value of $\overline{r}$ was set at approximately 4.3%. This value was obtained from the calibration procedure explained in details in the appendix of Caiani et al. (2016).

In order to consider alternative characterizations of equation 4.1, we jointly modify γ_1 and γ_2 so to change the relative weight given by firms to the capacity utilization and profit rate factors in their desired capacity growth function.[18] Giving more weight to the capacity utilization factor, by increasing γ_1, means that firms look more at their sales expectations and less at the rate of profit when taking their investment decisions. The opposite occurs if we increase γ_2. In our experiments we consider 5 different specifications of the couple $[\gamma_1, \gamma_2]$: $[0.00, 0.03]$, $[0.075, 0.0225]$, $[0.015, 0.015]$, $[0.0225, 0.075]$,$[0.03, 0.00]$. The first and the last configurations correspond to the most extreme scenarios where, respectively, firms give all the weight to the capacity utilization factor or to the profit rate. As for the experiment of section 3, also in this case we perform a sensitivity analysis on the usual four values of the parameter t_u for workmen, researchers, and office workers, for each of the five configurations of the investment function. Therefore, also for this second experiment we tested 20 different configurations obtained from the combination the 5 investment function specifications and the 4 wage regimes. For each configuration we ran 25 Monte Carlo repetitions for a total of 500 simulations.

4.1 Results

Figures 5 to 8 display the same dashboard of variables analyzed in the first experiment. For a matter of graphic rendering, each investment scenario has been synthetically identified on the corresponding horizontal axis by the difference between the values of γ_1 and γ_2, so that -0.03 identifies the first scenario, -0.015 the second, 0.0 the third, 0.015 the fourth, and 0.03 the latter one.

However, the first scenario has been scrapped from the plots for graphical reasons: indeed, when firms only look at the rate of capacity utilization the economy always ends up collapsing. Therefore, for most of variables investigated, the difference between the values under this scenario and those obtained under the other four cases is huge, thereby deteriorating the quality of the interpolation and making it difficult to appreciate the differences between the four non-collapsing scenarios.

We then analyze the first scenario in isolation from the others and we comment on the results displayed in the figures 5 to 8 afterwards.

When firms only look at their rate of capacity utilization to determine investment, this tends to become very pro-cyclical, in particular during recessions. During expansions, when aggregate demand increases and firms' sales improve, firms tend to operate at their full-capacity level. Since all the weight is given to the difference between the current and the normal rates of capacity utilization, this induces firms to increase their productive capacity, spurring investment. On the contrary, when demand falls firms reduce their level of activity, partly because they expect to sell less and partly because they are left with a growing stock of unsold inventories. As a consequence, firms are willing to let their productive capacity drop, not replacing (or replacing only partially) machineries reaching obsolescence. Depressed investment in turn reduces employment and aggregate demand further, negatively feeding back on consumption firms' sales and depressing investment further. When firms only look at their capacity utilization (i.e. at sales expectations) to determine investment, these vicious spirals are difficult to revert and sooner or later the economy will remain trapped into a depressive path, eventually leading to its complete collapse. This does not occur in the other scenarios where firms give some weight also to their past profitability in determining investment. In these cases, the fall of workers' wages caused by the recession and the downsizing of firms' capital stock allow firms to recover some profitability, thus counteracting the drop of investment caused by the fall of firms' capacity utilization rates. This mitigates the recession and eventually allows to break the vicious depressive spiral and to revert the cycle.

Furthermore, the recessionary spiral in the collapsing investment scenario is exacerbated by the tax rates revision rule of the government, which was designed to avoid an explosive path of public debt. This rule is effective in most scenarios: the debt-GDP ratios displayed in figures 4-c and 8-c appear to be relatively stable on a long time-span. However, such a rule is likely to act in a pro-cyclical way which can amplify the amplitude of economic cycles. In particular, during strong recessions – as those experienced already-depressed scenario where firms give all the weight to the capacity utilization term of the investment function – the rising path of public debt originated from the drop of tax revenues and the rise of outlays connected to unemployment benefits, and the concomitant fall on nominal GDP, are likely to induce successive increments of the tax rates. These in turn can exacerbate the ongoing recession, worsening debt-GDP ratios and motivating further increases of tax rates.

[18] The logic of this experiment is thus broadly in line with Napoletano et al. (2012) (see section 1), though distinguishing itself for the higher number of investment and wage scenarios analyzed, and for the different modeling framework adopted, where wages of households employed in the different hierarchical organizational tiers endogenously emerge from their decentralized interactions with firms on segmented labor markets.

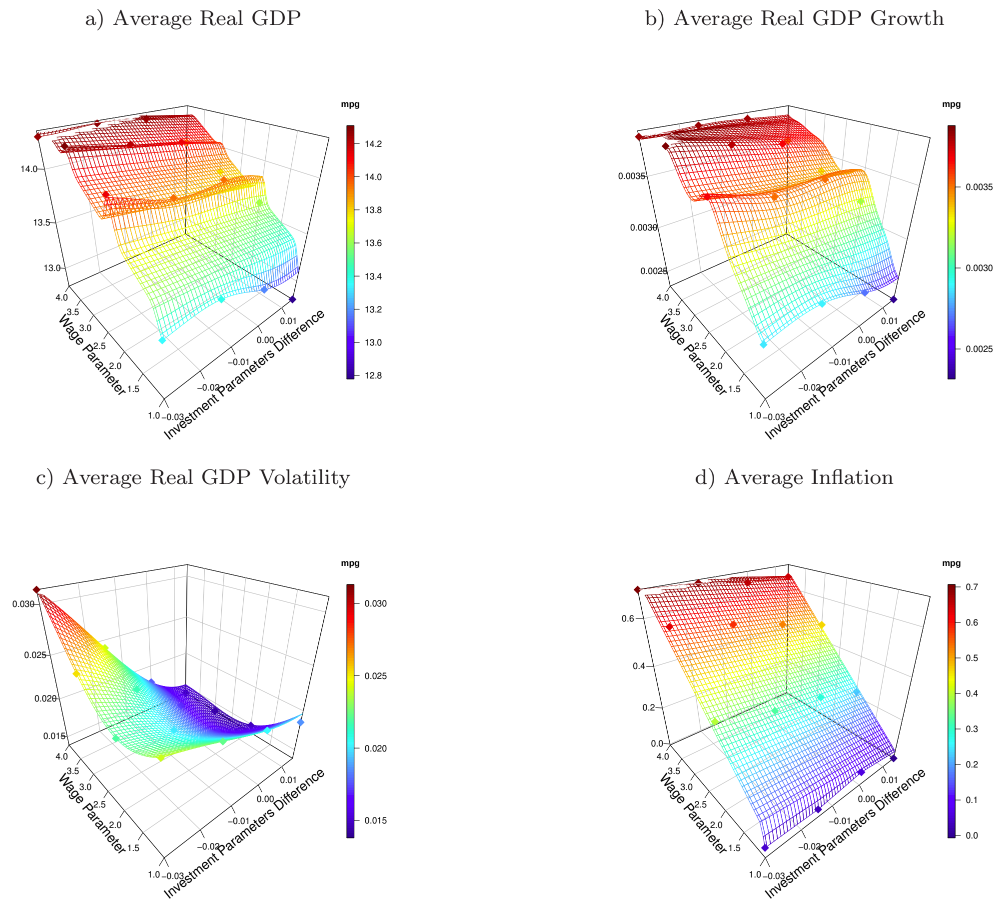

Figure 5: The effects of workers' wage regimes (t_u) and firms' investment function characterization ($\gamma_1 - \gamma_2$) on the economic performance.

To get an idea of the dynamics displayed by the system in the first scenario, consider that the highest value attained by average real GDP across the four wage regimes in the first investment scenario is 13574, corresponding to a negative average growth rate of -0.09% quarterly. The lowest and highest values across all other experiments are instead 354732 (in the experiment with $\gamma_1 = 0.0225$, $\gamma_2 = 0.075$, and $t_u = 1$) and 1637460 (in the experiment with $\gamma_1 = 0.0$, $\gamma_2 = 0.03$, and $t_u = 1$), which correspond to a quarterly average growth rate of 0.23% and 0.39%.

Unemployment in the collapsing scenario ranges between 68% and 76%, and public debt undergoes an explosive path, despite the tax rate revision rule designed to contain it: average debt-GDP ratio ranges between 10 (in the scenario with $t_u = 4$) and 135 (in the scenario with $t_u = 1$).[19]

In an economic system doomed to failure as that emerging from these simulations, changes of t_u which sustain workers' wages have at most the effect of slowing down or postpone the inevitable collapse of the economy. On the contrary, in all the other scenarios, configurations which tend to sustain the pace of growth of workers' wage relative to managers' always exert a beneficial effect on the evolution of main economic aggregates, as figures 5-a, 5-b, 6-a, and 6-c clearly show. Only in the two scenarios where firms give more weight to the rate of profit this gain occurs at a cost of greater cyclical volatility (figures 5-c, 6-b, and 6-d), whereas greater values of t_u seems to dampen economic fluctuations in the other two non-collapsing scenarios, where the weights of the desired capacity growth function are both equal to 0.015 or both positive, but with $\gamma_1 > \gamma_2$.

Similar beneficial effects are observed by looking at average unemployment rates (figure 8-a) which are consistently lower for higher values of t_u[20], despite the enhanced labor productivity growth, as one can observe in figures 7-a and 7-b: as already observed in the experiment discussed in section 3, also in this case

[19] On the contrary, in most of the experiments performed with $\gamma_2 > 0$ average unemployment ranges between approximately 35% and 10%. Public debt-to-GDP ratios instead range between 2.5 and 0.95.

[20] In addition, unemployment volatility across the various experiments (figure 8-b) seems to resemble the volatility of main economic aggregates analyzed before, where higher values of t_u amplify the volatility in the first two scenarios, while reducing it in the third and fourth investment regimes.

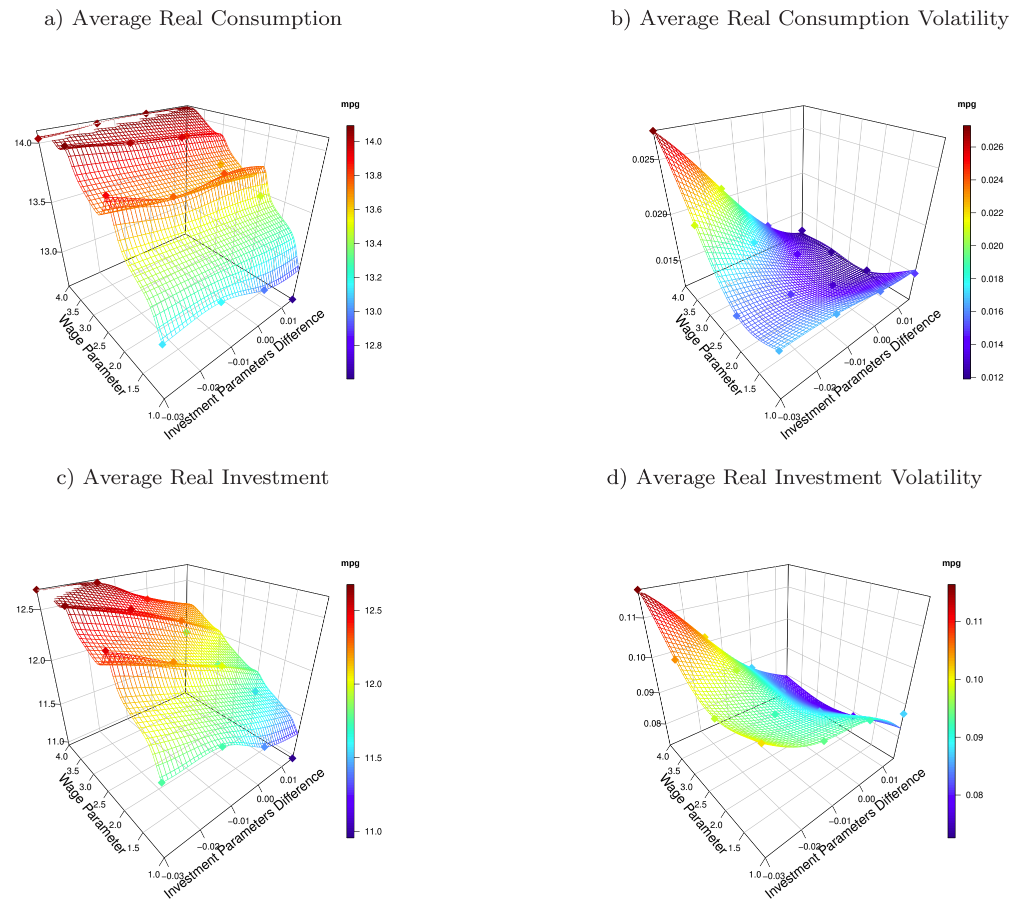

Figure 6: The effects of workers' wage regimes (t_u) and firms' investment function characterization ($\gamma_1 - \gamma_2$) on the economic performance.

wage regimes which favor workers over managers-capitalists exert positive effects on aggregate demand and real output that offset the labor-saving effect associated to the stronger technological progress.

The improved dynamics of the economy in the experiments where workers' wages proceed at faster pace in turn exert beneficial effects on public finance as average public debt-to-GDP ratios tends to fall for higher values of t_u: with $t_u = 4$, debt-GDP ratios are approximately half the values observed in the $t_u = 1$ case, or even less. Private wealth-to-GDP ratios (figure 8-d) display a similar negative relationship with t_u. As already discussed in section 3 this latter result can be interpreted as the byproduct of the change in the distribution of income from high-propensity-to-save/low-propensity-to-spend agents to low-propensity-to-save/high propensity-to-spend agents originated by an increase of t_u. However, the shape of the surface interpolating wealth-GDP ratios across scenarios does not bear a strong resemblance to that of public debt-GDP ratios, as observed for the experiment in section 3. As we have already explained, given the structure of the artificial economy depicted, the difference between the two figures is to be related to the value of real assets. Figure 8-d displays an increasing pattern of wealth-GDP as firms' investment becomes more dependent on their profitability and less on their capacity utilization rates. This relationship can be found for all values of t_u investigated. On the contrary, only in $t_u = 1$ case public debt-to-GDP displays a similar relationship. This discrepancy reveals that scenarios where investment is more dependent on firms' profitability (and less on firms' capacity utilization) are characterized by a greater investment and greater capital accumulation, as also confirmed by figure 6-c.

Figure 7 highlights the changes in the functional distribution of income between workers and managers-owners across the various experiments. Figures 8-e and 8-f instead present the Gini indexes relative to the income and wealth distributions. As in the former experiments, sustaining workers' wages growth shifts the functional distribution of income in favor of workers, while also reducing personal income and wealth inequality.

Furthermore, similarly to the experiments presented in section 3, the shift in the income and wealth distribution in favor of workers is not detrimental to firms' profitability. On the contrary, firms' average profit rates increase for higher values of t_u, though this relationship tends to flatten for scenarios where firms give more importance to the capacity utilization rate than to profits when deciding about investment (figure 7-d): in general, a faster growth of wages of low and middle tier workers stimulates aggregate demand, improves firms' sales, and increases firms' capacity utilization, thereby increasing revenues and the stream of profits relative to capital invested.

The plot in figure 7-d also displays another interesting feature: scenarios in which firms weigh the profit rate more are characterized by lower profit rates, compared to scenarios where firms pay more attention to the rate of capacity utilization. This result may appear somehow paradoxical if we consider that firms' real investment tends to be higher when γ_2 is higher and γ_1 is lower, as discussed above. That is, real investment is higher when firms weigh more their profitability, despite the fact that profit rates are lower in these scenarios. This alleged paradox is a consequence of the fact that firms in these scenarios tend to invest in excess with respect to their actual productive needs. Indeed, they tend to maintain a rate of capacity utilization which is constantly below the 'normal' one that they should target (i.e. 0.8 in our calibration). This excess investment tends to lower the profit rate as it increases the capital stock at the denominator without increasing firms' profits at the numerator. However, at the same time this excess investment contributes to sustain aggregate demand which ensures a stable flow of revenues. This twofold effect stabilizes the profit rate around a level which provides a stable flow of investment (offsetting the negative impact of the excess capacity on investment when $\gamma_1 > 0$), so that the excess capacity is neither widened nor absorbed. If firms paid more attention to their capacity utilization, they would probably recognize the abundance of idle machineries in their capital stock, reducing investment (or abstaining from investing) till the excess capacity is absorbed. Even though this lower investment (see figure 6-c) implies a lower level of aggregate demand which can possibly reduce revenues and gross profits, the fact that these profits are originated out of a smaller investment in capital accumulation improves firms' profit rates. This is what happens if γ_1 is increased and γ_2 is decreased. However, firms' higher profits are realized at the cost of a somewhat lower level of output, as figures 5-a, 5-b, 6-a, and 6-c highlight. Redistributing income and wealth towards low and middle tier workers may be a viable solution to counteract this effect without compromising firms' profitability, as the positive effects generated by such a redistribution eventually trickle up to firms, banks, and their owners.

To summarize, all the configurations investigated in this second experiment suggest that institutional, policy, and regulatory measures which allow to reduce the downward pressure on wages of low and middle income workers can be effective in boosting economic development, improving both demand and supply conditions. Furthermore, these measures – which shift the income distribution from capital (firms, banks, and managers) to (low and middle tier) workers – are also very effective in tackling income and wealth inequality. These experiments thus confirm the robustness of the results presented in Caiani et al. (2017).

Furthermore, the dynamics displayed by our artificial economy in all the investment scenarios investigated[21], seem to provide solid evidence in favor of the prevalence of a wage-led growth regime over a profit-led growth regime as claimed by Stockhammer et al. (2009) and Onaran and Galanis (2012) who find that domestic demand regimes,[22] respectively in European countries and in the G-20 economies, always tend to be wage-led.[23]

Even in the scenarios where firms pay much more attention to their profits, which should be in principle more favorable to the emergence of a profit-led growth regime, distributive configurations more favorable to workers are not detrimental to investment and output but, on the contrary, contribute to enhance investment and real output, besides exerting beneficial effects on several other important indicators.

Related to this point, our results seem to contradict the common belief that higher wages of workers would erode the return on investments in capital accumulation, thereby reducing the incentives to invest with detrimental effects on growth. These claims have been often employed in the political debate to support and justify labor market deregulation and other institutional reforms aiming at reducing the cost of labor for firms. The evidence emerging from our computational experiments not only provide a proof of concept against the existence of such a negative relationship, but suggest that, if anything, the opposite is true, at least in the context of a closed economy: a faster pace of growth of workers' wages contributes to feed aggregate demand and to stabilize the economy, thereby increasing the returns on investment made by firms and prompting investment, rather than depressing it.

[21] Apart from the collapsing scenario discussed at the beginning of the section, which does not allow to draw substantial conclusions on the effects of different wage regimes.

[22] In a wage-led demand regime, the stimulus to invest more may boost productivity thus also resulting in a higher long-term growth. See also Stockhammer and Onaran (2013) and Onaran and Obst (2016).

[23] Similar results were also obtained by Naastepad and Storm (2006) and Hein and Vogel (2008) who analyze overall demand regimes in eight and six OECD countries finding that most of them are globally demand-led.

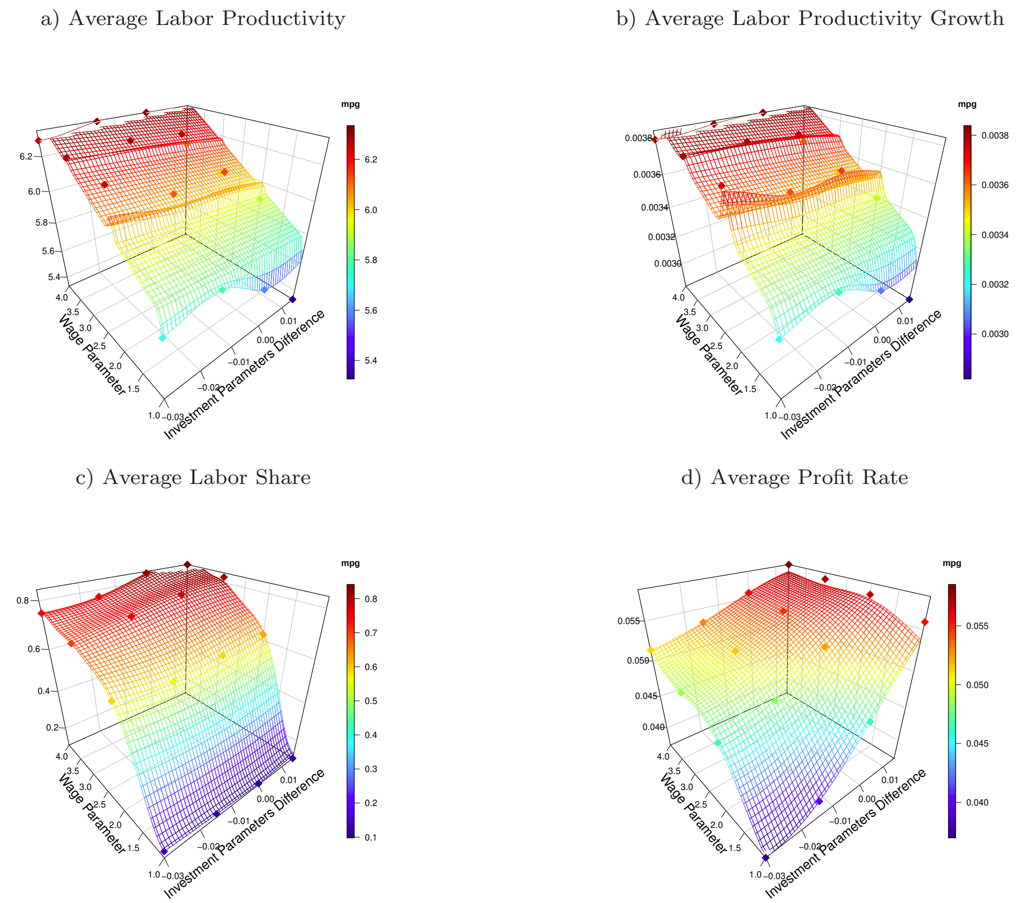

Figure 7: The effects of workers' wage regimes (t_u) and firms' investment function characterization ($\gamma_1 - \gamma_2$) on the economic performance, functional income distribution, and firms' profitability.

5 Final considerations and future investigations

The paper analyzed how different wage regimes for the classes of workers – i.e. workmen, office workers, and researchers as distinguished from managers who own firms and banks –, combined with different innovation and investment configurations, concur to shape the patterns of development of the artificial closed economy depicted in the model first presented in Caiani et al. (2017).

Our results show that innovations tend to improve the dynamics of many economic indicators, such as real investment, real consumption, labor productivity, firms' profit rates, while exerting non-linear effects on unemployment and the volatility of main economic aggregates. Furthermore, technological change in our model does not seem to be a source of greater inequality, as sometimes argued in the literature: indeed, a faster pace of technological change does not seem to affect neither the functional nor the personal income distribution in any significant way, apart from a reduction of inequality in personal income distribution (from the scenario with no technological progress at all to the scenarios with positive technological change).

Our experiments on the investment function instead first highlight that when firms' investment decisions are more dependent on firms' sales performance and less on their past profitability, the pro-cyclical character of aggregate investment is exacerbated, thereby fostering greater systemic instability. In the most extreme configuration where firms only look at their rate of capacity utilization, the economy always undergoes, sooner or later, a major downturn in which it remains locked.

As far as the effects of alternative wage regimes are concerned, our experiments confirm that when workers are less prone to reduce their reservation wage and more likely to increase it, the personal distribution of income and wealth tend to be more equal, while the functional income distribution tends to shift in favor of workers. This change in turn exerts significant beneficial effects under most of the scenarios investigated.

The experiment discussed in section 3 highlights that a faster growth of wages of low and middle level

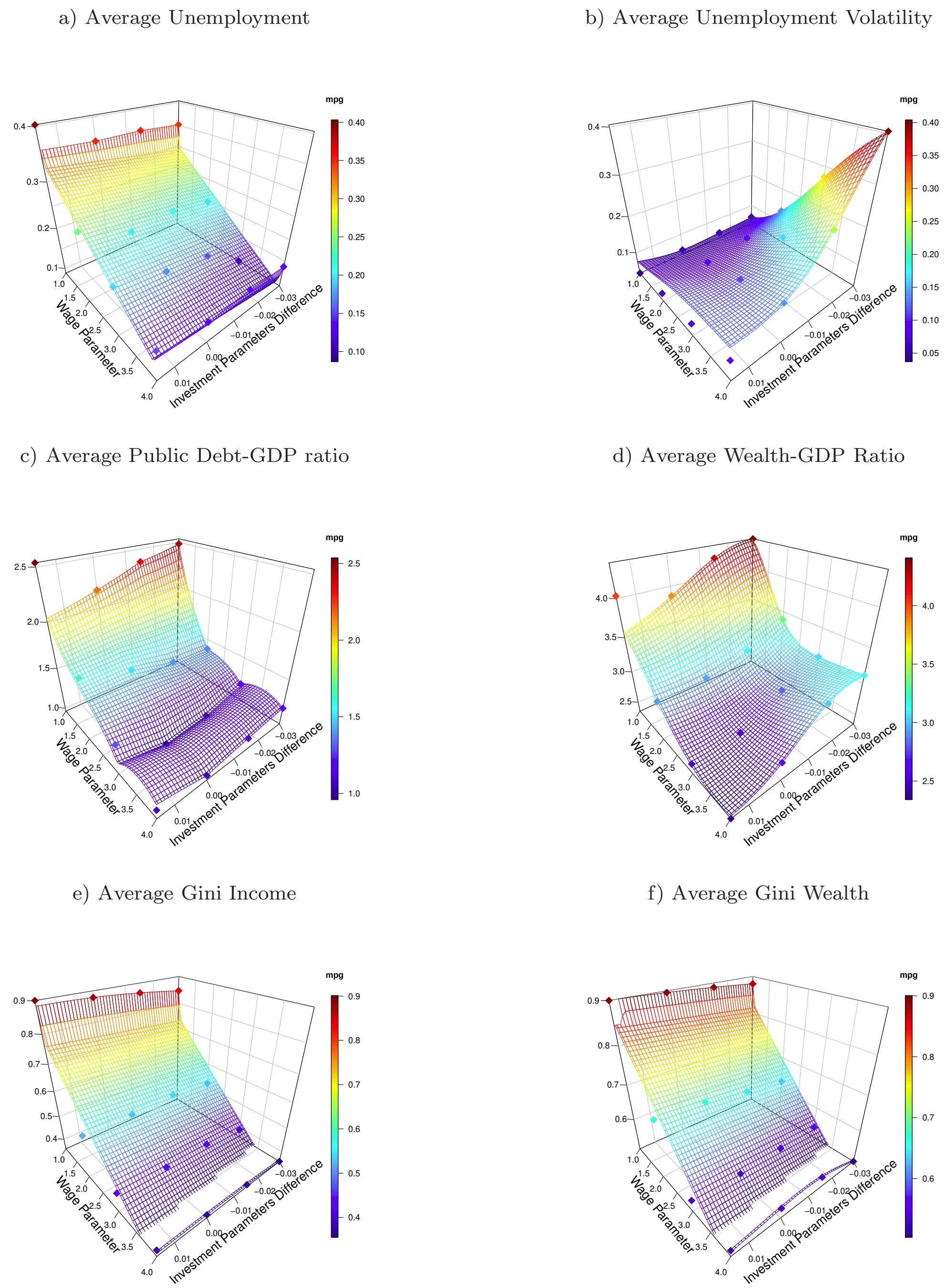

Figure 8: The effects of workers' wage regimes (t_u) and firms' investment function characterization ($\gamma_1 - \gamma_2$) on the economic performance, public finance, and personal income and wealth distribution.

workers, relative to that of managers, allow to counteract the labor-saving effect of technological change, improving employment and supporting the growth of real output. In turn, this improved dynamics has several further positive effects: it improves public finance, reducing public debt-GDP ratios; it increases firms' profitability; it contributes to dampen the volatility of main aggregates when technological change proceeds at faster pace. Finally, it also contribute to support technological change and labor productivity growth. Only in the scenario when innovation is totally absent, supporting workers' wage growth does not seem to yield any significant positive effect on the overall pattern of evolution of the economy.

The beneficial effects of a faster growth of wages of low and middle level workers are even more evident in the second experiment presented in section 4: under all the non-collapsing configurations of the investment function this is associated to an improvement of all the indicators considered. The improvement caused by a shift in the distribution of income in favor of workers (i.e. towards low-income, high-propensity to consume agents) thus seems to support the thesis of the prevalence of wage-led growth regimes over profit-led growth regimes, even in the scenarios where firms' investment decisions focus on their past profitability, which should be in principle more favorable to the emergence of a profit-led regime. Contrary to what is sometimes argued in the academic and political debate, a distribution more favorable to workers do not compromise firms' profitability but rather strengthen it, creating a more favorable macroeconomic environment in which operating.

Besides shedding light on the relationship between wage dynamics, technological change, investment, and economic growth, the present work also provides the necessary robustness checks of the policy implications drawn by Caiani et al. (2017) in relation to the characterization of the innovation process and the configuration of the investment function, as advocated in the concluding section of that article.

Admittedly, some caveats still apply given the simplified nature of the artificial economy depicted in the paper. In particular, the validity of our claims remains still circumscribed to relative closed economic systems. An open economy would complicate the analysis: a change in the distribution of income towards workers would affect both imports, given the higher propensity to consume which characterizes low income agents, and exports, given the impact on the international competitiveness of domestic firms of an increase in workers' wages. Building a multi-country model to perform such an analysis will thus be the next step of the present research line.

References

Abowd, J. M., Kramarz, F., and Margolis, D. N. (1999). High wage workers and high wage firms. *Econometrica*, 67(2):251–333.

Acemoglu, D. (1998). Why do new technologies complement skills: Directed technical change and wage inequality. *Quarterly Journal of Economics*, 113:1055–1089.

Acemoglu, D. (2002). Technical change, inequality, and the labor market. *Journal of Economic Literature*, 40:7–72.

Acemoglu, D. (2007). Equilibrium bias of technology. *Econometrica*, 75(5):1371–1409.

Acemoglu, D., Robinson, J. A., and Verdier, T. (2012). Can't we all be more like Scandinavians? Asymmetric growth and institutions in an interdependent world. *NBER Working Papers*, 18441.

Aghion, P., Akcigit, U., Bergeaud, A., Blundell, R., and Hemous, D. (2015). Innovation and top income inequality. *NBER Working Papers*, 21247.

Aghion, P. and Howitt, P. (1997). *Endogeneous Growth Theory*. MIT Press.

Antonelli, C. and Gehringer, A. (2013). Innovation and income inequality. Technical report, University of Turin. Department of Economics and Statistics Cognetti de Martiis LEI & BRICK, Collegio Carlo Alberto. WP series.

Atkinson, A. B., Piketty, T., and Saez, E. (2011). Top incomes in the long run of history. *Journal of Economic Literature*, 49(1):3–71.

Caiani, A., Godin, A., Caverzasi, E., Gallegati, M., Kinsella, S., and Stiglitz, J. E. (2016). Agent Based-Stock Flow Consistent macroeconomics: Towards a benchmark model. *Journal of Economic Dynamics & Control*, 69:375–408.

Caiani, A., Russo, A., and Gallegati, M. (2017). Does inequality hamper innovation and growth? *Journal of Evolutionary Economics*, (forthcoming):39.

Carlin, W. and Soskice, D. (1990). *Macroeconomics and the Wage Bargain: A Modern Approach to Employment, Inflation, and the Exchange Rate*. Oxford University Press.

Ciarli, T., Lorentz, A., Savona, M., and Valente, M. (2010). The effect of consumption and production structure on growth and distribution. A micro to macro model. *Metroeconomica*, 61(1):219–246.

Delli Gatti, D., Gallegati, M., Greenwald, B. C., Russo, A., and Stiglitz, J. E. (2010). The financial accelerator in an evolving credit network. *Journal of Economic Dynamics & Control*, 34:1627–1650.

Domar, E. (1947). Expansion and employment. *American Economic Review*, 37:34–55.

Dosi, G., Fagiolo, G., Napoletano, M., and Roventini, A. (2013). Income distribution, credit and fiscal policies in an agent-based Keynesian model. *Journal of Economic Dynamics and Control*, 37(8):1598–1625.

Dosi, G., Fagiolo, G., and Roventini, A. (2010). Schumpeter meeting Keynes: A policy-friendly model of endogenous growth and business cycles. *Journal of Economic Dynamics and Control*, 34(9):1748–1767.

Dosi, G., Pereira, M., Roventini, A., and Virgillito, M. (2017). When more flexibility yields more fragility: The microfoundations of keynesian aggregate unemployment. *Journal of Economic Dynamics and Control*, 81.

Dutt, A. K. (1987). Alternative closures again: a comment on growth, distribution and inflation. *Cambridge Journal of Economics*, 11(1):75–82.

Dynan, K. E., Skinner, J., and Zeldes, S. P. (2004). Do the rich save more? *Journal of Political Economy*, 112(2):397–444.

Eichner, A. S. (1976). *The Megacorp and Oligopoly: Micro Foundations of Macro Dynamics*. Cambridge University Press.

Goldin, C. and Katz, L. F. (2008). *The Race Between Education and Technology*. Harvard University Press.

Harrod, H. (1939). An essay in dynamic theory. *Economic Journal*, 49-193:14–33.

Hein, E. and Vogel, L. (2008). Distribution and growth reconsidered empirical results for six oecd countries. *Cambridge Journal of Economics*, 32:479–511.

Hopkin, J., Lapuente, V., and Moller, L. (2014). Lower levels of inequality are linked with greater innovation in economies. Technical report, London School of Economics and Political Science. LSE's USApp blog.

Jacobs, E. (2016). What do trends in economic inequality imply for innovation and entrepreneurship? A framework for future research and policy. Technical report, Washington Center for Equitable Growth.

Jaumotte, F. and Buitron, C. O. (2015). Inequality and labor market institutions. Staff Discussion Notes SDN/15/14.

Jones, C. I. and Kim, J. (2014). A Schumpeterian model of top income inequality. *NBER Working Papers*, 20637.

Kaldor, N. (1957). A model of economic growth. *Economic Journal*, 67(268):591–624.

Katz, L. F. and Murphy, K. M. (1992). Change in relative wages: Supply and demand factors. *Quarterly Journal of Economics*, 107:35–78.

Kumhof, M., Ranciere, R., and Winant, P. (2015). Inequality, leverage and crises. *American Economic Review*, 105(3):1217–1245.

Lavoie, M. (1992). *Foundations of Post-Keynesian Economic Analysis*. Edward Elgar, Aldershot.

Lavoie, M. (2015). *Post-Keynesian Economics: New Foundations*. Edward Elgar.

Lavoie, M. and Stockhammer, E. (2012). Wage-led growth: Concept, theories and policies. *International Labor Office. Conditions of Work and Employment Series*, 41.

Lydall, H. F. (1959). The distribution of employment incomes. *Econometrica*, 27(1):110–115.

McCombie, J. S. L. (2002). Increasing returns and the Verdoon law from a Kaldorian perspective. In McCombie, J. S. L., Pugno, M., and Soro, B., editors, *Productivity Growth and Economic Performance: Essays on Verdoon's Law*, pages 64–114. Palgrave Macmillan.

Naastepad, C. W. M. and Storm, S. (2006). Oecd demand regimes (19602000). 29: 21348. *Journal of Post-Keynesian Economics*, 29-2:213–248.

Napoletano, M., Dosi, G., Fagiolo, G., and Roventini, A. (2012). Wage formation investment behavior and growth regimes: An agent-based analysis. *Revue de l'OFCE. Debates and policies*, 124:235–261.

Nelson, R. and Winter, S. (1977). Simulation of Schumpeterian Competition. *The American Economic Review*, 67-1:271–276.

Nelson, R. and Winter, S. G. (1982). *An Evolutionary Theory of Economic Change*. Harvard University Press, Cambridge MA., Cambridge, MA.

Onaran, O. and Galanis, G. (2012). Is aggregate demand wage-led or profit-led? National and global effects. *International Labor Office. Conditions of Work and Employment Series*, 40.

Onaran, O. and Obst, T. (2016). Wage-led growth in the eu15 member states: the effects of income distribution on growth, investment, trade balance, and inflation. *Cambridge Journal of Economics*, 40-6:1517–1551.

Perugini, C., Holscher, J., and Collie, S. (2016). Inequality, credit and financial crises. *Cambridge Journal of Economics*, 40(1):227–257.

Piketty, T. (2014). *Capital in the Twenty-First Century*. Harvard University Press.

Piketty, T., Saez, E., and Stantcheva, S. (2014). Optimal taxation of top labor incomes: A tale of three elasticities. *American Economic Journal: Economic Poliy*, 6(1):230–271.

Piketty, T. and Zucman, G. (2014). Capital is back: Wealth-income ratios in rich countries 17002010. *Quarterly Journal of Economics*, 129-3:1255–1310.

Prescott, E. S. (2003). Firms, assignments, and earnings. *Federal Reserve Bank Richmond Economic Quarterly*, 89(4):69–81.

Riccetti, L., Russo, A., and Gallegati, M. (2015). An agent-based decentralized matching macroeconomic model. *Journal of Economic Interaction and Coordination*, 10-2:305–332.

Rowthorn, R. (1981). Demand, real wages and economic growth. *Thames Papers in Political Economy*, Autumn:1–39.

Russo, A., Riccetti, L., and Gallegati, M. (2016). Increasing inequality, consumer credit and financial fragility in an agent based macroeconomic model. *Journal of Evolutionary Economics*, 26(1):25–47.

Salle, I. and Yildizoglu, M. (2014). Efficient sampling and meta-modeling for computational economic models. *Computational Economics*, 44-4:507–536.

Simon, H. (1957). The compensation of executives. *Sociometry*, 20:32–35.

Steindl, J. (1952). *Maturity and Stagnation in American Capitalism*. Blackwell.

Stiglitz, J. E. (2012). *The Price of Inequality*. Norton & Co Inc.

Stiglitz, J. E. (2015). *The Great Divide: Unequal Societies and What We Can Do About Them*. Norton & Co Inc.

Stockhammer, E. and Onaran, O. (2013). Wage-led growth: theory, evidence, policy. *Review of Keynesian Economics*, pages 61–78.

Stockhammer, E., Onaran, O., and Ederer, S. (2009). Functional income distribution and aggregate demand in the euro area. *Cambridge Journal of Economics*, 33-1:139–159.

Storm, S. and Naastepad, C. W. M. (2012). *Macroeconomics Beyond the NAIRU*. Harvard University Press.

Taylor, L. (1983). *Structuralist Macroeconomics: Applicable Models for the Third World*. Basic Books.

Thirlwall, A. (1983). A plain mans guide to kaldors growth laws. *Journal of Post Keynesian Economics*, 5-3:345–358.

Vergeer, R. and Kleinknecht, A. (2010). The impact of labor market deregulation on productivity: A panel data analysis of 19 OECD countries (1960-2004). *Journal of Post Keynesian Economics*, 33(2):371–407.

Vergeer, R. and Kleinknecht, A. (2014). Do labor market reforms reduce labor productivity growth: A panel data analysis of 20 OECD countries (1960-2004). *International Labour Review*, 153(3):365–393.

Waldman, M. (1984). Workers allocation, hierarchies and the wage distribution. *Review of Economic Studies*, 51:95–109.

Weinhold, D. and Nair-Reichert, U. (2009). Innovation, inequality and intellectual property rights. *World Development*, 37(5):889–901.

Winter, S. G. (1984). Schumpeterian Comptetion in alternative technological regimes. *Journal of Economic Behavior and Organization*, 5:287–320.