WAGE FORMATION, INVESTMENT BEHAVIOR AND GROWTH REGIMES: AN AGENT-BASED ANALYSIS[1]

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Using the "Keynes+Schumpeter" (K+S) agent-based model developed in Dosi *et al.* (2010, 2012) we study how the interplay between firms' investment behavior and income distribution shapes the short—and long-run dynamics of the economy at the aggregate level. We study the dynamics of investment under two different scenarios. One in which investment is fully determined by past profits, and one in which investment is tied to expectations about future consumption demand. We show that, independently from the investment scenario analyzed, the emergence of steady growth with low unemployment requires a balance in the income distribution between profits and wages. If this is not the case, the economy gets locked either in stagnation equilibria, or into growth trajectories displaying high volatility and unemployment rates. Moreover, in the demand-led scenario we show the emergence of a non-linear relation between real wages and unemployment. Finally, we study whether increasing degrees of wage-flexibility are able to restore growth and unemployment and reduce the volatility in the economy. We show that this is indeed the case only when investment is profit-led. In contrast, in the scenario where investment is driven by demand expectations wage-flexibility has no effect on either growth and unemployment. In turn, this result casts doubts on the ability of wage-flexibility policies to stabilize the economy.

Keywords: Agent-Based Models, Growth Regimes, Income Distribution, Wage-Flexibility.

1. The authors gratefully acknowledge the financial support of the Institute for New Economic Thinking (INET) grant #220, "The Evolutionary Paths Toward the Financial Abyss and the Endogenous Spread of Financial Shocks into the Real Economy".

This work studies how the interplay between firms' investment behavior, wage formation and income distribution affect the short-run and long-run aggregate dynamics of an economy. We study the aggregate behavior of the economy under two different scenarios: one wherein investment in new productive capacities is determined by past profits of firms ("profit-led scenario") and one in which firm investment depends on expectations about future consumption demand ("demand-led" scenario). We show that in both scenarios the distribution of income between profits and wages crucially affects the characteristics of the growth path of the economy. Independently from the investment rule adopted by firms, the emergence of long-run growth associated with low rates of unemployment and short-run volatility always requires a balance in the distribution between profits and wages. Lacking such a requirement, the economy can get stuck either into stagnation equilibria with low growth and high unemployment, or into trajectories characterized by high and volatile growth. Furthermore, we study the relation between the level of real wages and unemployment in the economy. We show that the economy displays the Neo-Classical (positive) relation between the two variables only in the profit-led scenario. In contrast, in the demand-led scenario such a relation is non-linear. In particular, it exists a threshold below which unemployment increases (rather than decreasing) with a reduction in real wages. Finally, we explore whether increasing degrees of nominal wage sensitivity to unemployment variations are effective in curbing unemployment and stabilizing the economy. Our results show that this is the case only in the profit-led scenario, provided that the characteristics of the income distribution allow the economy to grow in the long-run. In contrast, in the demand-led scenario, wage-flexibility is never able to reduce unemployment, and can sometimes increase the incidence of economic crises.

Our work is motivated by two different streams of literature. First, we refer to a central debate in macroeconomics, *i.e.* the one about the role of wages in determining unemployment in the economy. On one side, the "Neo-Classical View" identifies into real wage rigidity the main source of unemployment in labor markets. Following an adverse shock to the economy, production

and labor demand will fall, and real wages must also decrease in order to equilibrate demand and supply of labor. A rigid real wage impedes such an adjustment and thus leads to unemployment in the labor market. In contrast, downward flexibility of nominal wages allows the reduction of the real wage down to the new level compatible with full employment and thus the reduction of unemployment.[2] On the opposite camp, we find all works that starting from Keynes (1936) pointed to deficiencies in effective demand as the main source of unemployment. Moreover, in line with the intuition of Keynes, these works (see Howitt, 1986; Amendola *et al.*, 2004) warned against the destabilizing effect of the downward nominal wage flexibility . This is because a reduction of nominal wages is likely to adversely affect consumption demand and to induce deflationary pressures in the economy, with the consequence of increasing (rather than decreasing) the level of unemployment in the economy.[3]

Second, our work is related to both evolutionary (Freeman and Perez, 1988; Coriat and Dosi, 2000; Chiaromonte *et al.*, 2000) and French "Régulation" research programs (see Aglietta, 1979, Boyer, 1988, see Lordon, 1991, for a survey), that study how "growth regimes", as well as crises, are generated by the matching or mismatching between, on the one hand, processes of technical change and, on the other hand, the characteristics of the processes governing firms' behavior and the division of income in the economy.

We contribute to the above strands of literature along several dimensions. First, we show how different growth regimes emerge out of micro-interactions between heterogeneous agents. In that fashion, our work provides a *micro-foundation* of early evolutionary and "regulationist" theories of the role of institutions, demand-formation patterns, and technical change in determining both

2. This approach is also largely followed by New Keynesian DSGE models (e.g. Smets and Wouters, 2007). These models claim that price and wage rigidities constitute the main impediments to full employment. Without such rigidities and in line with the Neo-Classical View the economy would be able to adjust to whatever shock and keep the labour market at the full employment equilibrium.

3. Another strand of research in the New Keynesian literature (Greenwald and Stiglitz, 1993) warns against the perils of downward flexibility of nominal wages. Still, in these models unexpected increases in real wages increase firms costs, thus leading to a reduction of firms' net worth and to lower levels of investment and output.

growth and business cycles. Second, we highlight the role of income distribution as a crucial factor determining the characteristics of growth paths followed by the economy. Third, by studying the relation between wages and unemployment into different investment scenarios, we study under which conditions one observes the validity of either the Neo-Classical or Keynesian view about the effectiveness of policies increasing the degree of wage flexibility in the economy. Finally, we extend the analysis of wage-flexibility to encompass also its long-term effects on the economy.

We perform the above investigations by extending the "Keynes+Schumpeter" (K+S) model developed in Dosi *et al.* (2010) and Dosi *et al.* (2012), that bridges Keynesian theories of demand-generation and Schumpeterian theories of technology-fueled economic growth. In Dosi *et al.* (2010), we studied the consequences of different "innovation regimes"—and related policies—and their interaction with (Keynesian) demand management. In Dosi *et al.* (2012) we focused instead on the interactions between income distribution on one hand, and monetary and fiscal policies on the other hand. In this paper we exclude fiscal and monetary policies from the picture, and we rather study how the interactions between income distribution and firm investment behavior affect the short—and long-run dynamics at the aggregate level. In addition, we try to assess whether different levels of nominal wage sensitivity to variations in unemployment may promote long-run growth and reduce output volatility and unemployment.

The work is structured as follows. Section 1 briefly presents the K+S model. Section 2 presents the simulation results, starting with the analysis of growth regimes under different income distributions and investment behavior (Section 2.1), and then moving to the analysis of the effects of wage-flexibility to unemployment variations (Section 2.2). Section 3 concludes.

1. The K+S model

Let us now briefly discuss the K+S model developed in Dosi *et al.* (2010) and extended in Dosi *et al.* (2012), to which we refer for more details. The model portrays an economy composed of a machine-producing sector made of F_1 firms (denoted by the subscript i), a consumption-good sector made of F_2 firms (denoted by

the subscript *j*), L^S consumers/workers, and a public sector. Capital-good firms invest in R&D and produce heterogeneous machines. Consumption-good firms combine machine tools bought by capital-good firms and labor in order to produce a final product for consumers. Capital-good firms are paid in advance for the machines they have to produce. Consumption-good firms finance their production and investment expenditures by using internal funds and external financing provided by an un-modeled banking sector. The latter provides credit to firms up to a credit ceiling that depends of firms' past sales.[4] Finally, the public sector levies taxes on firms' profits and pays unemployment benefits. In what follows, we present the timeline of events in the K+S model. Next we will briefly describe each part of it.

1.1. The timeline of events

In any given time period (*t*), the following microeconomic decisions take place in sequential order:

1. Policy variables are fixed (e.g. the "Government" setting tax rates and unemployment benefits, etc.).
2. Machine-tool firms perform R&D trying to discover new products and more efficient production techniques and to imitate the production technology and the products of their competitors. Capital-good firms advertise their machines to consumption-good firms.
3. Consumption-good firms decide how much to produce and invest. If investment is positive, consumption-good firms choose their supplier, send their orders and pay for the machines. When internal funds are not enough to finance production and investment plans, firms borrow up to a ceiling.
4. In both industries firms hire workers according to their production plans if below their credit ceiling or at the ceiling otherwise and start producing.
5. Imperfectly competitive consumption-good market opens. The market shares of firms evolve according to their price competitiveness.

4. In Dosi *et al.* (2012) we model a banking sector that gathers deposits from firms and provides credit to them on a pecking order that depends on the firms' past net-worth-to-sales ratio.

6. Firms in both sectors compute their net cash flow, pay back their due loans to the bank to the extent that they have cash flow to do that.
7. Entry and exit take place. In both sectors firms with near-zero market shares and/or a negative stock of net liquid assets are eschewed from their industry and replaced by new firms (for simplicity, we keep the number of firms fixed; any dead firm is replaced by a new one; and entrant firms are random copies of incumbent ones).
8. Machines ordered at the beginning of the period are delivered and become part of the capital stock at time $t + 1$.

At the end of each time step, aggregate variables (e.g. GDP, investment, employment) are computed, summing over the corresponding microeconomic quantities.

1.2. The capital-good industry

The technology of capital-good firms evolves along the vintages of produced machine-tools. Each firm-specific generation of machine-tools has indeed a distinct production cost and distinct labour productivity for the user. The price of machines is set with a mark-up rule[5] over production costs. The quality of each vintage is measured by the productivity of machines in the consumption-good sector.

Innovation and imitation are costly processes: firms invest in R&D a fraction of their revenues and hire researchers at the current market wage.

Both innovation and imitation follow a two-steps stochastic process. In the first step, the resources allocated to search determine in probability whether the events "innovation" and "imitation" are drawn. Note that the newly discovered capital goods might be a "failed innovation", because production costs might be higher and/or user-efficiency might be lower than the currently manufactured machines. Indeed, at the second stochastic stage, each firm draws the characteristics of the would-be machine and decide whether to keep on producing the current generation of machines or to switch to the new vintage, by evaluating the

5. This in line with survey data evidence on firm pricing behavior (see Fabiani *et al.*, 2006).

possible trade-off between production costs and productive efficiencies. Once the machine tool is chosen, capital-good firms try to reach their customers under conditions of imperfect information: hence, we assume that they send a "brochure" with the price and the productivity of their machines to both their historical clients and a random sample of potential new customers.

1.3. The consumption-good industry

Consumption-good firms produce an homogenous good using capital (*i.e.* their stock of machines) and labor under constant returns to scale. We assume alternative scenarios for firms' production and investment decisions.[6] In the first scenario, we assume as in Greenwald and Stiglitz (1993) and Delli Gatti *et al.* (2005) that desired production (Q_j^d) is determined by the level of firm stock of liquid assets (NW_j), according to[7]:

$$Q_j^d(t) = \sigma NW_j(t-1), \quad \sigma > 0 \tag{1}$$

In turn, the level of firms' net worth is determined—*via* cash flows—by the past level of profits. Following Boyer (1988) we label the above *profit-led investment scenario*. Notice that we here we attempt to describe the economic dynamics in a highly hypothetical scenario wherein both desired production and desired investment are not limited by demand.[8]

In contrast, in the second scenario, that we label *demand-led investment scenario*, firms plan their production according to adaptive demand expectations (D_j^e):

$$D_j^e(t) = f(D_j(t-1), D_j(t-2), \ldots, D_j(t-h)), \tag{2}$$

where $D_j(t-1)$ is the demand actually faced by firm j at time $t-1$ (h positive integer)[9]. The desired level of production depends on

6. To simplify notation and unless it needed for the sake of clarity, in what follows we suppress the time index to indicate variables in the text.
7. This kind of firm behavior may emerge in models where firms are equity rationed and face positive bankruptcy costs. See Greenwald and Stiglitz (1993) for more details.
8. As it is discussed at more length in Boyer (1988), this kind of scenario however captures some key features of the dynamics of investment in capitalistic economies of the 19th century.
9. For maximum simplicity, here we use the rule $D_j^e(t) = D_j(t-1)$. In Dosi *et al.* (2006) we check the robustness of the simulation results employing more sophisticated expectation-formation rules. We found that increasing the computational capabilities of firms does not significantly change either the average growth rates or the stability of the economy. These properties still hold in the model presented here.

the expected demand as well as on the desired inventories (N_j^d) and the actual stock of inventories (N_j):

$$Q_j^d(t) = D_j^e(t) + N_j^d(t) - N_j(t-1), \tag{3}$$

with $N_j^d(t) = \iota D_j^e(t), \iota \in [0,1]$.

Finally, in both scenarios, the output of consumption-good firms is constrained by their capital stock (K_j). If the desired capital stock (K_j^d)—computed as a function of the desired level of production—is higher than the current capital stock, firms invest (EI_j^d) in order to expand their production capacity[10]:

$$EI_j^d(t) = K_j^d(t) - K_j(t). \tag{4}$$

Consumption-good firms have a capital stock composed of heterogenous machines having different productivity levels. Firms decide whether to scrap their machines following a payback period rule, that is they assess whether the substitution cost of any current machine, *i.e.* the price of a new one, can be recovered in a given number of years through the savings obtained in production costs (new machines have lower unit production cost than incumbent ones). In this way, technical change and capital-good prices affect the replacement decisions of consumption-good firms.[11] The latter choose their capital-good supplier comparing the price and productivity of those machine tools which they know via the brochures they received. Machine production is a time-consuming process: consumption-good firms receive the ordered machines at the end of the period.[12] Gross investment of each firm is the sum of expansion and replacement investment. Aggregate investment is just the sum of the investments of all consumption good firms.

Given their current stock of machines, consumption-good firms compute their average productivity and unit costs of production. Firms fix prices applying a variable mark-up (μ_j) over the latter. More precisely, we set an initial value for the mark-up $\bar{\mu}(0)$, which

10. We assume that in any give period firm capital growth rates cannot exceed a fixed maximum threshold consistent with the maximum capital growth rates found in the empirical literature on firm investment patterns (Doms and Dunne, 1998).

11. This in line with a large body of empirical papers (Feldstein and Foot, 1971; Eisner, 1972; Goolsbee, 1998) showing that replacement investment is typically not proportional to the capital stock.

12. The presence of gestation-lag effects in firm investments expenditures is supported by a large body of empirical literature (see Del Boca *et al.*, 2008).

is equal across firms. The variation of mark-ups over time are regulated by the evolution of firms' market shares (f_j): firms raise (cut) mark-up whenever the growth rate of their market shares is positive (negative):

$$\mu_j(t) = \mu_j(t-1)\left(1+\upsilon\frac{f_j(t-1)-f_j(t-2)}{f_j(t-2)}\right), \tag{5}$$

with $0 \leqslant \upsilon \leqslant 1$. This process in turn implies that the average mark-up rate $\overline{\mu}(t)$ (as well as firms' ones) fluctuate around a sort of peg represented by the initial mark-up rate $\overline{\mu}(0)$. The level of real wages (*w/cpi*) is determined by the average mark-up rate in the consumption-good sector, it follows that by by tuning up and down the level $\overline{\mu}(0)$ one can vary the long-term income distribution between wages and profits in the economy.

Prices are one the key determinants of firms' competitiveness. The other ones are the levels of unfilled demand. If firms cannot fully satisfy their customers, their competitiveness is accordingly reduced.

Market shares evolve according to a replicator-type dynamics operating under conditions of imperfect information,[13] so that even if the product is homogeneous, firms may charge different prices. In such dynamics, firms with above-average competitiveness expand their market shares, while those below shrink (or even die).

1.4. The labor market

We do not impose any assumption of labor-market clearing: as a consequence involuntary unemployment as well as labor rationing are the rule rather than the exception. The aggregate labor demand is computed summing up the labor demand of capital—and consumption—good firms. The aggregate supply of labor is exogenous and inelastic. Aggregate employment is then the minimum between labor demand and supply. The wage is set according to:

$$w(t) = w(t-1)\left(1+\psi_1\frac{\Delta\overline{AB}(t)}{\overline{AB}(t-1)}+\psi_2\frac{\Delta cpi(t)}{cpi(t-1)}+\psi_3\frac{\Delta U(t)}{U(t-1)}\right), \tag{6}$$

13. See Rotemberg (2008) for a survey of the empirical literature on consumers' imperfect price knowledge.

where $\overline{AB}(t)$ is the average labor productivity, $cpi(t)$ is the consumer price index, and $U(t)$ is the unemployment rate. The wage rate is determined by institutional and market factors, with both indexation mechanisms upon consumption prices and average productivity, on the one hand, and, adjustments to unemployment rates, on the others. Notice that, by varying the magnitude of the parameters ψ_1,ψ_2 and ψ_3 in Equation (6), and the initial mark-up rate $\bar{\mu}(0)$ we are able to tune the distribution of productivity gains between workers and firms as well as the sensitivity of wages no unemployment variations (see Section 2 fore more discussion). In this way, and inn line with works in the "Régulation" literature, we capture different institutional regimes governing labor market dynamics and demand formation (see Boyer, 1988, for a taxonomy of those regimes). More precisely, in Section 2.1 we begin our analysis of the role of wages and income distribution in determining aggregate dynamics by restricting ourselves to a regime wherein wage just grows with average productivity, *i.e.* where $\psi_2 = \psi_3$ and = 0 and $\psi_1 > 0$. In Section 2.2, we remove this hypothesis and we perform experiments where nominal wages are also a function of variations in unemployment.[14]

1.5. Consumption, taxes, and public expenditures

As in Dosi *et al.* (2010) and Dosi *et al.* (2012) the model has a public sector that levies taxes on firm profits and worker wages (or on profits only) and pays to unemployed workers a subsidy, that is a fraction of the current market wage. In those models, redistributive fiscal policies significantly affect the aggregate dynamics both in the short- and in the long-run. Therefore, in what follows we set both the tax and unemployment subsidy rate to zero. This allows us to better analyze the role of income distribution and wage formation on aggregate dynamics, and the one of nominal wage flexibility on unemployment in particular.

All wages are consumed in the model. The aggregate consumption (C) is the sum of income of both employed and unemployed

14. In the experiments we present below average inflation is always very close to zero (see Tables 2 and 3). However, we also experimented with regimes wherein wage move also as a function of inflation rates (*i.e.* where $\psi_2 > 0$). All the properties discussed below robustly hold.

workers, as the model satisfies the standard national account identities: the sum of value added of capital—and consumption-goods firms (Y) equals their aggregate production since in our simplified economy there are no intermediate goods, and that in turn coincides with the sum of aggregate consumption, investment and change in inventories (ΔN):

$$\sum_{i=1}^{F_1} Q_i(t) + \sum_{j=1}^{F_2} Q_j(t) = Y(t) \equiv C(t) + I(t) + \Delta N(t). \qquad (7)$$

The micro decisions of a multiplicity of heterogenous, adaptive agents and their interaction mechanisms is the explicit microfoundation of the dynamics for all aggregate variables of interest (e.g. output, investment, employment, etc.).

2. Simulation results

In line with Dosi *et al.* (2010) and Dosi *et al.* (2012), we investigated the micro and macro properties of the model through extensive Monte-Carlo simulations.[15] We perform our simulation analysis in two complementary steps (see also the paper by Fagiolo and Roventini in this issue for a discussion of this methodology). First, we identify a "benchmark" setup for which the model is empirically validated (see Table 1), *i.e.* it is able to replicate a wide spectrum of microeconomic and macroeconomic stylized facts. Next, we turn to a battery of "experiments", by identifying sets of parameters (e.g. the level of the initial mark-up rate, the degree of wage-indexation to unemployment) whose values capture different structural conditions and/or policies.

The macro and micro stylized facts robustly replicated by the model are the same statistical regularities produced by and discussed at much greater length in Dosi *et al.* (2010) and Dosi *et al.* (2012). There we show that the model is able to generate macroeconomic time-series of output, consumption and aggregate investment characterized by self-sustained growth patterns and by persistent fluctuations. Moreover, aggregate investment is more volatile than GDP whereas consumption is less volatile.

15. All results discussed below refer to averages over $MC = 50$ Monte-Carlo iterations. Each iteration has $T = 600$ time-steps.

Table 1. Benchmark Parameters

Description	Symbol	Value
Number of firms in capital-good industry	F_1	50
Number of firms in consumption-good industry	F_2	200
R&D investment propensity	υ	0.04
R&D allocation to innovative search	ξ	0.50
Firm search capabilities parameters	$\zeta_{1,2}$	0.30
Beta distribution parameters (innovation process)	(α_1, β_1)	(3,3)
Beta distribution support (innovation process)	$[\underline{x}_1, \overline{x}_1]$	[–0.15,0.15]
New-customer sample parameter	γ	0.50
Desired inventories	ι	0.10
Payback period	b	3
"Physical" scrapping age	η	20
Capital-good firm mark-up rate	μ_1	0.04
Consumption-good firm initial mark-up	$\overline{\mu}(0)$	0.10
Coefficient in the consumption-good desired production rule *(profit-led scenario)*	σ	2
Coefficient in the consumption-good firm mark-up rule	υ	0.10
Competitiveness weights	$\omega_{1,2}$	1
Replicator dynamics coefficient	χ	1
Wage setting $\Delta\overline{AB}$ weight	ψ_1	1
Wage setting Δcpi weight	ψ_2	0
Wage setting ΔU weight	ψ_3	0
Tax rate	tr	0
Unemployment subsidy rate	φ	0
Loan-to-value ratio	λ	2
Baseline Interest Rate	r	0.025

In addition, the model replicates the empirically observable co-movements between a large set of macro time series and GDP (net investment and consumption pro-cyclical coincident, inflation pro-cyclical and lagging, counter-cyclical mark-up rates, etc.). In particular, the K+S model is also able to replicate two among the most relevant statistical properties characterizing labor markets, namely the fact that unemployment is strongly counter-cyclical whereas real wages display little variation at business cycles frequencies. At the same time, at the microeconomic level, the

model matches a wide set of stylized facts concerning firm dynamics (including right-skewed distribution of firm sizes, fat-tailed distributions of firm growth rates, wide and persistent productivity differences across firms, lumpy investment dynamics).

Figure 1. Profit-led investment scenario. Average GDP growth rate as a function of the mark-up rate (confidence bands in gray)

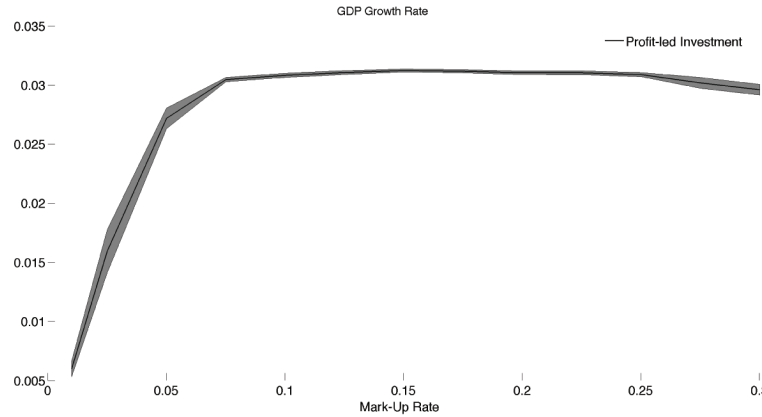


Figure 2. Profit-led investment scenario. Average unemployment rate as a function of the mark-up rate (confidence bands in gray)

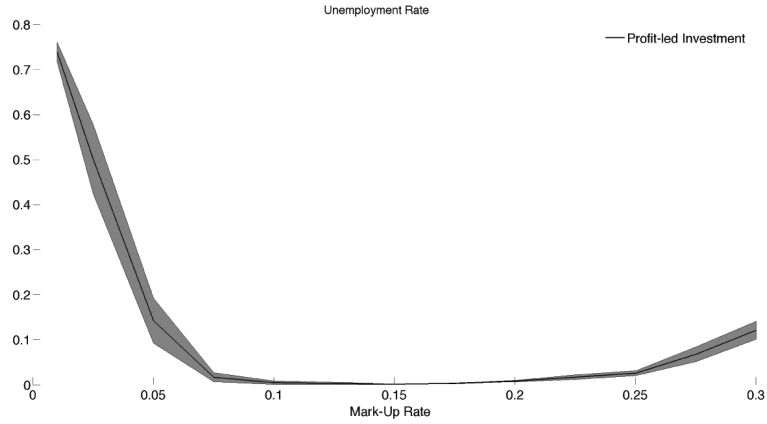


Figure 3. Profit-led investment scenario. Standard deviation of GDP growth rate as a function of the mark-up rate (confidence bands in gray)

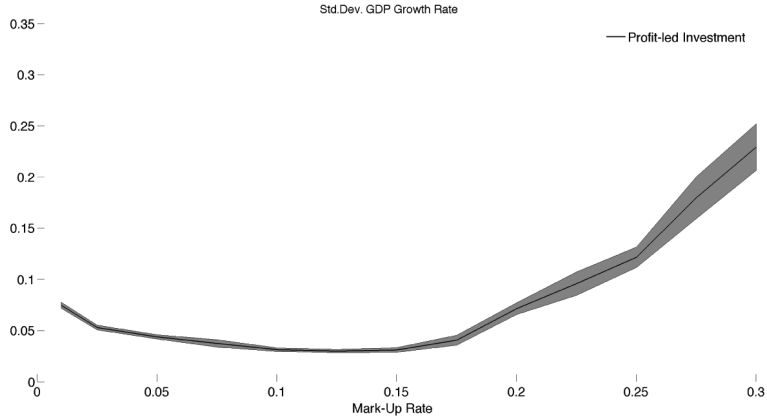
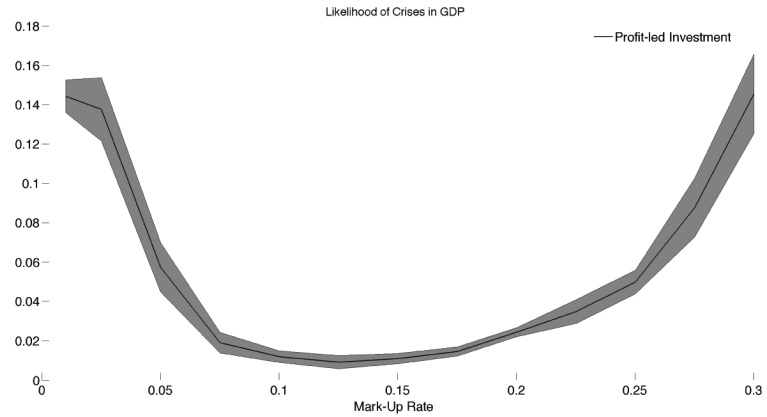


Figure 4. Profit-led investment scenario. Likelihood of crises in GDP as a function of the mark-up rate (95% confidence bands in gray)



Note: Crises are defined as time periods with growth rates lower than –3%.

Encouraged by the empirical performance of the model, in the next sections we turn to explore the behavior of the economy under different income distribution hypotheses, and under different regimes of adjustment of nominal wages to variations in unemployment.

2.1. Income distribution and growth regimes

Real wages in the model have a dual role. On the one hand, they affect the level of firms' costs and therefore profits, thus determining the ability of firms to survive and to finance production and investment expenditures. On the other hand, real wages determine aggregate consumption and via the latter they impact on firms' investment decisions. The first effect is the one already emphasized by Neo-Classical economists as well as by the works in the New Keynesian literature with financial market imperfections (see Greenwald and Stiglitz, 1993), and it should have a detrimental effect on growth and employment. In contrast, the second effect, as emphasized by Keynes in his General Theory (see e.g. also Howitt, 1986, for a discussion), should affect aggregate demand and thus output and unemployment. In what follows, we study the behavior of macro-variables in the model under different levels of the wage-share in the economy. We change the dynamics of real wages (and of profits) by tuning up and down the level of the initial mark-up rate of consumption good firms. The latter indeed determines consumption-good prices in the model, and therefore it determines how real income is divided between profits and wages (see also Section 1.3). Moreover, we perform the aforementioned experiment on income distributions under different regimes of firms' investment behavior. In the first scenario, desired investment is "profit-led". More precisely, desired investment in new productive capacity is determined only by the degree of financial robustness of the firm, proxied by its stock of net liquid assets. In the second scenario, instead, desired expansionary investment is "demand-led", *i.e.* driven by expectations about future consumption demand (see also Section 1.3). Finally, notice that in both scenarios desired investment plans can be constrained by the availability of internal and external finance, respectively determined by the level of past profits, and by the external credit ceilings.

Let us start by discussing the result of the experiment under the "profit-led" investment scenario. Figures 1 and 2, show average growth and unemployment in relation to the (initial) mark-up rate. Both figures indicate that very low levels of the mark-up rate (and, thus, very high levels of real wages) have a detrimental effect on average growth and average unemployment. These outcomes correspond to the "Neo-Classical" result, according to which high

real wages have a negative effect on long-run growth and employment. More specifically, a high level of real wages implies lower firms' profits, and therefore a lower incentive of firms to invest in new productive capacities, and thus to absorb the existing labor supply. In addition, also productivity growth is lower, as the introduction of more productive machines is limited to the substitution of the existing capital stock.

Furthermore, Figures 3 and 4 show that volatility and (even more so) the likelihood of crises are high when the mark-up rate is very low. In this profit-led investment scenario, short-run business fluctuations are generated by a Goodwin-type dynamics (Goodwin, 1967). An increase in profits promotes *via* investment an increase in both production and productivity (due to introduction of new and more productive machines). Productivity gains however imply also an increase in real wages and a reduction in the profit rate thereby creating the conditions for a fall in economic activity. The lower is the mark-up rate the stronger is the above described predator-prey dynamics. Accordingly, both GDP volatility and the likelihood of crises turns out to be high at low levels of the mark-up rate.

What happens if one increases the mark-up and therefore decreases the level of real wages in this scenario? As Figures 1-4 show quite starkly, increasing the mark-up has the effect of increasing growth and reducing unemployment. The economy enters into a "Classical Growth Regime" (see Boyer, 1988) where productivity increases are able to promote profits, hence investment and effective demand, which enhance employment. In addition, in this growth scenario, the above-described dynamics between profits and wages is dampened by a lower mark-up rate because the process of workers' appropriation of productivity gains through real wages is weakened. As a result, both GDP volatility and the likelihood of crises are lowered. In particular, notice that the economy is characterized by a wide region of high and stable growth (corresponding to levels of mark-up between 0.075 and 0.15) wherein, on one side, average growth is maximized and, on the other side, unemployment, volatility and the probability of crises are zero.

As real wages are reduced further ($\overline{\mu}(0) > 0.15$), however, the economy enters a region where high growth are associated to wild

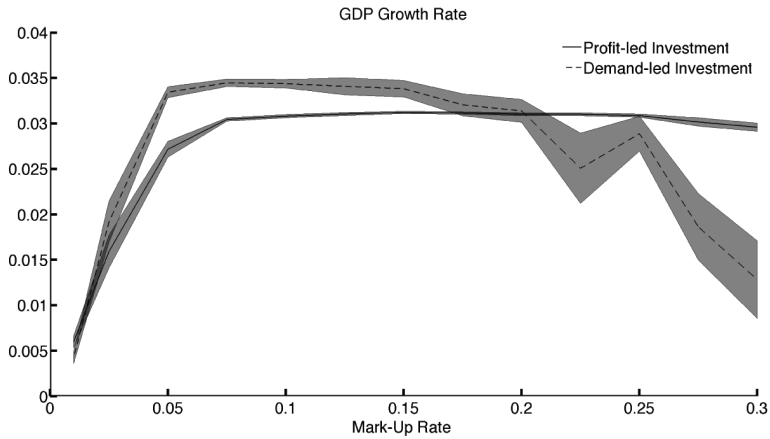
fluctuations, higher incidence of crises and positive unemployment. This occurs because the aforementioned "Classical" engine of growth is hampered by the credit constraints imposed on firms investment. More precisely, in this region the strong incentives of firms to invest in large productive capacities imply also high debt accumulation by firms. As time goes by, increasingly high debt burdens erode profits, thereby creating the conditions for the incoming recession. Accordingly, both volatility and the incidence of crises become higher.

How do the above results change when firm investment is "demand-led"? Figures 5, 6 and 7 compare the dynamics of macrovariables in the profit-led vs. the demand-led scenarios, always as a function of the mark-up rate. As in the profit-led scenario, low levels of the mark-up rate are associated with low growth and high unemployment and crisis incidence also in the demand-led regime. The mechanisms generating this result are however completely different between the two scenarios. In the profit-led regime, low growth and high unemployment rates are determined by the low incentive of firms to invest in new productive capacities. In contrast, in the demand-led scenario, the incentive to invest is high when the mark-up rate is low, because wages and thus expectations of consumption demand are very high. However, firms desired investment plans are constrained by the availability of internal and external financing, which are on average lower in presence of a low profits. Moreover, a higher incentive to invest induce a dynamics of debt accumulation similar to the one analyzed in the case of the high-growth profit-led regime, thereby causing higher volatility (not shown) and crises incidence (*cf.* Figure 7). In light of the above, it comes as no surprise that a small reduction in the (already high) level of real wages is able to restore growth and reduce volatility and unemployment (see Figure 5).

As the distribution of income between wages and profits gets more balanced ($0.05 \leq \bar{\mu}(0) \leq 0.15$), the economy enters a regime characterized high average growth rates and low unemployment and volatility rates. Following the taxonomy suggested in Boyer (1988), we shall label this a "Fordist Growth Regime", roughly matching the institutional conditions characterizing advanced economies in the post-WWII period. Such a regime associates

investment led by demand expectations with a balanced sharing of productivity gains between workers and firms. In that, improvements in productivity lead to significant increases in wages, thereby rising aggregate demand *both* via consumption *and* investment by firms. Notice that this regime is characterized by significantly higher average growth rates than the Classical one discussed before. In turn, this occurs because high levels of consumption demand now reinforce *via* expectations aggregate investment, rather than crowding it out as in the Classical regime.

Figure 5. Average GDP growth rate as a function of the mark-up rate (confidence bands in gray)



The high dependence of growth on expectations about consumption demand also implies the emergence of a wide region wherein real wages and unemployment are inversely (rather than directly) related. More precisely, in the demand-led scenario, further increasing the profits rate in the economy result into a significant increase of unemployment and of the incidence of crises (see Figures 6 and 7). Moreover, very high levels of the mark-up rate ($\overline{\mu}(0) > 0.20$, *cf.* Figure 5) locks the economy into a low-growth trajectory (similar to what very high real wages do). This is explained by the fact (see also Dosi *et al.*, 2012 for a more detailed discussion) that in presence of very low levels of expected demand, firms have low incentive to undertake investments into new and productive machines. This hampers the growth of productivity and therefore the long-term growth prospects of the economy.

Figure 6. Average unemployment rate as a function of the mark-up rate (confidence bands in gray)

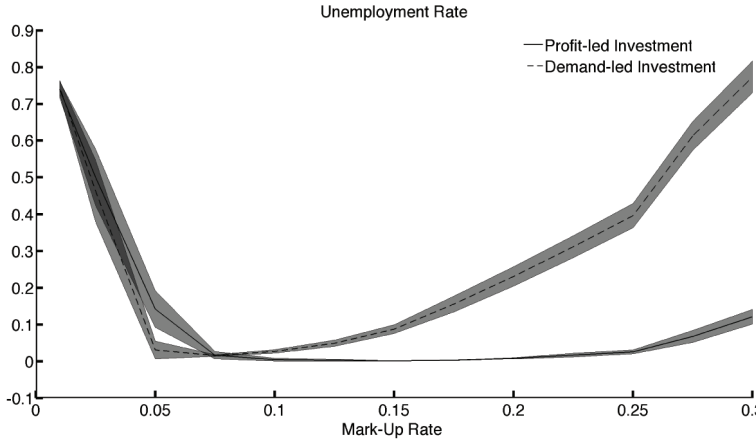
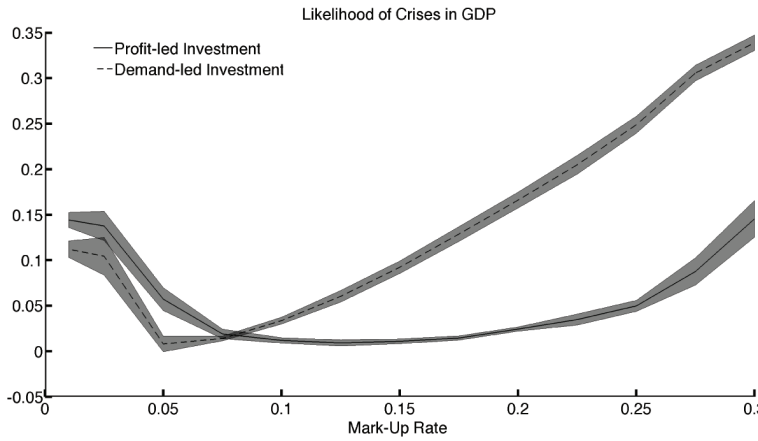


Figure 7. Likelihood of crises in GDP as a function of the mark-up rate (95% confidence bands in gray)



Note: Crises are defined as time periods with growth rates lower than -3%.

Let us now summarize the different results of the section as well as provide some implications for theory. First, our results indicate that the economy is not always characterized by an inverse relation between real wages and employment. The presence of such a relation is indeed closely associated to a profit-led investment behavior by firms. In contrast, under regimes where investment is driven by firms expectations such a relation is non-linear.

In particular, there exists a threshold (corresponding to a low level of mark-ups) above which unemployment decreases (rather than increasing) with the level of the real wage in the economy. Second, in line with Boyer (1988) and Freeman and Perez (1988), our experiments indicate that endogenous innovation is not able by itself to guarantee high and stable growth without the presence of specific institutional conditions determining investment behavior and the distribution of income between wages and profits. However, differently from that literature our analysis shows that independently from firm investment behavior the presence of high growth together with low levels of volatility and unemployment, always requires a balance in the distribution of income between profits and wages. When such a condition is not fulfilled the economy gets either into a low and highly volatile growth trap (low mark-up rate in either investment scenario, high mark-up rate in the demand-led scenario), or into a situation where high growth rates are associated with significant volatility and high unemployment rates (high mark-up rate in the profit-led scenario). In the next section we investigate the robustness of the above results in presence of wage flexibility to unemployment variations.

2.2. Nominal wages flexibility, growth and unemployment

In the previous section we have shown that the distribution of income between profits and wages crucially affects the properties of the macroeconomic dynamics and the rate of unemployment in the economy. However, these results were obtained assuming that in the labor market wages were only a function of labor productivity. In this section, we remove this hypothesis, and we allow for nominal wages that depend also on changes of the unemployment rate. More precisely, we select different levels of the mark-up rate and we run different Montecarlo experiments by varying the level of the parameter ψ_3 in Equation (6), *i.e.* the parameter tuning the response of nominal wages to relative changes in the unemployment rate U. We perform the experiment for the scenario wherein investment is profit-led and for the one in which investment is demand-led. In this way, we study how all the results discussed in the previous section change under higher levels of nominal wages flexibility to unemployment variations.

Table 2 and 3 present the results of the above described experiments. Notice that the levels of mark-ups presented in the tables

correspond to different growth regimes (see previous section) . Let us start by discussing the results for the scenario with profit-led investment and low mark-up rate ($\bar{\mu}(0) = 0.01$). In this region of the parameters' space, the high-level of real wages depresses profits and therefore the incentive to invest. One could therefore expect a positive effect of downward wage flexibility on the economy. This is not the case, however. Introducing wage flexibility does not affect growth and it does not reduce unemployment (see Table 2, first and second column). Furthermore, increasing nominal wage-flexibility exacerbates the volatility of the economy. More precisely, increasing the sensitivity of wages to unemployment implies a significant increase both in the standard deviation of GDP growth and in the likelihood of crises (Table 2, columns 3 and 4). The same occurs for the standard deviation of the inflation rate (column 6). The significant increase in volatility is explained by the fact that wage flexibility strengthen the competition between profits and wages, which is one of the main mechanisms generating fluctuations in the profit-led investment scenario.

The situation dramatically changes when we consider higher levels of the mark-up rate. Take for instance the scenario with mark-up rate $\bar{\mu}(0) = 0.05$. There, the distribution of income between profits and wages ensures that firms have enough incentive to invest and therefore growth unfolds according to the "Classical" mechanisms described in the previous section. In that growth regime, wage-flexibility is able to significantly reduce unemployment. In addition, the increases in growth and inflation volatility are small and in most cases not significant. Notice, however, that wage flexibility also induces a small reduction in the average growth rate of the economy. In turn, this outcome is explained by the fact that wage flexibility reduce firm incentives to replace their machines, thus curbing productivity growth.

All the patterns described above emerge even more starkly in the high mark-up scenario ($\bar{\mu}(0) = 0.03$ see Table 2). More precisely, wage-flexibility significantly reduces unemployment and brings a small reduction in average growth. However, and differently from the case with $\bar{\mu}(0) = 0.05$ discussed before, now an increase in wage-flexibility results in a reduction both of the standard deviation of GDP growth and of the likelihood of crises.

Table 2. Profit-led investment scenario. Experiments with different degrees of nominal wages flexibility to unemployment variations (Monte-Carlo simulations standard errors in brackets)

	Avg.GDP growth rate	Avg.unempl. rate	St.dev. GDP growth rate	Avg.likel. GDP crises	Avg. infl. rate	St.dev. infl. rate
Mark-Up Rate 0.01						
$\psi_3 = 0.0$	0.0060 (0.0003)	0.7386 (0.0108)	0.0746 (0.0015)	0.1442 (0.0042)	0.0001 (0.0000)	0.0591 (0.0017)
$\psi_3 = 0.2$	0.0068 (0.0003)	0.7113 (0.0110)	0.0746 (0.0014)	0.1963 (0.0057)	0.0005 (0.0000)	0.0673 (0.0019)
$\psi_3 = 0.4$	0.0086 (0.0004)	0.6300 (0.0206)	0.0819 (0.0043)	0.2023 (0.0055)	0.0010 (0.0001)	0.0732 (0.0016)
$\psi_3 = 0.6$	0.0074 (0.0004)	0.6703 (0.0193)	0.1294 (0.0350)	0.1816 (0.0089)	0.0009 (0.0002)	0.0723 (0.0022)
$\psi_3 = 0.8$	0.0040 (0.0010)	0.7124 (0.0174)	0.4883 (0.1149)	0.2106 (0.0134)	0.0006 (0.0002)	0.0708 (0.0022)
Mark-Up Rate 0.05						
$\psi_3 = 0.0$	0.0270 (0.0005)	0.1463 (0.0287)	0.0456 (0.0014)	0.0582 (0.0066)	0.0001 (0.0000)	0.0353 (0.0018)
$\psi_3 = 0.2$	0.0266 (0.0005)	0.1098 (0.0248)	0.0491 (0.0014)	0.0733 (0.0067)	0.0019 (0.0001)	0.0413 (0.0017)
$\psi_3 = 0.4$	0.0247 (0.0007)	0.0694 (0.0187)	0.0562 (0.0021)	0.0770 (0.0054)	0.0035 (0.0002)	0.0534 (0.0028)
$\psi_3 = 0.6$	0.0198 (0.0011)	0.0576 (0.0188)	0.0600 (0.0059)	0.0752 (0.0067)	0.0053 (0.0004)	0.0531 (0.0032)
$\psi_3 = 0.8$	0.0177 (0.0013)	0.0391 (0.0134)	0.0548 (0.0023)	0.0714 (0.0048)	0.0069 (0.0005)	0.0565 (0.0040)
Mark-Up Rate 0.20						
$\psi_3 = 0.0$	0.0309 (0.0001)	0.0032 (0.0010)	0.0332 (0.0015)	0.0118 (0.0014)	0.0000 (0.0000)	0.0147 (0.0007)
$\psi_3 = 0.2$	0.0311 (0.0001)	0.0019 (0.0003)	0.0470 (0.0035)	0.0261 (0.0024)	0.0017 (0.0002)	0.0288 (0.0019)
$\psi_3 = 0.4$	0.0278 (0.0007)	0.0028 (0.0006)	0.0574 (0.0047)	0.0414 (0.0050)	0.0027 (0.0003)	0.0389 (0.0035)
$\psi_3 = 0.6$	0.0250 (0.0012)	0.0024 (0.0003)	0.0526 (0.0041)	0.0362 (0.0046)	0.0033 (0.0004)	0.0347 (0.0028)
$\psi_3 = 0.8$	0.0207 (0.0015)	0.0030 (0.0008)	0.0476 (0.0035)	0.0334 (0.0041)	0.0054 (0.0007)	0.0373 (0.0031)
Mark-Up Rate 0.30						
$\psi_3 = 0.0$	0.0295 (0.0002)	0.1318 (0.0097)	0.2360 (0.0091)	0.1596 (0.0089)	-0.0001 (0.0000)	0.0243 (0.0008)
$\psi_3 = 0.2$	0.0307 (0.0002)	0.0712 (0.0113)	0.1849 (0.0108)	0.1311 (0.0080)	0.0014 (0.0002)	0.0398 (0.0025)
$\psi_3 = 0.4$	0.0263 (0.0008)	0.0532 (0.0111)	0.1707 (0.0100)	0.1431 (0.0072)	0.0033 (0.0004)	0.0593 (0.0042)
$\psi_3 = 0.6$	0.0222 (0.0012)	0.0521 (0.0112)	0.1605 (0.0111)	0.1352 (0.0076)	0.0049 (0.0005)	0.0627 (0.0047)
$\psi_3 = 0.8$	0.0173 (0.0014)	0.0519 (0.0112)	0.1435 (0.0124)	0.1168 (0.0088)	0.0061 (0.0007)	0.0572 (0.0043)

Table 3. Demand-led investment scenario. Experiments with different degrees of nominal wages flexibility to unemployment variations (Monte-Carlo simulations standard errors in brackets)

	Avg.GDP growth rate	Avg.unempl. rate	St.dev. GDP growth rate	Avg.likel. GDP crises	Avg. infl. rate	St.dev. infl. rate
Mark-Up Rate 0.01						
$\psi_3 = 0.0$	0.0042 (0.0003)	0.7447 (0.0092)	0.1952 (0.0237)	0.1121 (0.0045)	0.0001 (0.0000)	0.0687 (0.0026)
$\psi_3 = 0.2$	0.0042 (0.0006)	0.7356 (0.0135)	0.2080 (0.0193)	0.1206 (0.0048)	0.0005 (0.0001)	0.0767 (0.0034)
$\psi_3 = 0.4$	0.0045 (0.0004)	0.7364 (0.0115)	0.1881 (0.0226)	0.1222 (0.0050)	0.0007 (0.0001)	0.0772 (0.0037)
$\psi_3 = 0.6$	0.0040 (0.0006)	0.7432 (0.0130)	0.1997 (0.0208)	0.1336 (0.0051)	0.0011 (0.0001)	0.0766 (0.0022)
$\psi_3 = 0.8$	0.0038 (0.0007)	0.7629 (0.0136)	0.2884 (0.0697)	0.1465 (0.0059)	0.0012 (0.0002)	0.0824 (0.0034)
Mark-Up Rate 0.05						
$\psi_3 = 0.0$	0.0334 (0.0003)	0.0307 (0.0119)	0.0293 (0.0008)	0.0080 (0.0043)	0.0002 (0.0000)	0.0137 (0.0010)
$\psi_3 = 0.2$	0.0333 (0.0002)	0.0318 (0.0080)	0.0291 (0.0008)	0.0092 (0.0033)	0.0025 (0.0001)	0.0133 (0.0007)
$\psi_3 = 0.4$	0.0330 (0.0003)	0.0509 (0.0150)	0.0304 (0.0012)	0.0169 (0.0058)	0.0048 (0.0001)	0.0170 (0.0013)
$\psi_3 = 0.6$	0.0335 (0.0002)	0.0285 (0.0086)	0.0285 (0.0008)	0.0080 (0.0028)	0.0074 (0.0001)	0.0175 (0.0009)
$\psi_3 = 0.8$	0.0331 (0.0003)	0.0540 (0.0178)	0.0301 (0.0012)	0.0151 (0.0053)	0.0093 (0.0003)	0.0218 (0.0014)
Mark-Up Rate 0.20						
$\psi_3 = 0.0$	0.0314 (0.0006)	0.2307 (0.0132)	0.7430 (0.0680)	0.1660 (0.0043)	0.0000 (0.0001)	0.0858 (0.0033)
$\psi_3 = 0.2$	0.0308 (0.0006)	0.2356 (0.0124)	0.7018 (0.0751)	0.1683 (0.0038)	0.0016 (0.0001)	0.0826 (0.0031)
$\psi_3 = 0.4$	0.0296 (0.0012)	0.2289 (0.0123)	0.8236 (0.0914)	0.1586 (0.0042)	0.0026 (0.0001)	0.1004 (0.0047)
$\psi_3 = 0.6$	0.0280 (0.0015)	0.2374 (0.0173)	0.8185 (0.1028)	0.1612 (0.0055)	0.0037 (0.0002)	0.1007 (0.0036)
$\psi_3 = 0.8$	0.0289 (0.0015)	0.2356 (0.0105)	0.6773 (0.0632)	0.1624 (0.0037)	0.0046 (0.0003)	0.1132 (0.0046)
Mark-Up Rate 0.30						
$\psi_3 = 0.0$	0.0128 (0.0021)	0.7733 (0.0216)	1.7748 (0.0998)	0.3388 (0.0042)	-0.0003 (0.0001)	0.1810 (0.0088)
$\psi_3 = 0.2$	0.0128 (0.0020)	0.8144 (0.0226)	1.8682 (0.0831)	0.3416 (0.0042)	-0.0003 (0.0001)	0.1835 (0.0091)
$\psi_3 = 0.4$	0.0128 (0.0017)	0.7836 (0.0215)	2.0117 (0.0765)	0.3390 (0.0037)	-0.0006 (0.0002)	0.1884 (0.0102)
$\psi_3 = 0.6$	0.0125 (0.0019)	0.8259 (0.0237)	1.9303 (0.0869)	0.3401 (0.0044)	-0.0004 (0.0001)	0.1705 (0.0100)
$\psi_3 = 0.8$	0.0136 (0.0020)	0.8018 (0.0249)	1.8278 (0.0794)	0.3384 (0.0045)	-0.0004 (0.0001)	0.1816 (0.0103)

Overall, the results of the above experiments indicate that the flexibility of nominal wages to unemployment variations can stabilize the economy and reduce unemployment, when growth is driven by a Classical mechanism, linking productivity growth to investment determined by firms' profits. Moreover, the role of wage-flexibility as a stabilizing device is stronger the more the distribution of income is biased towards profits.

How does the above picture change when we turn to the demand-led scenario? Notice that in that scenario, investment is tied to the level of real wages via expectations of consumption demand. In turn, such a Keynesian expectation effect can be stronger than the cost-saving effect when wages are reduced following an increase in unemployment. Accordingly, higher wage-flexibility to unemployment can de-stabilize (rather than stabilize) investment and aggregate demand (see Keynes, 1936; Howitt, 1986; Amendola *et al.*, 2004). A rise in the degree of wage-flexibility does not provoke a reduction in average unemployment in any of the scenarios considered in the table. Consider for instance the experiments with high mark-up rates (respectively $\bar{\mu}(0) = 0.20$ and $\bar{\mu}(0) = 0.30$). Except for inflation volatility, none of the macroeconomic statistics reported in Table 3 display a statistically significant variation when we increase the degree of wage-flexibility.

One could expect the above results to be different in the scenarios with low mark-up rates ($\bar{\mu}(0) = 0.05$ and $\bar{\mu}(0) = 0.01$). There, real wages and the level of consumption demand are expected to be high, and therefore the cost-saving effect associated with wage reductions in presence of unemployment could dominate the Keynes' expectation effect. Once again, the results in Table 3 show that this does not happen. Higher degrees of wage-flexibility do not lead to unemployment reductions. On the contrary, unemployment increases (even though the variation is not statistically significant). In addition, high levels of wage-flexibility lead to an increase in the likelihood of crises when the level of the mark-up is very low ($\bar{\mu}(0) = 0.01$).

3. Concluding remarks

Using the Keynes+Schumpeter (K+S) agent-based model developed in Dosi *et al.* (2010, 2012) we investigated the characteristics of growth regimes emerging different rules for firms' investment decisions and different distributions of income between profits and wages. We studied the aggregate dynamics when investment is determined by the stock of liquid assets of the firm ("profit-led investment scenario") and when it is determined according to expected demand ("demand-led investment scenario"). We showed that, independently from the investment scenario, the occurrence of stable growth associated with low unemployment requires a balanced distribution of income between profits and wages. Moreover, we showed that in the demand-led scenario the economy is characterized by a non-linear relation between the level of real wages and the unemployment rate. In particular, we find a threshold below which further reductions in the average real wage are associated with an increase (rather than an decrease) in unemployment. Finally, we investigated whether the introduction of increasing degrees of nominal wage-flexibility to unemployment variations are able to restore growth and curb unemployment. We showed that this is indeed the case when investment is profit-led and the mark-up rate in the economy is able to ensure positive growth. In contrast, in the demand-led scenario wage-flexibility never brings reductions in unemployment and in some cases can also result into a higher incidence of crises in the economy. Accordingly, our results cast doubts on the effectiveness of policies promoting wage-flexibility when investment is related to expectations about future consumption demand.

The present work could be extended in at least two directions. First, one could extend the above analysis by considering several open economies, whose ability to export may depend on the level of wages, and there study how the results of this work may change in that context. Second, we considered only a very stylized representation of labor market interactions. However, one could easily extend the above framework to introduce a full-fledged analysis of the labor market, e.g. like in Fagiolo *et al.* (2004); Dawid *et al.* (2011) and study the inter-play between this market and the processes of technical change and of the determination of income-distribution in the economy.

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