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Essays on Technical Change, Economic Growth and Income Distribution: a Complex Adaptive System Approach

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Contents

Chapter 1

Introduction

This thesis is composed by three essays aimed at analyzing the interplay between technical change, long-run economic growth and functional income distribution, by focusing in particular on the possible explanations accounting for the persistent declining pattern of aggregate wage share observed during the last decades in many advanced economies. From a methodological perspective, I analyze this topic with the Complex Adaptive System approach, and in particular by implementing two Agent Based-Stock-Flow Consistent (AB-SFC) models in Chapter 2 and Chapter 3, whereas in Chapter 4 I propose an analytical two-sector Kaleckian model.

In Chapter 2[1] I present a model wherein the classical idea about the so-called *directed* and *induced* technical change (ITC) has been introduced within a *Keynesian* demand-side and *evolutionary* endogenous growth model. The ITC process is analyzed within a closed-economy AB-SFC model, wherein credit-constrained heterogeneous firms choose both the *intensity* and the *direction* of the innovation towards a labor- or capital-saving choice of technique. In the long-run, the model reproduces the so-called 'Kaldor stylized facts' (i.e. with a purely labor-saving technical change), however during the transitional phase the model shows a labor-saving/capital-using innovation pattern, as the aggregate output-capital ratio decreases until it stabilizes in the long-run, as well as declining labor share for long time periods and we can ascribe these evidences mainly to the directed technical change process and to its detrimental effect upon the aggregate demand of the economy. In order to stress the effective role of the innovation bias on the model dynamics, I compare the baseline scenario with a 'counterfactual' scenario wherein a 'neutral' technical progress is at work.

[1] A version of the model presented in this chapter has been already published as Fanti L. (2018) '*An AB-SFC Model of Induced Technical Change along Classical and Keynesian Lines*' , DSSE Papers Series 3/2018, Department Social Sciences and Economics (DSSE).

In Chapter 3[2] I propose a multi-country extension of the model presented in Chapter 2. Building on Caiani et al. (2017) and Caiani et al. (2017a), the model is aimed at analyzing the role of *biased* technical change process on long-run economic growth, distributive shares and employment dynamics within an artificial monetary union wherein a given number of countries interact on different markets (i.e. tradable goods, credit, deposits and bonds). The model is able to confirm the results obtained with its closed-economy version, that is the emergence of a persistent declining pattern of aggregate wage share. Furthermore, the two-sector specification also allows us to analyze different pattern of sectoral wage shares, due to different intensities and directions of the innovation effort and different 'capital-deepening' between sectors, leading to a shift of the employment share from tradable to non-tradable sector, whereas the multi-country modeling framework shows the emergence of persistent growth and technological gaps across countries belonging to our artificial monetary union.

In Chapter 4[3] I look at structural change, and in particular at the shrinking size of manufacturing in favor of the service sector, as one additional source of decline in the wage share. To the purpose, I build on Dutt (1988) to develop a two-sector Kaleckian model of growth and distribution, where the economy consists of the service and manufacturing sectors. The service good is only used for consumption while the manufacturing good is used both for consumption and accumulation of the capital stock. I assume that structural change is exogenous as it arises from a shift in consumers' preferences. I show that, when mark-ups are relatively higher in the service sector, a shift in the sectoral composition of demand in favor of the service sector good generates a rise in the profit share. The unique (non-trivial) steady state is asymptotically stable.

[2]The model presented in this chapter is part of a joint research project with Ermanno Catullo and Mauro Gallegati.

[3]The model presented in this chapter is part of a joint research project with Elton Beqiraj and Luca Zamparelli.

Chapter 2

'Kaldor Facts' and the Decline of Wage Share: an Agent Based-Stock Flow Consistent Model of Induced Technical Change along Classical and Keynesian Lines

2.1 Introduction

Since the inception of classical political economy the effect of technological progress upon long-run economic growth and the distribution of income among social classes represents a crucial question. For many years the bearings for modern theory of economic growth and distribution have been the empirical regularities known as 'Kaldor stylized facts' (Kaldor 1957), and in particular the constancy of aggregate output-capital ratio and of distributive shares.

However, over the last few decades we have observed a persistent decline in the wage share together with moderate growth of real wages (especially compared to the pace of labor productivity growth) and different pattern of output-capital ratio in advanced economies.

The social and economic consequences of declining labor share, growing capital-output ratio[1] and different pattern of the rate of profit have been brought to the

[1] See Stiglitz (2016) for a detailed discussion about the definition of capital-output ratio adopted by Piketty and its relation with the Kaldor facts.

center of economic debate by Piketty’s book (2014) and his analysis about inequalities and capital concentration in a weak growth scenario in advanced economies. The declining pattern of aggregate wage share is nowadays at the core of economic and political economy debate about the interplay among technological change, wage-bargaining, institutional factors and distributive shares (see for example Piketty 2014, Stiglitz 2012), so as to lead many economists to highlight the evidence for ‘new stylized fact’ (Stiglitz 2016 and Jones 2015).

The Organisation for Economic Co-operation and Development (OECD 2012 and OECD 2015) and the International Monetary Fund (IMF 2017) provide a detailed analysis of key factors proposed in literature as the main drivers of falling labor share during the last decades and special attention has been devoted to the excessive labor-saving technical change and to the discrepancies between productivity growth and real wages pattern, especially within the European Monetary Union and the US. Within the economic literature, different explanations have been proposed in order to account for the evidence of a declining labor share mainly through neoclassical and classical ‘*technology-based*’ or Post-keynesian ‘*demand-driven*’ lenses. From a Post-keynesian perspective, the increasing role played by globalization and financialization in advanced economies have been identified as the main factors accounting for the declining wage share (Stockhammer and Lavoie 2012 and Stockhammer 2013), whereas within the neoclassical stream of literature both theoretical and empirical contributions mainly rely on the hypothesis of different values of elasticity of substitution between production input (labor and capital).

Also from an empirical perspective, many economists within the neoclassical stream of literature try to account for the role of technical change and its direction in affecting the declining labor share (Bentolila 2003, Bassanini 2012, Hutchinson and Persyn 2012, Karabarbounis and Neiman 2014). However, all of these contributions have been focused on the estimation of an elasticity of substitution between production inputs greater than one as the sole explanation of an increasing ‘capital deepening’ affecting in turns the labor share.

During the nineties, Acemoglu proposes a revival of the so-called *induced* (ITC) and *directed* technical change hypothesis, stemming from Hicks (1932), by implementing an explicit direction of technical change, i.e. biased towards skilled or unskilled labor (Acemoglu 1998) or towards labor or capital input (Acemoglu 2002 and Acemoglu 2003), in order to explain the dynamics of wages and labor share in the US and European countries. Acemoglu proposes an endogenous growth model, similar to the monopolistic competition models implemented by Romer (1989), Grossman and Helpman (1991) and Howitt and Aghion (1998), by combining the assumption of elasticity of substitution less than one with the endogenous bias of technical change towards labor or capital productivity improvement as the theoretical explanation for labor share fluctuations in the medium-run, whereas in the long-run the model exhibits constant distributive shares in line with the 'Kaldor Facts'.

On similar grounds, in order to account for fluctuations in distributive shares Jones (2003) presents a growth model implementing a production function with different values of the elasticity of substitution for short and the long-run that is, respectively, less than and equal to one.

Before Acemoglu, the ITC hypothesis has been developed along neoclassical lines during the sixties by Kennedy (1964), who proposes a growth model with the so-called 'Invention Possibility Frontier' (IPF) in order to represent the trade-off between improvements in labor or capital productivity, and then by Samuelson (1965) and Drandakis and Phepls (1966).

Moreover, from quite distant theoretical perspectives, the puzzling question about the interplay between technical change, growth and functional distribution have been also addressed along purely classical (Van Der Ploeg 1987, Foley and Michl 1999, Foley 2003, Foley 2003 and Zamparelli 2015) or classical/evolutionary (Dumenil and Levy 2010) lines by implementing the ITC approach.

Notwithstanding, if we accept the idea of directed input-saving technical change process induced by different paces of growth for wages and labor productivity (so-called 'Habbakkuk Hypothesis'[2]) as one of the main explanation for declining labor share in advanced economies, an interesting puzzling question remains why the moderate growth of wages in the early eighties could have not reversed the labor-saving trend of technical change pattern. Blanchard (1997), for example, explained this phenomenon with weaker bargaining power of workers and with lagged factor substitution process triggered by the 'wage push shock' after the seventies, for example within many European countries.

Recently, Stiglitz (2015) and Stiglitz and Greenwald (2015) also propose a model with directed technical change by using the Kennedy's IPF in order to show the impact of different values of the elasticity of substitution between labor and capital input upon long-run growth, distributive shares and unemployment. Stiglitz highlights how, in a fixed coefficient scenario (the case analyzed within the present model), excessive labor-saving technical change may have relevant negative effects upon functional income distribution and may also reflect in excessively high levels of unemployment. The contributions illustrated so far, are built upon a 'supply-side' and purely technological-based approach to growth and distribution. Nevertheless, a 'demand-

[2]In the early sixties, some contributions in the field of economic history (Salter 1962 and Habakkuk 1962) suggest the relevance of 'labor scarcity' as a key element accounting for the induced labor-saving technical change, especially in Great Britain and United States in the nineteenth century.

side' Keynesian approach has been increasingly developed by many scholars, in order to account for the effects of aggregate demand on the dynamics of real and financial side of a monetary production economy. On this ground, a relatively new and promising literature implementing macroeconomic models with strong interdependence between demand- and supply-side and real and financial side of the economy comes from the Complex Adaptive System approach applied to economics, stemming from Arthur (1997), Kirman (2010), and Delli Gatti et al. (2007). Thus, the so-called '*Keynes + Schumpeter*' (K+S) class of models (Dosi et al. 2010, Napoletano et al. 2012, Dosi et al. 2017), the Eurace@Unibi AB-SFC models (Dawid et al. 2012) and the Agent-Based Stock-Flow Consistent (AB-SFC) models (Caiani et al. 2016, Caiani et al. 2017, Caiani et al. 2018, Caiani et al. 2018a), concentrate the analysis upon the interplay among the evolutionary endogenous growth process[3], income and wealth distribution, aggregate demand and credit and financial issues. Following this stream of literature I try to exploit some insight provided by the *classical* interpretation of the ITC hypothesis by introducing it into a *Keynesian* demand-side and *evolutionary* endogenous growth model in order to suggest a possible explanation for some evidence about growth and distribution, such as persistent fluctuations of the labor share. The main goal is the analysis of the interplay among technical change, long-run economic growth and functional income distribution without recurring to any distinction between short-run (Keynesian) and long-run (classical) framework[4] as well as the investigation of the interplay between the directed and biased technical change process and the demand-side of our artificial economy.

The present model is mainly built upon the (post-) Keynesian AB-SFC models implemented by Caiani et al. (2016), Caiani et al. (2018), Caiani et al. (2018a). In particular, a capital-good sector has been introduced and the household sector has been divided into workers and capitalist agents within the main framework implemented by Caiani et al. (2018a). The AB-SFC approach stems from the 'benchmark' model implemented by Caiani et al. (2016) and aims to integrate the Agent-Based tradition developed upon the decentralized matching protocols for interactions among heterogeneous agents (Riccetti et al. 2015) with the Stock-Flow Consistent macro modeling approach stemming by Godley and Lavoie (2009), thus allowing us to explicitly taking into account real- and financial-side stock and flow variables and the supply- and demand-side of our artificial economy.

[3]See also Dawid (2006) for a detailed discussion on Agent-Based Modeling approach applied to economics of innovation and technical change.

[4]For example, a '*traverse*' model has been proposed by Dumenil and Levy (1999), where two different investment behaviors are implemented depending on the time horizon: a Keynesian investment function in the short-run and a classical investment function in the long-run. Dosi et al. (2013) also propose an interesting analysis of *classical* and *Keynesian* accumulation regimes as different roots of business fluctuations.

The evolutionary technical change process has been modeled by following the two steps procedure stemming from the ‘K+S’ models (Dosi et al. 2010), although this process takes place within the consumption-good sector (i.e. with ‘disembodied’ technical change). Furthermore, I introduce within this framework a *classical-fashioned* directed technical change as the heterogeneous consumption-good firms choose both the *intensity* and the *direction* of the innovation towards a labor- or capital-saving choice of technique, and as they decide to adopt the new production technique depending on a classical *profitability criterion* (Okishio 1961, Shaikh 1978, Nakatani 1979, Shaikh 1999, Park 2001 and Shaikh 2016).
This modeling framework allows us to enrich the analysis of *non-neutral* technical change and its effects upon key macroeconomic variables. Indeed, many traditional directed innovation models adopt the IPF á-la-Kennedy in order to analyze the trade-off between labor or capital productivity improvements, whereas the Agent-Based approach allows us to let the ‘*innovation bias*’ be an *emergent property* of the evolutionary technical change process engaged by consumption-good firms. Thus by introducing the classical-fashioned directed innovation mechanism and the profitability criterion for the choice of new techniques within the well-established tradition of evolutionary demand-driven endogenous growth we are bridging two different theoretical traditions: the *directed* technical change process implemented in many purely ‘supply-side’ growth models and the *localized* evolutionary innovation mechanism implemented within many recent (post-) Keynesian endogenous growth models[5]. Moreover, the AB approach also allows us to present a richer dynamics for the pattern of long-run growth, productivity and functional distribution in the light of both ‘Kaldor facts’ and ‘new’ evidences, such as the persistent declining pattern of the labor share. On similar grounds, Delli Gatti et al. (2006) also propose a ‘supply side’ Agent-Based model wherein the interplay among R&D investment, labor-saving technical change, capital accumulation, wage-profit dynamics and financial factors have been analyzed in order to reproduce Kaldor facts and Goodwin-like growth cycles. In line with their long-run findings the present model, enriched by explicitly modeling the demand-side of the economy, is able to reproduce the ‘Kaldor facts’ (i.e. with purely labor-saving technical change). However, during the transitional phase the model presents a labor-saving/capital-using innovation pattern, as the aggregate output-capital ratio decreases until it stabilizes in the long-run, as well as declining labor share for long time periods. We can ascribe these findings to the directed and biased technical change process and in order to stress the effective role

[5]Acemoglu (2015) recently highlights some connection between the localized technical change framework, stemming by the Atkinson and Stiglitz ‘new view’ (Atkinson and Stiglitz 1969), the ITC hypothesis and the directed and biased innovation framework. Dosi et al. (2016) also propose a discussion about the Atkinson and Stiglitz approach by analyzing it through ‘*Schumpeterian*’ lenses, thus from a theoretical perspective much closer to the one embraced in the present contribution.

of the innovation bias, the baseline scenario has been compared with a *counterfactual* scenario wherein a *neutral* technical progress is at work.

2.2 The Model

The model is populated by K firms producing a homogeneous capital good, only using labor input, and C consumption firms producing a homogeneous final good over two inputs (labor and capital). Consumption-good firms also innovate their production process in order to save the (relatively) expensive production input and try to obtain some profitability gain (Dumenil and Levy 2010, Foley and Michl 1999, Foley 2003, Zamparelli 2015, Stiglitz 2015).
Household sector is composed by two classes of agents: workers and capitalists. Workers sell their labor force to the capital and consumption firms and capitalists represent the equity investors (i.e. the firms and banks' equity owners) receiving their income in the form of dividends. All the agents within the household sector consume their income on the final good market and they save the residual amount (in the form of bank deposits or equity investment as capitalists agents).
Commercial banks offer deposit accounts to households and firms and endogenously create private money by providing loans to the consumption firms.
Our artificial economy also has a government and a central bank (see subsections 3.2.6 and 3.2.7). As in Caiani et al. (2017) we have an endogenous entry/exit process. Thus, the simulation model starts with no firms and banks and they are progressively created during the simulation by means of investment out of capitalists' savings.
As in the SIM model, the simplest SFC model implemented by Godley and Lavoie (2009), everything starts with government public expenditure, in the form of lump-sum transfers distributed across workers and capitalists. This transfers are initially saved by households, and then begun to be invested by capitalist agents for the creation of new firms (primarily) and eventually new banks. After that the production starts and then possibly also the demand for loans by consumption firms to commercial banks.
Each period the heterogeneous agents directly interact on each market by means of decentralized matching protocols (Riccetti et al. 2015 and Caiani et al. 2016). The demand-side agents observe a random subset of suppliers, whose size is given by a fixed parameter measuring the degree of imperfect information.

2.2.1 The Simulation Schedule

1. Capital-good firms decide the wage to be offered and the selling price for their production;

2. Consumption firms determine the production planning by deciding the desired quantity of output, the desired quantity of labor input, wages, selling prices, the desired amount of resources to be invested in R&D and, eventually, the demand for loans;

3. Commercial banks and consumption-firms interact on the credit market;

4. Consumption-good firms decide the accumulation plan by computing the desired growth rate of production capacity (and hence the desired quantity of capital goods);

5. Capital and consumption firms interact with workers on the labor market;

6. Capital firms interact with consumption firms in the capital goods market;

7. Workers receive their wages and are employed for production and R&D activities. Capitalist agents receive dividends generated in the previous period;

8. Consumption-good firms undertake the innovation process and compare the new random technique with the one inherited from the previous period. Then they produce the final good;

9. Government decides the tax-rate and the public expenditure planning;

10. Bonds are issued by Government and then purchased by commercial banks on the bonds market. The residual amount of bonds, not purchased by private banks, is absorbed by the Central Bank;

11. Households pay taxes on their income and receive the tax-exempt transfers by the Government. Then, they compute the desired consumption and interact with the consumption-good firms;

12. Firms compute their profits and net worth and the taxes to be paid in the next period. Consumption firms also compute the dividends to be distributed in the next period to the equity investors (capitalists);

13. Entry/exit process. Capitalists invest and eventually create new firms and banks.

2.2.2 Capital-good Firms

We have $k = 1, \ldots, K$ firms (capital sector) producing each period a certain quantity of intermediate capital goods, $y^K_{k,t}$, depending on the demand requested by the consumption-good firms as capital input. Thus we have

$$y^K_{k,t} = a_k N^D_{k,t} \tag{2.1}$$

with a_K indicating the (constant) labor productivity for workers employed in the capital production process and $N^D_{k,t}$ indicating the desired quantity of labor needed in order to produce the capital output.
Thus, they demand a certain quantity of labor input as follows

$$N^D_{k,t} = \frac{y^K_{k,t}}{a_K} \tag{2.2}$$

and decide the quantity of capital output to be produced, $y^K_{k,t}$, depending on the desired quantity requested by the consumption goods firms,

$$y^K_{k,t} = y^{KD}_{c,t}. \tag{2.3}$$

Capital firms adopt an adaptive wage rule depending on the wage offered in the previous period and on the difference between labor demanded and labor actually employed in the previous period (Caiani et al. 2018), as follows:

$$w_{k,t} = \begin{cases} w_{k,t-1}(1 - U[0,\delta]), & \text{if } N^D_{k,t-1} - N_{k,t-1} = 0 \text{ with } Pr(u_t) = 1 - e^{u_t v} \\ w_{k,t-1}(1 + U[0,\delta]), & \text{if } N^D_{k,t-1} - N_{k,t-1} > 0 \end{cases} \tag{2.4}$$

If firms were not satisfied, that is labor demanded is greater than the employed one in $t-1$, they have a positive probability $Pr(u_t)$ of downward revising the offered wage. This probability is inversely related to the level of unemployment in the economy u_t, with a positive (fixed) parameter v indicating the strength of their relation (the lower v the higher the probability of reducing the wages).

Then, the capital firms adopt this simple pricing rule

$$p_{k,t} = (1 + \mu_k)\frac{w_{k,t}}{a_k} \tag{2.5}$$

with a fixed mark-up over the unit labor costs.

2.2.3 Consumption-good Firms

Production, Prices and Wages

We have $c = 1, \ldots, C$ heterogeneous firms producing a homogeneous consumption good over two inputs (labor and capital) assuming a fixed coefficient Leontief production function, as follows

$$y_{c,t} = \min\{u_{c,t}\varphi_{kc,t}y^K_{c,t}; \varphi_{lc,t}N_{c,t}\} \tag{2.6}$$

with $u_{c,t}$ indicating the degree of capacity utilization, $\varphi_{kc,t}$ and $\varphi_{lc,t}$ being, respectively, the capital and labor productivity, whereas $y^K_{c,t}$ and $N_{c,t}$ are the capital and labor input. Consumption-good firms may improve the inputs' productivity ($\varphi_{kc,t}$ and $\varphi_{lc,t}$) by means of the R&D activity, and they adopt a new production technique depending on a *profitability criterion*, that is if the expected profit rate related to new innovation is greater than the actual one (see subsection 3.2.3). Once the firm has chosen the production technique, it can compute the desired output and the desired quantity of labor (for simplicity, hereafter we refer again to t and $t-1$ as the actual and previous period) given, respectively, by

$$y_{c,t} = u_{c,t}\varphi_{Kc,t}y^{KD}_{c,t} = \varphi_{lc,t}N^D_{c,t} \tag{2.7}$$

and

$$N^D_{c,t} = u^D_{c,t}y^K_{c,t}\frac{\varphi_{kc,t}}{\varphi_{lc,t}}. \tag{2.8}$$

Each period, consumption firms adaptively revise prices and their expectations about selling, as follows:

$$\text{if } \overline{y}_{c,t} \geq \overline{y}^e_{c,t-1} : \begin{cases} \overline{y}^e_{c,t} = \overline{y}^e_{c,t-1}(1+U[0,\delta]) \\ p_{c,t} = p_{c,t-1}(1+U[0,\delta]) \end{cases} \tag{2.9}$$

$$\text{if } \overline{y}_{c,t} \leq \overline{y}^e_{c,t-1}\text{and } y^{tot}_{c,t-1} > \overline{y}_{c,t-1} : \begin{cases} \overline{y}^e_{c,t} = \overline{y}^e_{c,t-1}(1-U[0,\delta]) \\ p_{c,t} = p_{c,t-1}(1-U[0,\delta]) \end{cases} \tag{2.10}$$

$$\text{if } \overline{y}_{c,t} \leq \overline{y}^e_{c,t-1}\text{and } y^{tot}_{c,t-1} = \overline{y}_{c,t-1} : \begin{cases} \overline{y}^e_{c,t} = \overline{y}^e_{c,t-1} \\ p_{c,t} = p_{c,t-1} \end{cases} \tag{2.11}$$

where $\overline{y}_{c,t-1}$ indicates the output sold in the previous period and $y^{tot}_{c,t} = y_{c,t-1} + inv_{c,t}$. The desired output can be computed as $y^D_{c,t} = y^e_{c,t}(1+\theta) - inv_{c,t}$[6].
Moreover, the selling price cannot be less than the unit labor costs[7].

Finally, also consumption firms adopt an adaptive wage rule, as follows:

$$w_{c,t} = \begin{cases} w_{c,t-1}(1 - U[0,\delta]), & \text{if } N^D_{c,t-1} - N_{c,t-1} = 0 \text{ with } Pr(u_t) = 1 - e^{u_t v} \\ w_{c,t-1}(1 + U[0,\delta]), & \text{if } N^D_{c,t-1} - N_{c,t-1} > 0 \end{cases} \tag{2.12}$$

Innovation

Each period firms C undertake an evolutionary innovation process and they decide to adopt the new random technology only by comparing its expected profit rate with the actual one (Okishio 1961, Shaikh 1978, Nakatani 1979, Shaikh 1999, Park 2001 Shaikh 2016).
The innovation process starts after the decision about the desired investment in the R&D activity, which is a (fixed) share γ of the expenditure for workers. Thus, since R&D activity is made by workers also employed in production activities, R&D investment depends in turns on production planning and on sales expectations (as in Caiani et al. 2018):

$$IN^D_{c,t} = \gamma w_{c,t} N^D_{c,t}. \tag{2.13}$$

Then, the innovation process takes place in two steps as in the 'K+S' tradition Dosi et al. 2010). In a first step, firms compute a Bernoulli experiment in order to determine whether the R&D activity has been successful, so we have:

$$Pr_{IN_t} = 1 - e^{-\nu INc,t} \tag{2.14}$$

and this probability is affected by the amount of resources invested in innovation. Then, we have a second step were the new production technique is obtained with two random draws for the growth rate of capital and labor productivity, as follows:

$$\varphi^+_{kc,t+1} = \varphi_{kc,t}(1 + \hat{\varphi}_k) \tag{2.15}$$

and

$$\varphi^+_{lc,t+1} = \varphi_{lc,t}(1 + \hat{\varphi}_l) \tag{2.16}$$

[6]The desired quantities (here of labor and output) could be lower then the effective ones, so we could have that $N^D_{c,t} \geq N_{c,t}$ and $y^D_{c,t} \geq y_{c,t}$.
The desired quantity of (fixed) capital stock is computed depending on the accumulation decision (see subsection 3.2.3).

[7]That is $p_{c,t} < (1+\mu_c)(\frac{w_{c,t}}{\varphi_{lc,t}})$ with μ_c indicating a (fixed) mark-up over the unit labor costs.

with $\hat{\varphi}_k \sim U[-\delta, \delta]$ and $\hat{\varphi}_l \sim U[-\delta, \delta]$.
Thus, we have a symmetric support for the random draws of labor and capital productivity improvements. This allows us to let the innovation bias emerge without imposing any analytical trade-off between a labor or capital productivity improvement, i.e. without imposing an 'Invention Possibility Frontier' á-la-Kennedy.
As stated above, the adoption of the new technique depends on a *profitability criterion*, i.e. it is adopted only if

$$r^{+}_{c,t+1} > r_{c,t}. \tag{2.17}$$

The profit rate is given by the ratio between the firm's profit[8] and the stock of capital, as follows:

$$\frac{\Pi^*_{c,t}}{K_{c,t}} \equiv r_{c,t} = \frac{p_{c,t}y_{c,t} - w_{c,t}N_{c,t} - p_{kc,t}y^K_{c,t} - IN_{c,t} - i^l_{c,t}L_{c,t}}{p_{kc,t}y^K_{c,t}} \tag{2.18}$$

with $p_{c,t}y_{c,t}$ indicating the revenues obtained by selling production in the previous period, $w_{c,t}N_{c,t}$ and $p_{kc,t}y^K_{c,t}$ indicating, respectively, the costs of the production factors and $i^l_{c,t}L_{c,t}$ being the repayment for loans obtained before production process (see subsection 3.2.3).
After some substitution we obtain the profit rate inherited from t and the potential profit rate expected from the adoption of the new random technique $(\varphi^+_{kc}, \varphi^+_{lc})$ in $t+1$, as follows

$$r_{c,t} = \frac{u_{c,t}\varphi_{kc,t}[p_{c,t} - \frac{w_{c,t}}{\varphi_{lc,t}}(1+\gamma)]}{p_{kc,t}} - 1 - \frac{i^l_{c,t}L_{c,t}}{p_{kc,t}y^K_{c,t}} \tag{2.19}$$

and

$$r^+_{c,t+1} = \frac{u^D_{c,t+1}\varphi^+_{kc}[p_{c,t} - \frac{w_{c,t}}{\varphi^+_{lc}}(1+\gamma)]}{p_{kc,t}} - 1 - \frac{i^l_{c,t}L_{c,t}}{p_{kc,t}y^K_{c,t}} \tag{2.20}$$

with $\frac{w_{c,t}}{\varphi_{lc,t}} = \omega_{c,t}$, $\frac{w_{c,t}}{\varphi^+_l} = \omega^+_{c,t+1}$ indicating, respectively, the wage share of c without and with the adoption of the new production technique. Thus, firms compare (eq. 2.17) the 'old' and the 'transient' profit rate within a 'real competition' framework (Shaikh 1999, Park 2001 and Shaikh 2016).

Consumption-good firms presenting productivity gaps with respect to the sectoral average (Φ_x) may try to catch-up by imitating the leading competitors, as follows:

$$\varphi_{xc,t+1} = \varphi_{xc,t} + U[0, \Phi_{x,t} - \varphi_{xc,t}] \text{ if } \varphi_{xc,t} < \Phi_{x,t} \tag{2.21}$$

[8] As in Caiani et al. (2016) and Caiani et al. (2018), we refer to $\Pi^*_{c,t}$ as the Operating Cash Flow, that is the firm's profit excluding the variation of the inventories (see subsection 3.2.3).

with $x = \{l, k\}$.

Investment and Capital Accumulation

Consumption firms compute each period their desired rate of growth of productive capacity depending on their profitability and their capacity utilization compared to their 'normal' rates (as in Caiani et al. 2016, Caiani et al. 2018), as follows

$$g^D_{c,t} = \delta_1 \frac{r_{c,t-1} - \overline{r}}{\overline{r}} + \delta_2 \frac{u^D_{c,t} - \overline{u}}{\overline{u}} \tag{2.22}$$

with δ_1 and δ_2 representing, respectively, the investments' sensitivity to the profit rate and to the capacity utilization, and $u^D_{c,t}$ is the desired capacity utilization[9], and $\overline{r}$ and $\overline{u}$ indicating, respectively, the 'normal' profit rate and capacity utilization rate[10]. Thus we have both a *classical* and a *Kaleckian* engine for the investment decision undertaken by consumption firms depending, respectively, on the weight given to the profit rate and on the weight given to the desired degree of capacity utilization.
After the accumulation decision, c computes the desired nominal investment, $i^D_{c,t}$, as the number of capital units needed due to the obsolescence of capital (given a fixed depreciation rate δ and a given life span for machines) and/or fill the possible gap between the current and the desired capacity. Then, the desired real investment will be $I^D_{c,t} = i^D_{c,t} p_{kc,t}$.

Financing Demand, Profits and Net Worth

Each consumption-good firm may finance its production activity by means of internal funds, that is its net worth $A_{c,t}$, and/or, if necessary, by means of external funds, that is a desired quantity of loans[11], $L^D_{c,t}$, with an interest rate $i^l_{c,t}$ (see subsection 3.2.5).
The demand for loans requested to the banking sector depends on the cost of the desired quantity of productive inputs and on the disposable internal funds, as follows

$$L^D_{c,t} = \begin{cases} w_{c,t} N^D_{c,t} + p_{kc,t} y^{KD}_{c,t} - A_{c,t}, & \text{if } w_{c,t} N^D_{c,t} + p_{kc,t} y^{KD}_{c,t} > A_{c,t} \\ 0, & \text{otherwise.} \end{cases} \tag{2.23}$$

[9]Depending on the desired output $y^D_{c,t}$, that is $u^D_{c,t} = min(1, \frac{y^D_{c,t}}{y^K_{c,t} \varphi_{kc,t}})$.

[10]Assumed to be constant and equal across firms. Caiani et al. (2018) and Caiani et al. (2018a) calibrate the values for these 'normal' rates by computing the steady-state solution of the aggregate model preceding the simulation.

[11]For simplicity, we assume that each loans lasts only one period.

The desired quantity of loans could differ from the effective amount obtained, that is we could have $L^D_{c,t} \geq L_{c,d}$, due to an unsatisfactory amount of loans to be supplied by the banks or due to an individual credit rationing (as production activity has the priority on the R&D expenditure).
Firms' profits are given by the difference between revenues and expenditure:

$$\Pi_{c,t} = p_{c,t}\overline{y}_{c,t} + \Delta INV_{c,t} - w_{c,t}N_{c,t} - p_{kc,t}y^K_{c,t} - IN_{c,t} - i^l_{c,t}L_{c,t}. \tag{2.24}$$

where $\Delta INV_{c,t}$ indicates the variation of inventories, and firms' net worth evolves according to the following law of motion:

$$NW_{c,t} = NW_{c,t-1} + \Pi^*_{c,t-1} - T^\pi_{c,t} - DIV_{c,t}. \tag{2.25}$$

When the operating cash flows are positive ($\Pi^*_{c,t-1} > 0$), firms pay taxes on their profits ($T^\pi_{c,t}$) and distribute dividends ($DIV_{c,t}$) to equity owners (capitalists), as follows

$$T^\pi_{c,t} = \begin{cases} \tau_t \Pi^*_{c,t}, & \text{if } \Pi^*_{c,t} > 0 \\ 0, & \text{otherwise.} \end{cases} \tag{2.26}$$

and

$$DIV_{c,t} = \begin{cases} \rho(\Pi^*_{c,t} - T^\pi_{c,t}), & \text{if } \Pi^*_{c,t} > 0 \\ 0, & \text{otherwise.} \end{cases} \tag{2.27}$$

with τ_t indicating the tax-rate decided by the government (see subsection 3.2.7).

2.2.4 Households

We have $h = 1, \ldots, H$ households (workers and capitalists) consuming their income on the consumption goods market, saving in the form of bank deposits and paying taxes over their income. Only workers sell their labor force to consumption- and capital-good firms, whereas capitalists only own firms and banks receiving dividends as a share of their profits.

Workers

Workers update each period their reservation wage depending on their occupational status, as follows

$$w_{w,t} = \begin{cases} w_{w,t-1}(1 + U[0,\delta]), & \text{if employed in } t-1 \text{ with } Pr(u_t) \\ w_{w,t-1}(1 - U[0,\delta]), & \text{if unemployed in } t-1 \end{cases} \tag{2.28}$$

with $Pr(u_t)$ indicating a positive probability of increasing the wage claims (as for consumption firms).
Workers gross income is given by

$$y_{w,t} = w_{w,t} + i^d_{b,t} D_{w,t} + TF_t \tag{2.29}$$

with $i^d_{b,t} D_{w,t}$ indicating the interest rate gained from bank deposits[12] and TF_t representing the tax-exempt transfer received by government[13].

Capitalists

Capitalists gross income is given by

$$y_{m,t} = DIV_{m,t} + i^d_{b,t} D_{m,t} \tag{2.30}$$

with $DIV_{m,t}$ indicating the dividends received by the firms/banks they own and $i^d_{b,t} D_{m,t}$ being the interests on their deposits.
Capitalists may save their wealth ($NW_{m,t}$) either as deposit accounts $D_{m,t}$ or as investment in firms/banks' equity $A_{m,t}$. The choice between these two assets depends on a certain degree of liquidity preference ($LP_{m,t}$) [14].

Thus, capitalists compute the desired level of wealth depending on their disposable income and the desired consumption, as follows

$$NW^D_{m,t} = NW_{m,t-1} + y^{DISP}_{m,t} - C^D_{m,t} \tag{2.31}$$

then they obtain the desired level of deposits and equity as

$$D^D_{m,t} = NW^D_{m,t} - (A^D_{m,t} - A_{m,t-1}) \tag{2.32}$$

and

[12] For simplicity we assume the same interest rate offered by the banking sector.

[13] These transfers represent the public expenditure in this model, as in Caiani et al. (2017), see subsection 3.2.7.

[14] See Caiani et al. (2017), for a detailed description of how capitalists compute their liquidity preference. In the original model, the household sector is not composed by both workers and capitalists so households as a whole act as consumers, workers and equity owners. On the contrary, in the present model only capitalist agents may invest in equity asset.

$$A_{m,t}^{D} = \max\{A_{m,t-1}, (1 - LP_{m,t})NW_{m,t}^{D}\} \tag{2.33}$$

with $A_{m,t}^{D} - A_{m,t-1}$ indicating the desired investment in equity, which is bounded to be non-negative (Caiani et al. 2017).
As for the other desired variables in the model, we could also have that $C_{h,t}^{D} > C_{h,t}$ (with $h = m, w$), and in the case of capitalist agents this means that $NW_{m,t}^{D} < NW_{m,t}$. In this case deposits act as a buffer stock variable with $A_{m,t}$ remaining at the planned level.

The disposable income for a generic agent within the household sector (worker or capitalist) is given by

$$y_{h,t}^{DISP} = (1 - \tau_t)y_{h,t} \tag{2.34}$$

with $h = w, m$ and τ_t indicating the tax-rate in the current period.
Each period, households also decide the desired quantity of consumption depending on their current disposable income and their wealth (i.e. bank deposits), as follows

$$C_{h,t}^{D} = \alpha_{1h}y_{h,t}^{DISP} + \alpha_{2h}D_{h,t} \tag{2.35}$$

with $0 < \alpha_{1h} < 1$ and $0 < \alpha_{2h} < 1$ and $\alpha_w > \alpha_m$.
Thus, the desired savings are

$$S_{h,t}^{D} = y_{h,t}^{DISP} - C_{h,t}^{D} \tag{2.36}$$

2.2.5 Banks

We leave the banking sector functioning as well as the Government and the Central Bank behavior exactly as in Caiani et al. (2017). Thus, we have $b = 1, \dots, B$ banks collecting deposits from households and firms (i.e. capitalists' deposits), offering an interest rate $i_{b,t}^{d}$ (which is a constant fraction of the discount rate i_t fixed by the central bank), they endogenously create means of payment by providing credit to consumption-good firms and they may purchase government bonds.
The probability of receiving credit by banks depends on the firms' leverage

$$Pr(L_{c,t}) = e^{-\iota \frac{L_{i,t}^{D}}{A_{i,t}}} \tag{2.37}$$

$$i_{c,t}^{l} = \chi \frac{L_{c,t}^{D}}{A_{c,t}} + i_t \tag{2.38}$$

with i_t indicating the discount rate fixed by central bank.
The desired supply of loans depends on banks' net worth

$$L_{b,t}^{SD} = \mu_1 A_{b,t} \tag{2.39}$$

and the maximum amount that a bank may provide to each firm is a maximum share of its supply ($\zeta L_{b,t}^{SD}$).
Commercial banks have a minimum amount of reserves to be held by the Central Bank as a proportion of their deposits

$$R_{b,t}^{min} = \mu_2 D_{b,t} \tag{2.40}$$

receiving a fixed interest rate i_{res}.
Then, banks may also spend the remaining amount of liquidity by purchasing government bonds $B_{b,t}$, yielding an interest rate i_t^b [15].
Thus, banks' profit is given by

$$\Pi_{b,t} = \sum_{c=1}^{C} i_{c,t} L_{c,b,t} + i_t^b B_{b,t} + i_{res} R_{b,t} - BD_{c,b,t} - i_t^d D_{b,t} - i_t L_{b,t}^{cb} \tag{2.41}$$

with $BD_{c,b,t}$ indicating the 'bad debt', that is the non performing loans due to firms' defaults.
Also banks' profits are subject to taxation, and then net profit are eventually distributed to the equity owners as for firms (see equations 2.26 and 2.27).

2.2.6 Central Bank

We have a central bank offering cash advances (CA_t) requested by commercial banks, holding their reserves ($R_{CB,t}$), and eventually purchasing the residual amount of government bonds ($B_{CB,t}$).
Central bank also computes its profits and we assume that they are automatically distributed to government, so we have

$$\Pi_{CB,t} = i_t^b B_{CB,t} + i_t CA_t - i_{res} R_{CB,t}. \tag{2.42}$$

2.2.7 Government

Government receives taxes from household sector (capitalists and workers) and from firms and banks, thus

[15] As in Caiani et al. (2017) banks randomly access the bond market with a probability of purchase them, depending on the riskiness of the economy (i.e. the debt-on-GDP ratio): $Pr(b_t) = e^{-\iota \frac{B_t}{Y_t}}$.

$$T_t = \sum_{h=1}^{H} \tau T^y_{h,t} + \sum_{c,\pi^*>0}^{C} \tau T^\pi_{c,t-1} + \sum_{b,\pi>0}^{B} T^\pi_{b,t-1}. \tag{2.43}$$

Government public expenditure G_t is represented by tax-exempt transfers to households (TF_t).
In each period, government may has a budget surplus SUR_t or deficit DEF_t, so we have

$$DEF_t = G_t + i^b_{t-1} B_{t-1} - T_t \tag{2.44}$$

with public debt defined as

$$B_t = B_{t-1} + DEF_t - SUR_{t-1}. \tag{2.45}$$

Finally, the interest rate on public bonds depends on the debt-on-GDP ratio and on the central bank's discount rate, as follows:

$$i^b_t = \chi_b \frac{B_t}{Y_t} + i_t \tag{2.46}$$

2.3 Simulation Results

The model has been ran for 1000 periods (each period corresponds to a quarter, thus we have a time-span of 250 years) and for 50 Monte Carlo simulations following a baseline calibration (see Table 3.5). Following Dosi et al. (2010) and Caiani et al. (2016) I check for the validity of the model by means of a minimum empirical validation. The model is indeed able to reproduce a collection of macroeconomic stylized facts as his ancestors (Caiani et al. 2016, Caiani et al. 2017 and Caiani et al. 2018).

Figure 2.1 shows the cross-correlation functions related to cyclical component of some key macroeconomic variable. The position of the peak in each figure, that is to the left, centered or to the right, indicates whether the variable is, respectively, lagged, coincident or leading with respect to the other one. Cross-correlation functions of real consumption, public expenditure and wages with real GDP show that these variable are coincident and strongly pro-cyclical, whereas real investment, unemployment and public expenditure-GDP ratio are coincident and counter-cyclical. The cross-correlation of private saving with firms' wage share provides evidences for lower workers' propensity to consume. Moreover, cross-correlation between labor productivity and, respectively, real output and wages show that both a *Kaldorian/Smithian* and a *Ricardian*[16] mechanism boosts labor

[16]For a detailed discussion about the so-called 'Smith' and 'Ricardo effect' in shaping technical

productivity dynamics within the present model.

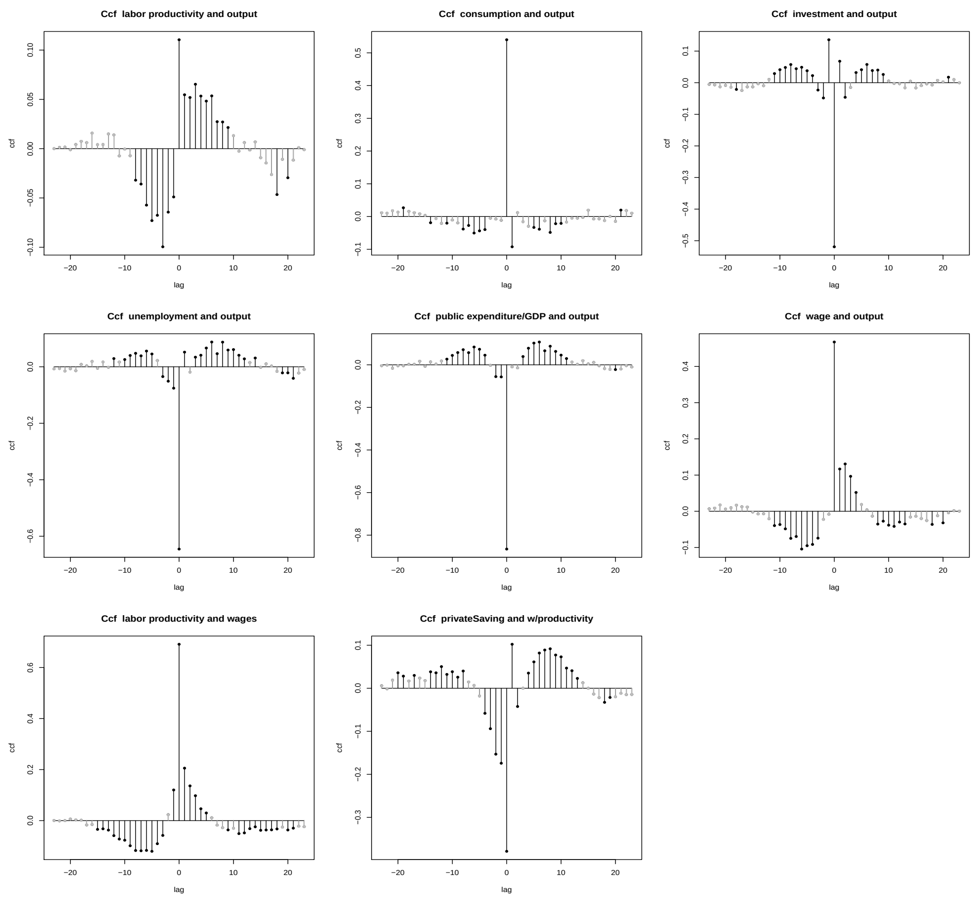

Figure 2.1. Average cross-correlations (across 50 Monte Carlo) of labor productivity, consumption, investment, unemployment, public expenditure, public expenditure-GDP ratio and wage with real GDP, average cross-correlations of labor productivity with wage, and of wage share with private saving.

Figures 3.3 and 3.4 represent the model dynamics showing the trend component of the artificial time series related to some key macroeconomic variables across 50 Monte Carlo runs. As we can see the model shows self-sustained endogenous growth process, with exponential growth of real-GDP, real consumption and aggregate labor productivity (Y/L), which follows the pattern of real-GDP (so-called 'Kaldor effect' or 'Smith effect'). Indeed, the analysis of the interplay among technical change and capital accumulation processes together with the pattern of wages and labor productivity is pivotal to understand the dynamics of our model at both micro and macroeconomic level. The model endogenously reproduces persistent fluctuations of aggregate wage share (i.e. total labor costs over total output or aggregate real wage-labor productivity ratio) due to different paces of the growth of wages and

progress dynamics in capitalist economies see Sylos Labini (1983).

labor productivity (fig. 3.4). Thus, by definition we have that when real wages grow slower (faster) than labor productivity the wage share decreases (increases). However these fluctuations are driven by the predominance of two different economic forces during the technical change process.

On the one hand, firms are encouraged to improve their inputs' productivity by means of R&D investment, and thus by hiring workers for innovation and production activities, in order to increase their selling and conquer greater market shares. Therefore higher levels of R&D investments result in higher probability of innovating (eq. 2.14) so that more productive firms can also reduce their selling prices and improve their competitiveness as long as they achieve higher levels of productivity and greater market performances compared to their competitors. From a macroeconomic point of view these phases of 'virtuous circles' triggered by innovation and production processes driven in turn by greater sales expectations (that is by real consumption and aggregate demand) also improve aggregate employment dynamics creating positive feedback mechanisms for the overall economy. Of course some firms may suffer from productivity gaps and may have difficulties to sell production output and thus to increase their profit margins, however they may also try to catch up with leading firms by imitating their production technique (eq. 2.21). All in all, the *Schumpeterian* evolutionary dynamics may lead more productive firms to survive whereas less productive ones may go bankrupt due to less willingness to grant credit by commercial banks (see in fig. 2.5 the dynamics of credit and firms survival) and due to difficulties to sell their product with an excessive stockpiling process.

Nevertheless, on the other hand firms also increasingly accumulate capital stock due to technological progress progressively improving labor productivity (to a greater extent than the improvement of capital productivity as shown in fig. 2.4), so that a greater amount of output can be produced by using less workers, as shown in fig. 3.4 with exponential growth of aggregate output-labor ratio as well as increasing 'capital-deepening' [17] (fig. 2.7).

The predominance of these two opposite forces, that is virtuous innovative cycles and excessive labor-saving innovation pattern, also affects wage dynamics. Indeed more productive firms achieving greater market shares with higher levels of profitability and larger size in terms of internal financing and net worth are able to hire more workers for R&D and production activities, however on the other hand an excessive labor-saving pattern of technical change may lead to higher levels of unemployment thus weakening the bargaining power of workers as their wage claims are negatively affected

[17] In this respect, we also compare our findings with the results provided by the ABM implemented by Delli Gatti et al. (2006) where they analyze the interplay between R&D investment, labor-saving technical change, capital accumulation, wage-profit dynamics and financial factors in order to shade a light on 'Kaldor facts' and Goodwin-like growth cycles.

by higher levels of unemployment (eq. 2.28). This negative feedback mechanism may be further exacerbated when capital-good firms fail to absorb the workers fired by consumption-firms. Indeed, the increasing accumulation process of capital stock engaged by consumption-firms generate growing capital demand that cannot be continuously fulfilled given our assumption of fixed labor productivity for capital firms (i.e. we have capital shortage), thus capital-good firms try to hire an increasing amount of workers trying to satisfy the requested demand of capital goods[18].

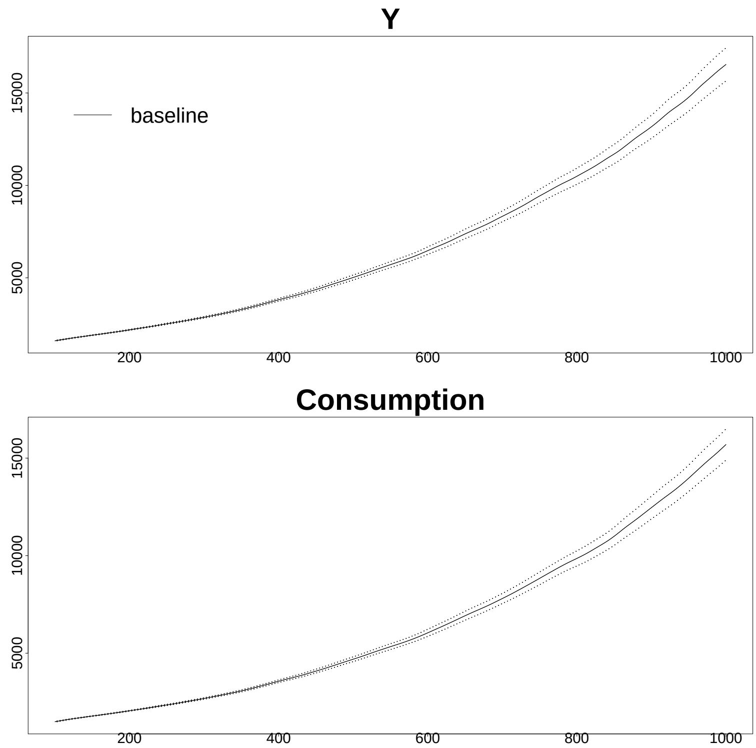

Figure 2.2. Average trend across 50 Monte Carlo runs of real GDP and (real) consumption from time period 100 to 1000.

Moreover, as stated above firms do not innovate to the same extent in order to gain labor- or capital-productivity improvements, i.e. we have a *directed* and *biased* technical progress. Indeed, the pattern of the difference between average labor and capital productivity ($\varphi_{lt} - \varphi_{kt}$) shows (fig. 2.4) how the '*innovation bias*' endogenously emerges from the choice of techniques made by consumption firms, depending in turn on a classical profitability criterion (equation 2.17), by means of different random draws from a symmetric support (equations 2.14 and 2.15) without imposing any 'Innovation Possibility Frontier' á-la-Kennedy.

[18]See Vivarelli (2015) Calvino and Virgillito (2018) for a detailed survey about different 'compensation' mechanisms proposed in literature in order to explain the interplay between innovation and employment.

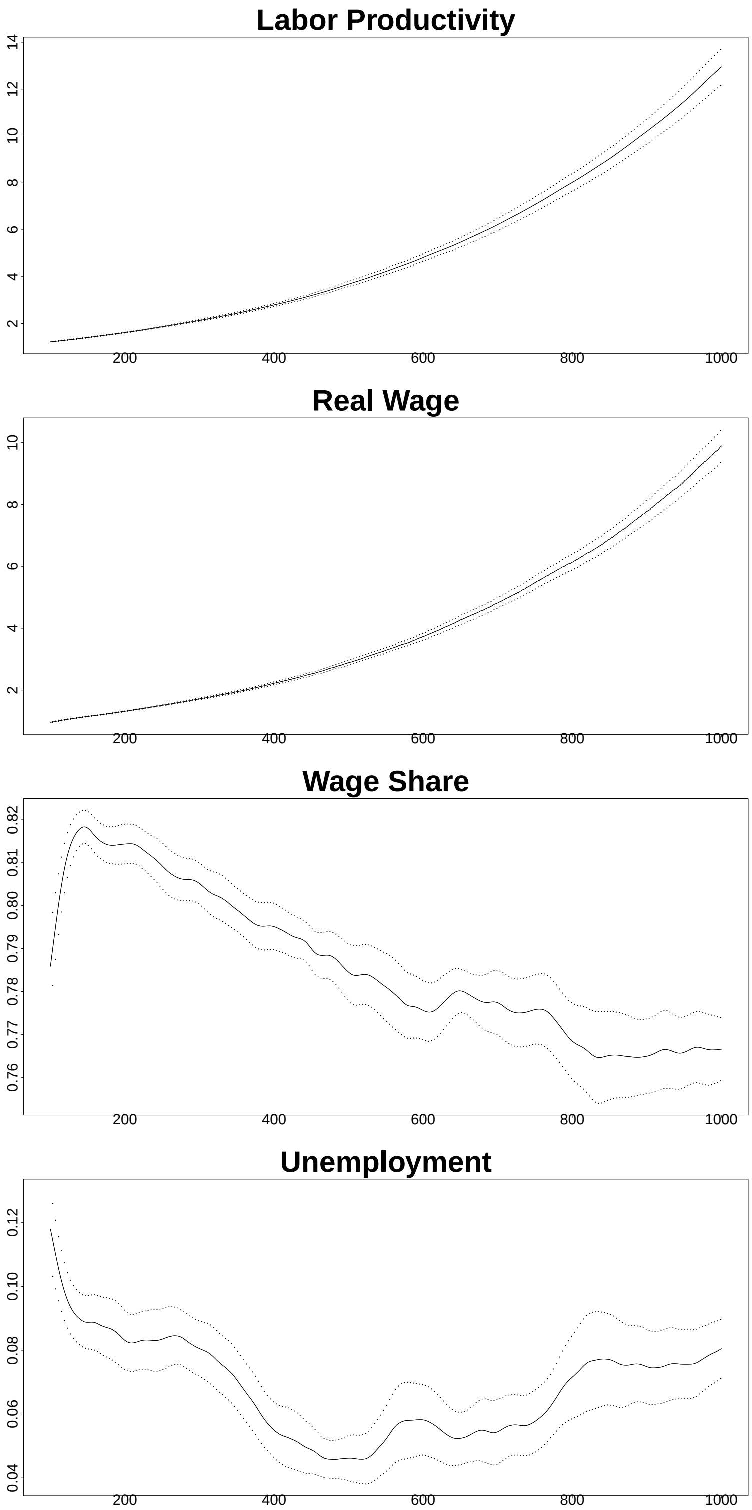

Figure 2.3. Average trend across 50 Monte Carlo runs of average labor productivity, average real wages, wage share for consumption-good firms and rate of unemployment from time period 100 to 1000.

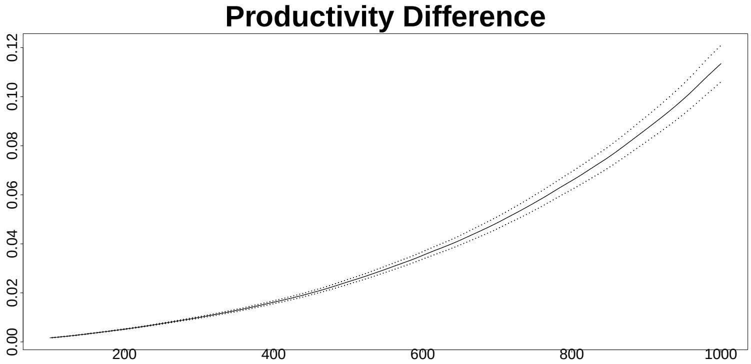

Figure 2.4. Percentage difference between average labor productivity and capital productivity, i.e. the difference between the inputs' productivity chosen from the random draws depending on the profitability criterion. Continuous and dashed lines indicate, respectively, average trend and trend of standard deviation across 50 Monte Carlo simulations (from time period 100 to 1000).

As pointed out by Stiglitz (2015) and Stiglitz and Greenwald (2015), a '*learning-to-learn*' process is at work, that is the factor-biased technical change process may feed upon itself as firms become more skilled at learning how to save the labor input.

In order to corroborate the hypothesis about the emergence of the innovation bias from the stochastic evolutionary technical change process, I investigate what happens in a 'counterfactual' scenario with 'neutral'technical change (i.e. *Hicks-neutral*), that is with the same random draw for the growth rate of labor and capital productivity ($\hat{\varphi}_l = \hat{\varphi}_k$). Figure 2.5 shows average trend across 50 Monte Carlo runs for the artificial time series related to the baseline and the 'counterfactual' scenario. The artificial time series have been detrended by means of the Hodrick-Prescott filter and continuous and dashed lines indicate, respectively, average trends and trends standard deviations across the Monte Carlo runs. As we can see, in the 'innovation bias scenario' the direction of the choice of techniques towards an 'excessive' labor-saving technical change overall negatively affects the macroeconomic environment in our economy by weakening real-GDP and real consumption growth as a persistent slowdown of wages with respect to labor productivity (i.e. exacerbating faster growth of labor productivity with respect to wage growth) also reflects in contractions of the purchase power for workers, that is the class of households' agents with higher propensity to consume, leading to contractions of aggregate demand. Within the neutral innovation scenario firms almost indiscriminately choose improvement of both production input (labor and capital) without directing the innovation effort towards the input exerting higher pressure upon firms' cost structure (i.e. labor input). Hence, the neutral innovation hypothesis should not allows us to analyze the endogenous emergence of fluctuations in the labor share together with relatively

higher levels of unemployment. Thus, the ‘innovation bias’ scenario allows us to provide a possible explanation for the endogenous emergence of persistent negative pattern of distributive shares as a consequence of ‘non-neutral’ technical progress.
As stated above, in the long-run the model is also able to reproduce the so-called ‘Kaldor Stylized Facts’, thus, we have (fig. 2.7) increasing growth of output-labor ratio (i.e. the aggregated labor productivity), real wages (fig. 3.3) and growing capital-labor ratio (i.e. the ‘capital deepening’) (fig. 2.7). According to the Kaldor facts, we also have roughly constant: distributive shares, average profit rate and output-capital ratio (i.e. the aggregated capital productivity) as shown in fig. 2.7. However, these are solely long-run phenomena. During the overall simulation, these variables show a richer dynamics. The average firms’ profit rate shows decreasing pattern for long time periods until it stabilizes around its ‘normal’ value. Indeed the rate of profit it is crucial either for firms’ choice of technique and for their investment planning. Indeed, according to eq. 2.17 consumption firms discriminate among different productivity improvements depending on the expected profitability associated to new random techniques by trying to gain higher profitability due to an input-saving innovation process. However, many economic factors may lead to a ‘fallacy of coordination’ underling the aggregate pattern of the profit rate due to the relevant feedback mechanisms among technical change, wages, capital accumulation and the profit rate. For example, firms are profit-oriented and increasingly try to improve labor productivity by means of R&D activities in order to reduce the quantity of workers needed to expand their production and to improve the profit margins. However, as discussed above, an excessive labor-saving trajectory of technical change may be detrimental for the dynamics of wage as both firms and workers have a certain probability of reducing the offered and requested wage depending on the unemployment level in our economy (eq.2.12 and eq. 2.28). On the one hand the weaker dynamics of wages increases firms’ profit margins though a reduction in the labor cost, but on the other hand it reduces the purchase power of the class with higher propensity to consume (that is, workers) thus weakening the aggregate demand. A contraction of the aggregate consumption may lead a greater number of consumption-good firms to suffer from weaker selling performances and lower revenues thus reducing in turns internal financing capacity and inducing higher loans demand to commercial banks (whose willingness to accord loan requests depends in turns on firms leverage and thus on firms’ net worth). Moreover the ongoing capital accumulation process boosts the growth of firms capital stocks so to further deteriorate profit margins and thus the rate of profit. Then, we also observe decreasing output-capital ratio for the overall simulation until it stabilizes in the long-run, providing support for purely labor-augmenting technical change (i.e.

Harrod-neutral) in the long-run but for labor-saving/capital-using technical change in the short- and medium-run. This trend is driven either by the accumulation of capital stock and by the faster growth of capital prices with respect to the inflation of consumption-good prices. Indeed, consumption firms may reduce their selling prices due to increasing productivity gains whereas in our model capital firms cannot undertake innovation activity in order to improve their production process and they are more constrained in reducing the price of capital goods for competitiveness purposes. Finally, as discussed above we observe fluctuations of the labor share, and particularly a falling trend for long time periods due to the innovation bias towards an excessive labor-saving technical change (fig. 2.5 and 2.6). Thus we can conclude that the magnitude of firms' capital accumulation process together with the direction of biased technical change if not offset by means of strong 'wage-push' forces (see section 2.4) may lead to worse macroeconomic performances compared to the outcome obtained within the neutral innovation scenario.
We ought to highlight that in this model we focus our analysis on the effect of a 'non-neutral' technical change process upon long-run growth and *functional* income distribution, and that we are analyzing only *process* innovation. Thus, a more sophisticated model wherein we also consider *product* innovation and a segmented labor market, depending on different skills and/or different income-classes, would allows us to deeper analyze the interplay among technical change, growth, distributive shares and employment as we can consider, for example, the effects of different wage regimes upon different classes of workers. This is the case in Caiani et al. (2018) and Caiani et al. (2018a) wherein the effects of an excessive labor-saving technical change are considered not detrimental for growth and employment (or, *rectius*, wherein these effects are offset by a greater propensity to consume of lower-income workers) and where higher levels of unemployment are explained as a consequence of growing income and wealth inequalities. However, a quite general dynamics has been presented for our artificial economy triggered by an excessive labor-saving technical change process which reproduces realistic patterns highlighted in theoretical and empirical contributions.

2.4 Sensitivity Analysis

A sensitivity analysis has been performed on the fiscal target for government's adaptive decisions about public expenditure and taxation (fig. 2.8), and on the initial wage offered by new created consumption firms during the simulation (fig. 2.11).
As in Caiani et al. (2017), I implement a fiscal policy experiment, in order to assess whether restrictive (i.e. 'austerity' policies) or expansionary fiscal policies, have

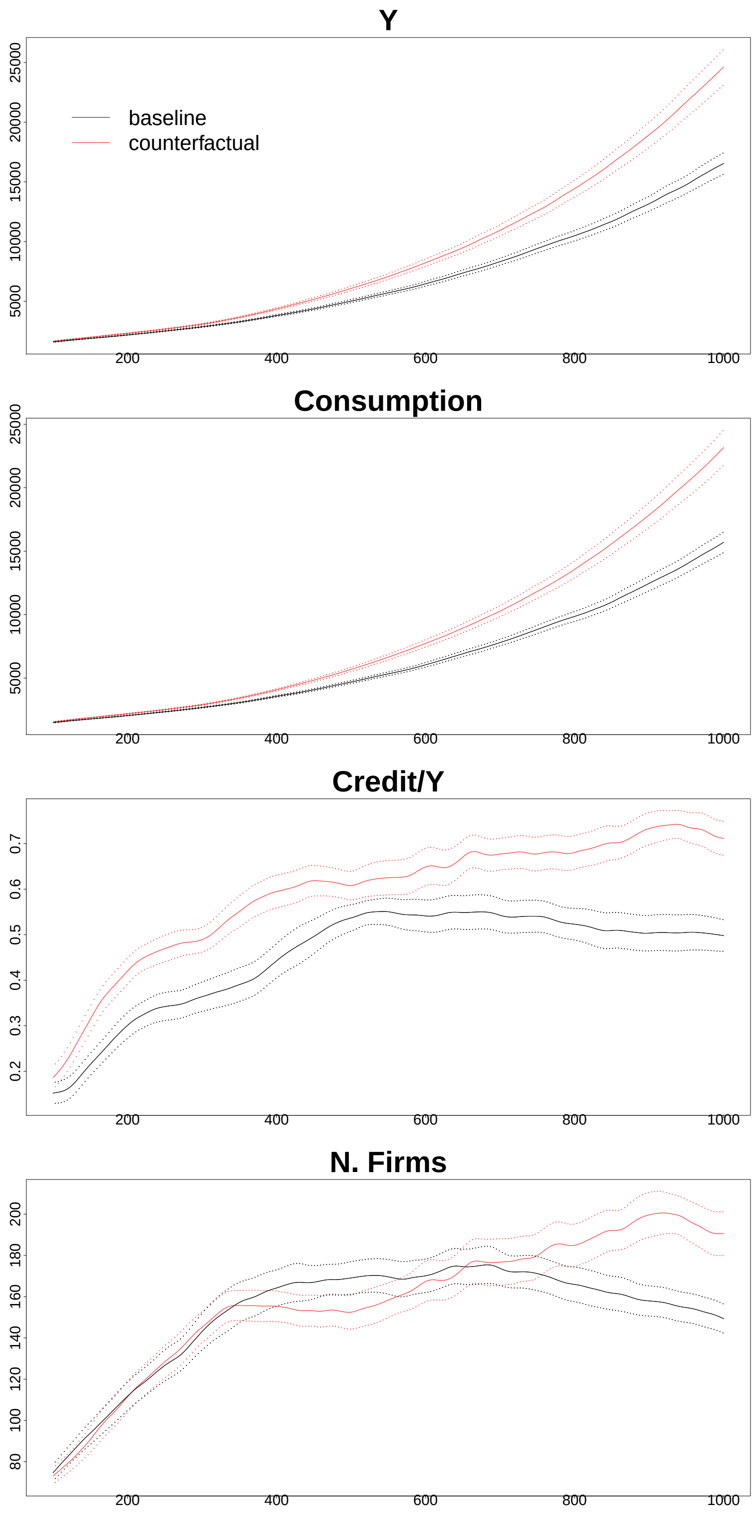

Figure 2.5. Average trend (continuous lines) and trend of standard deviations (dashed lines) across 50 Monte Carlo simulations from time period 100 to 1000. I analyze two different scenarios: the 'baseline' scenario (black line) and a 'counterfactual' scenario wherein I implement a 'neutral' technical change process (red line).

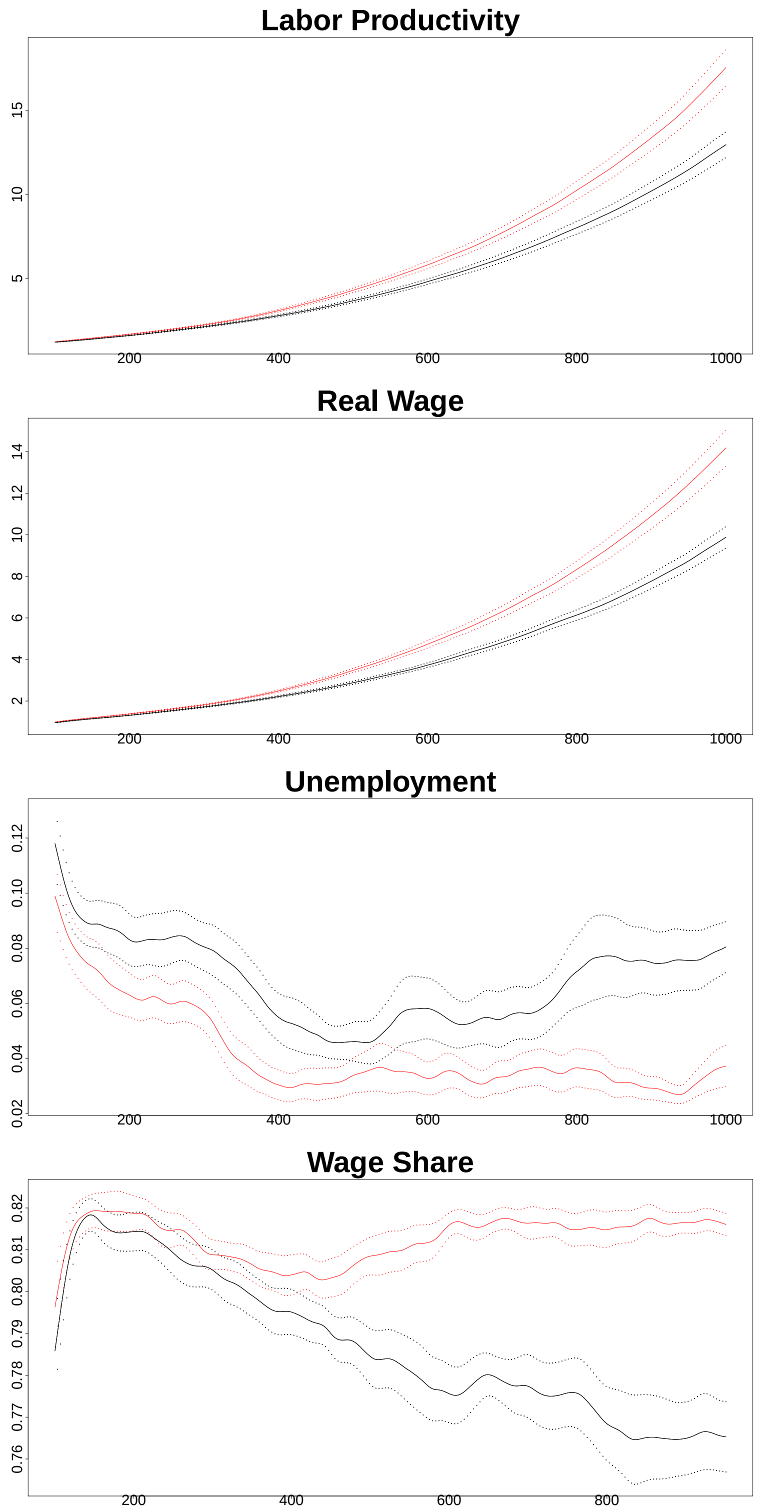

Figure 2.6. Average trend (continuous lines) and trend of standard deviations (dashed lines) across 50 Monte Carlo simulations from time period 100 to 1000. I analyze two different scenarios: the ’baseline’ scenario (black line) and a ‘counterfactual’ scenario wherein I implement a ‘neutral’ technical change process (red line).

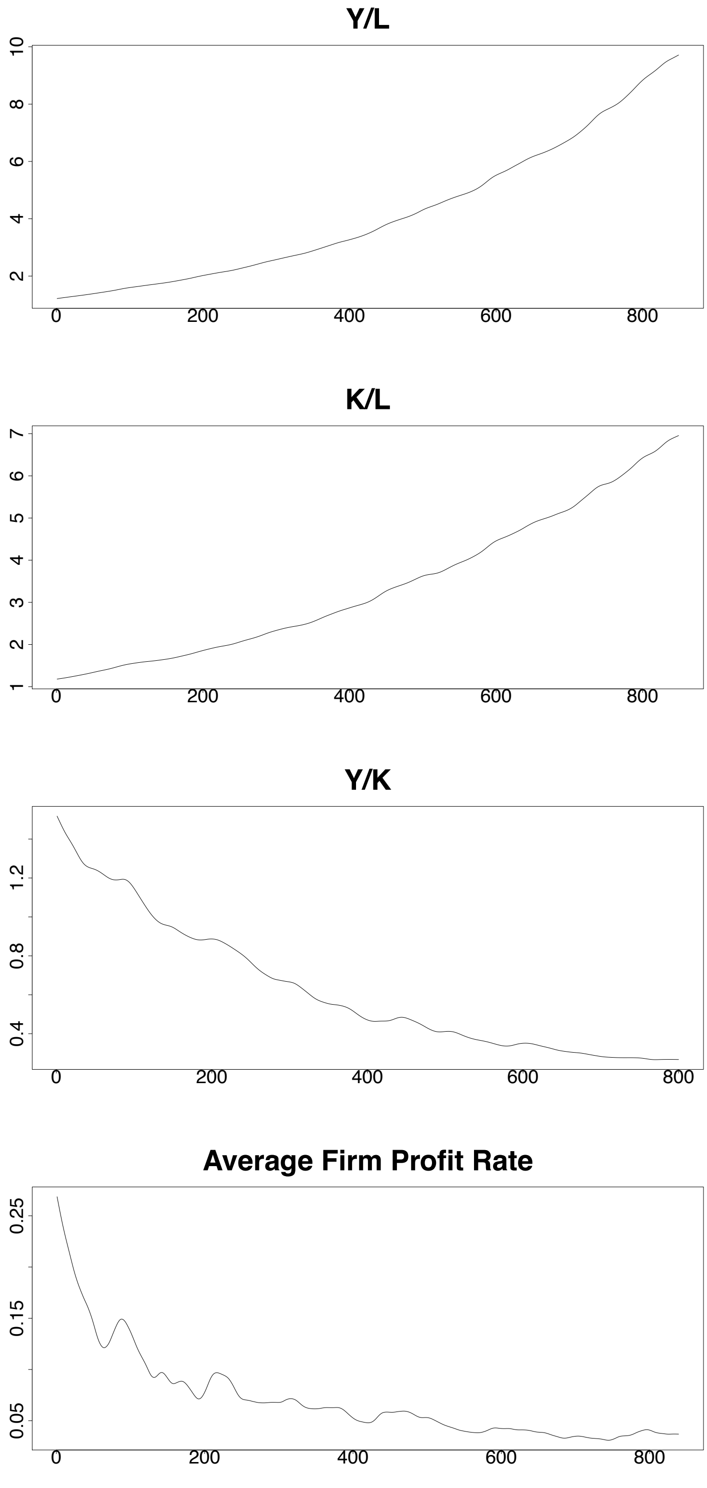

Figure 2.7. Trend component (obtained by means of Hodrick-Prescott filter) of aggregate output-labor ratio (Y/L), capital-labor ratio (K/L), average profit rate and output-capital ratio (Y/K) for a single simulation run from time period 500 to 1000.

some effect on long-run growth, productivity, distributive shares and unemployment, besides affecting the overall macroeconomic performance of our economy[19]. The fiscal policy experiment has been performed for different values of the maximum deficit/GDP ratio (d^{max}) representing the target for the adaptive decisions about public expenditure planning and tax rate revision by the government. This target is initially set to $d^{max} = 0.03$ (i.e. 'Maastricht constraint') in the 'baseline ' and then we change its value at period $t = 500$. The government follows an adaptive behavior rule in order to adjust the public expenditure and the tax rate[20], as follows:

$$\text{if } d_t \geq d^{max} \text{and } G_t^D \leq G_{t-1} : \begin{cases} G_t = G_{t-1}(1 - U[0, \delta]) \\ \tau_{t+1} = \tau_t(1 + U[0, \delta]) \end{cases} \tag{2.47}$$

$$\text{if } d_t \geq d^{max} \text{and } G_t^D > G_{t-1} : \begin{cases} G_t = G_{t-1} \\ \tau_{t+1} = \tau_t(1 + U[0, \delta]) \end{cases} \tag{2.48}$$

$$\text{if } d_t < d^{max} \text{and } G_t^D \leq G_{t-1} : \begin{cases} G_t = G_{t-1}(1 - U[0, \delta]) \\ \tau_{t+1} = \tau_t(1 - U[0, \delta]) \end{cases} \tag{2.49}$$

$$\text{if } d_t < d^{max} \text{and } G_t^D > G_{t-1} : \begin{cases} G_t = G_{t-1}(1 + U[0, \delta]) \\ \tau_{t+1} = \tau_t \end{cases} \tag{2.50}$$

thus we define the fiscal policy as a revision of public expenditure and tax rate depending on the maximum fiscal target (d^{max}).

Figures 2.8, 2.9 and 2.10 show the average trend across 25 Monte Carlo simulations of real-GDP, labor productivity, capital and consumption-good prices, wages, real consumption and investment, number of consumption firms, credit-GDP ratio, R&D expenditure-GDP ratio, labor share and unemployment rate for different values of the maximum deficit/GDP ratio. The baseline scenario (black line) corresponds to $d^{max} = 0.03$ (i.e. the value imposed by the Maastricht Treaty), the restrictive scenarios are investigated with $d^{max} = 0.025$ (orange line), with $d^{max} = 0.02$ (red line) and $d^{max} = 0.015$ (red line), whereas the expansionary scenarios correspond to $d^{max} = 0.035$ (light blue line) and $d^{max} = 0.04$ (blue line). As we can see, a restrictive (expansionary) fiscal policy exerts negative (positive) long-run effect upon growth and distribution in our artificial economy. In line with the results provided by Caiani et al. (2017), we find that an expansionary (restrictive) fiscal policy positively (negatively) affects the macroeconomic performance of our

[19] Dawid et al. (2017) also propose a multi regional AB-SFC about the effects of fiscal transfers in a monetary union.

[20]See Caiani et al. (2017) for a detailed discussion of this adaptive fiscal rule and the effects of different fiscal target scenarios in a multicountry monetary union model.

economy showing stronger (weaker) growth patterns of real-GDP, labor productivity, consumption and investment, as well as an improvement of consumption- and capital-good prices and wages dynamics. A virtuous (viscous) dynamics of growth and productivity also reflects on credit dynamics as firms with greater profit margins can successfully apply for bank loans in order to expand their production and innovation activities (see the pattern of innovation expenditure over GDP ratio), and on the 'Schumpeterian' competitive race among firms showing a greater number of firms surviving under the two expansionary scenarios (the opposite occurs under the restrictive scenarios). Furthermore, the positive effect exerted by an expansionary fiscal target also reflects in higher labor share and lower unemployment rate. Thus we can say that the detrimental effects exerted of the innovation bias upon growth and distribution in our economy can be offset by an expansionary Keynesian fiscal policy. Furthermore, as stated above, the sensitivity analysis has been also performed on the initial wage (w_0) offered by firms and then revised during the simulation following the adaptive rule (eq. 2.12) described in section 3.2.3. As discussed in section 3.3, within our artificial economy the magnitude of firms' capital accumulation process together with the direction of biased technical change may lead to worse macroeconomic performances compared to the outcome obtained within the neutral innovation scenario, thus we analyze the effect of an increase in the initial wage offered by new firms during the endogenous entry/exit process[21]. As we can see in figure 2.11, the so-called 'paradox of costs' (Kalecki 1971) holds in our economy. Thus, an increase in the initial wage offered by firms gives a positive stimulus to the dynamics of growth and labor productivity through the positive effect of the aggregate demand, that is due to an increase in the purchase power of workers reflecting in turns in greater aggregate consumption.

[21] See Caiani et al. (2017) for a detailed description.

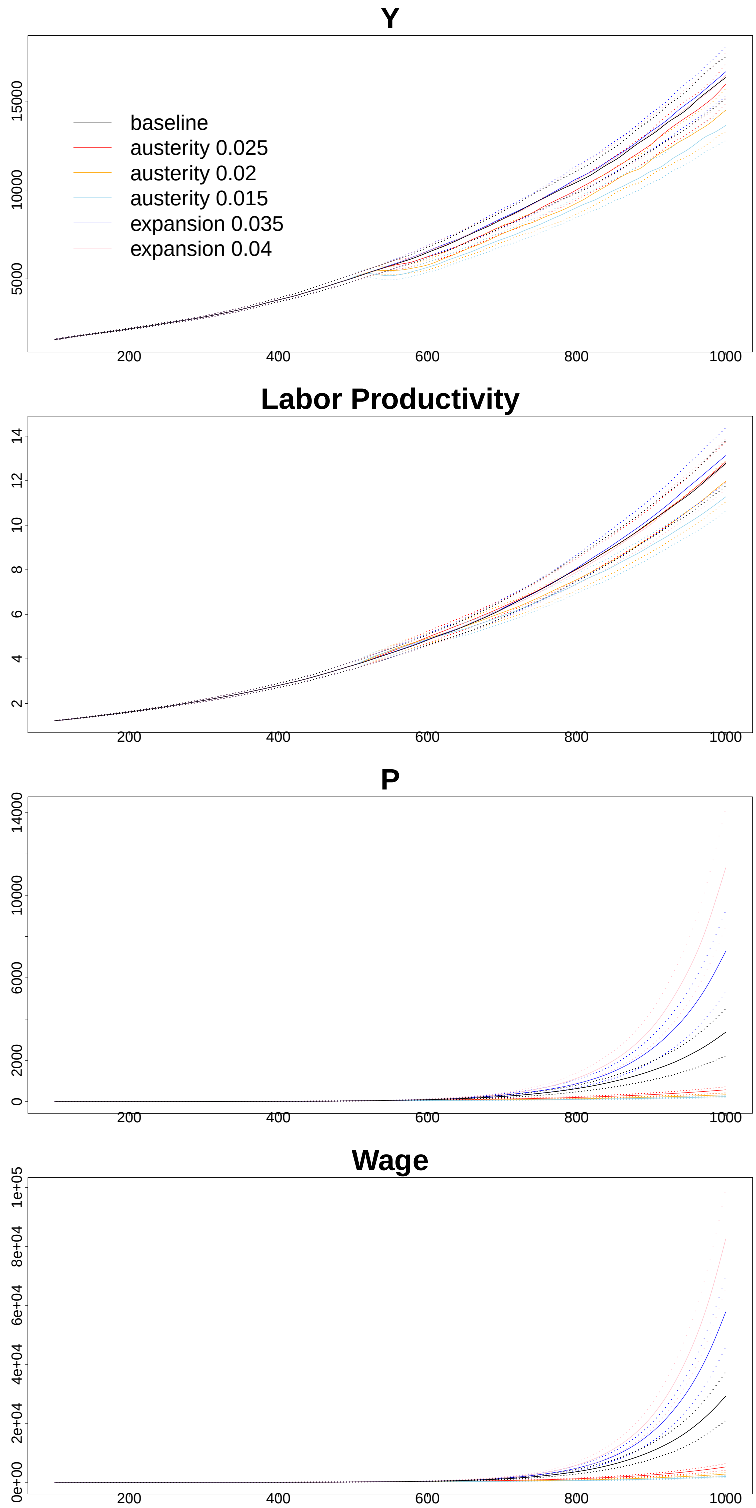

Figure 2.8. Average trends (continuous lines) and trends standard deviations (dashed lines) across 25 Monte Carlo simulations. We have the 'baseline' scenario (black line) with $d^{max} = 0.03$ and then three restrictive ('austerity') scenario with $d^{max} = \{0.025; 0.02; 0.015\}$ (respectively, red, yellow and light blue line) and two expansionary scenarios with $d^{max} = \{0.035; 0.04\}$ (respectively, blue and pink line).

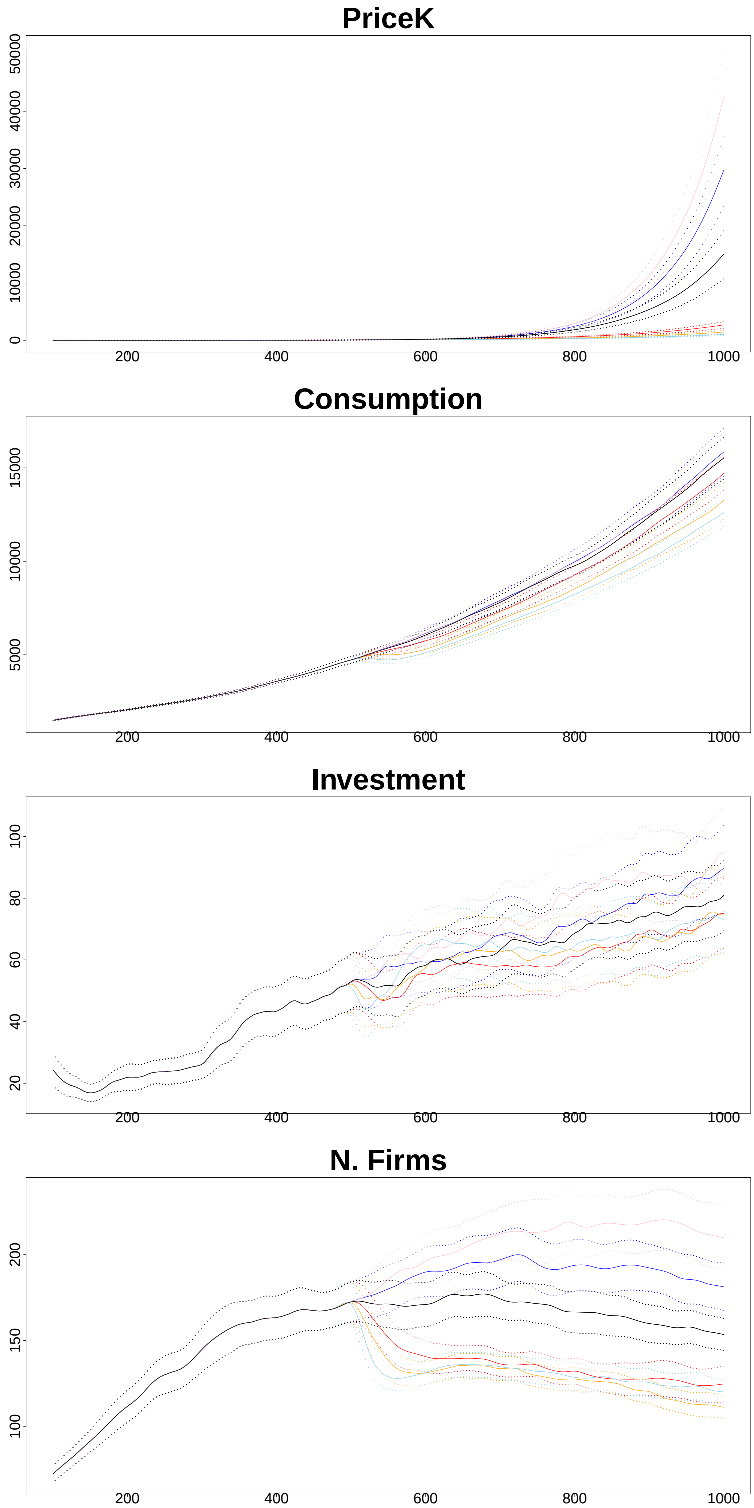

Figure 2.9. Average trends (continuous lines) and trends standard deviations (dashed lines) across 25 Monte Carlo simulations. We have the 'baseline' scenario (black line) with $d^{max} = 0.03$ and then three restrictive ('austerity') scenario with $d^{max} = \{0.025; 0.02; 0.015\}$ (respectively, red, yellow and light blue line) and two expansionary scenarios with $d^{max} = \{0.035; 0.04\}$ (respectively, blue and pink line).

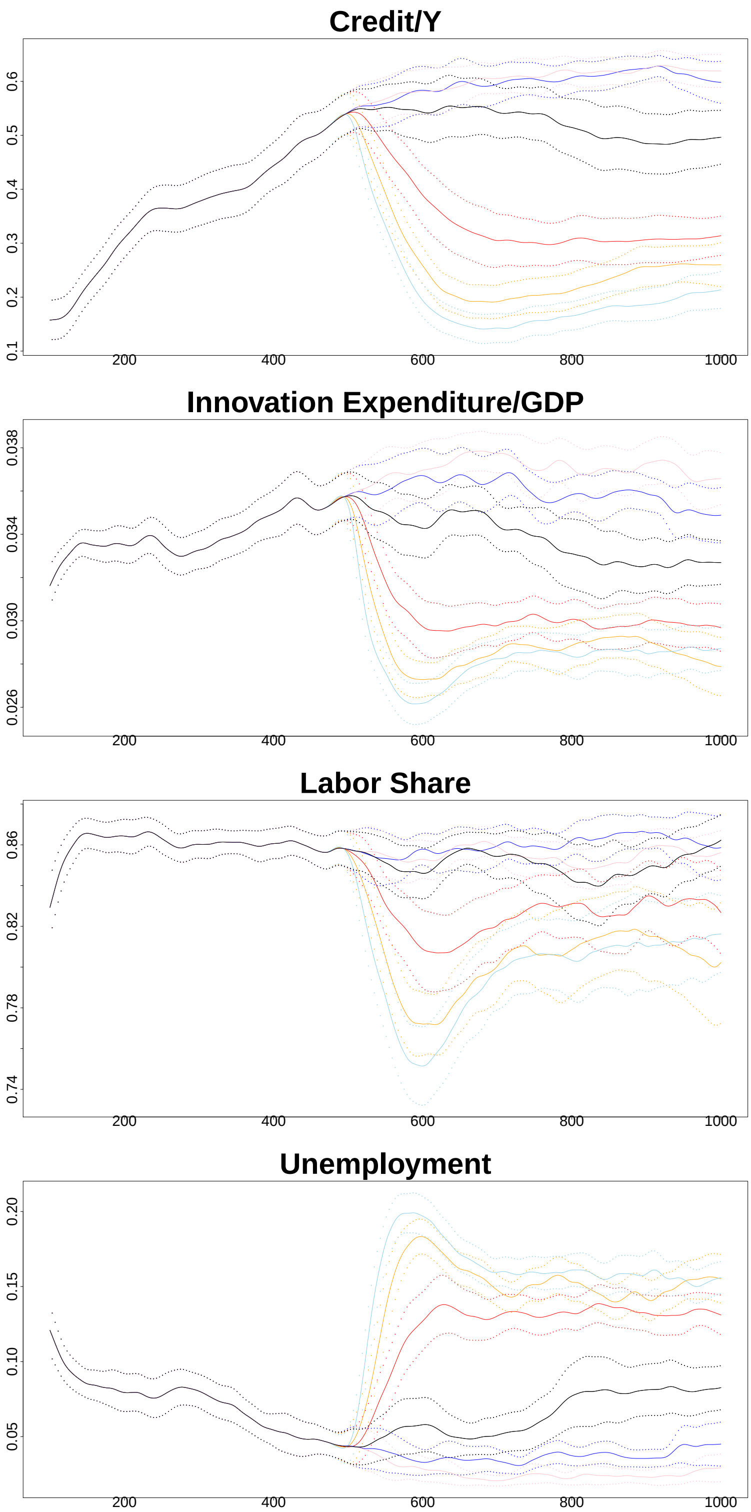

Figure 2.10. Average trends (continuous lines) and trends standard deviations (dashed lines) across 25 Monte Carlo simulations. We have the 'baseline' scenario (black line) with $d^{max} = 0.03$ and then three restrictive ('austerity') scenario with $d^{max} = \{0.025; 0.02; 0.015\}$ (respectively, red, yellow and light blue line) and two expansionary scenarios with $d^{max} = \{0.035; 0.04\}$ (respectively, blue and pink line).

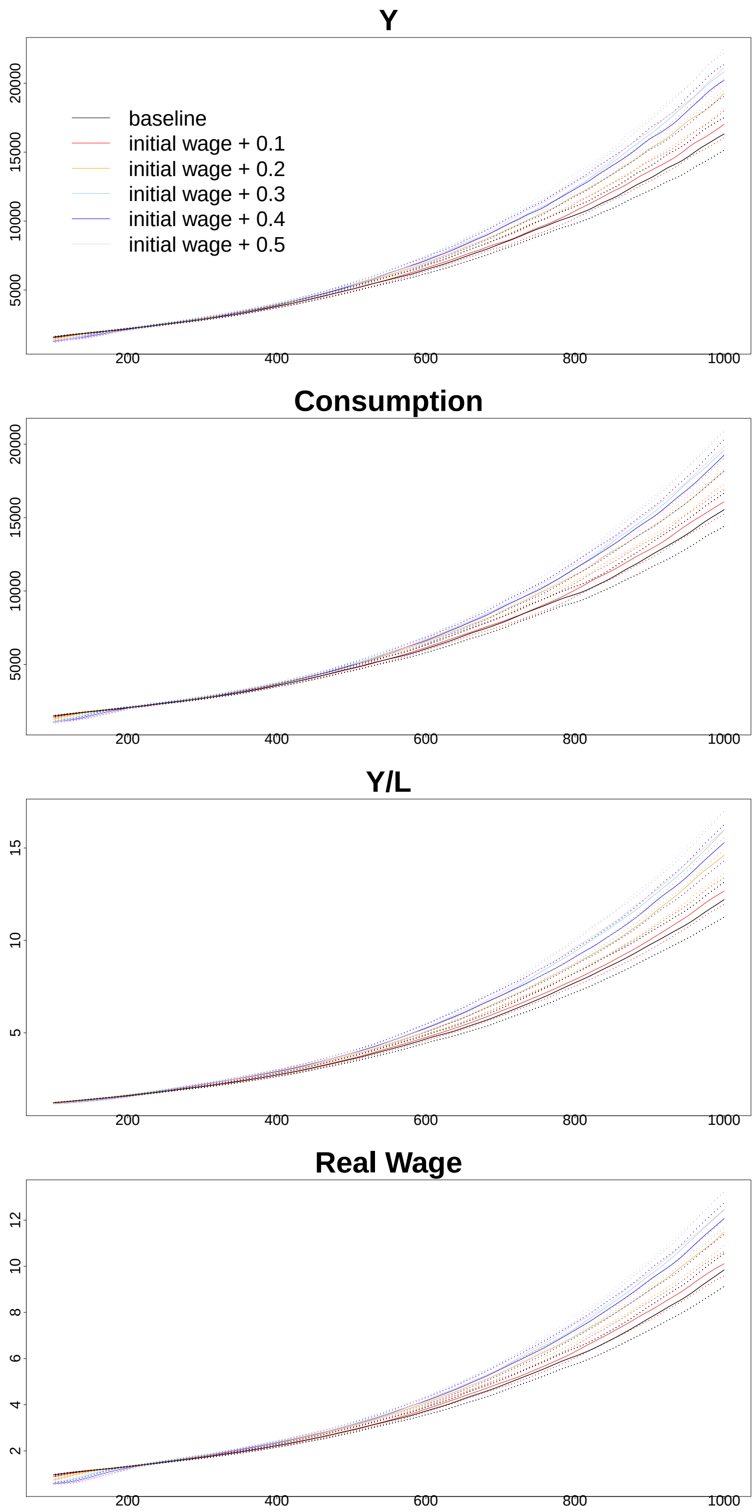

Figure 2.11. Average trends (continuous lines) and trends standard deviations (dashed lines) across 25 Monte Carlo simulations.We compare the baseline scenario (black line) with different scenarios representing the pattern of real output, consumption, aggregate labor productivity and real wages with progressively higher values of initial wage (w_0).

2.5 Conclusions

The main strength of the present contribution concerns the integration of a *classical-fashioned* induced and directed innovation process within a *Keynesian* demand-led and *evolutionary* endogenous growth model. The AB-SFC macro modeling approach allows us to analyze the '*innovation bias*' as an *emergent property* of the technical change process engaged by heterogeneous consumption-good firms choosing both the *intensity* and the *direction* of the innovation towards a labor- or capital-saving choice of technique.
In the long-run the model reproduces the so-called 'Kaldor Stylized Facts' (i.e. we have a purely labor-saving technical change), however during the transitional phases the model shows a labor-saving/capital using innovation pattern as the aggregate output-capital ratio decreases until it stabilizes in the long-run. Moreover, the model reproduces endogenous fluctuations of labor share with a declining pattern for long time periods and we can ascribe this evidence to the directed and biased technical change process. Indeed, the comparison between the baseline scenario with the 'counterfactual' scenario wherein a 'neutral' technical progress is at work, confirms our hypothesis showing weaker growth of both real-GDP and real consumption within the 'innovation bias' scenario as well as persistent downswings in labor share and relatively higher unemployment rate with respect to the 'neutral innovation' scenario. Of course, this is just a first step towards the analysis of the interplay among biased technological change, employment, growth and income distribution. Indeed, there are many aspects that should be further investigated starting from this model. For instance, the analysis of technical progress implemented within the present model exclusively considers process innovation in a closed-economy model, whereas further investigations could also concern product innovation and competitiveness gaps between two (or even more) countries. Such an approach would allows us to analyze, for instance, the non-convergence issues affecting the core-periphery asymmetrical structure of the European Monetary Union (EMU).

2.6 Appendix: Baseline Calibration

Symbol	*Description*	*Value*
W	Number of workers	1500
M	Number of capitalists	100
Ψ	Matching Parameter	10
A_0	Firms' initial net worth	10
u	Wage revision probability parameter	2.0
φ_{l0}	Initial labor productivity (consumption firms)	1.0
φ_{k0}	Initial capital productivity (consumption firms)	1.0
a_K	Labor productivity (capital firms)	2.0
w_0	Initial wage	1.0
p_0	Initial consumption-good price	1.0
δ	Adaptive parameter	0.03
ρ	Share of dividends distributed	0.95
γ	Share of R&D expenditure	0.03
ν	R&D success probability parameter	1.0
$\mu_{c,0}$	Consumption firms' initial mark-up	0.2
$\mu_{k,0}$	Capital firms' initial mark-up	0.04
θ	Inventories share parameter	0.2
κ	Capital goods duration	20
δ_1	Investment function profit rate weight	0.025
δ_2	Investment function capacity utilization weight	0.025
$\overline{r}$	'Normal' profit rate	0.045
$\overline{u}$	'Normal' rate of capacity utilization	0.9
α_{1w}	Workers' propensity to consume out of income	0.95
α_{2w}	Workers' propensity to consume out of wealth	0.35
α_{1m}	Capitalists' propensity to consume out of income	0.65
α_{2m}	Capitalists' propensity to consume out of wealth	0.15
η	Banks-firms minimum proportion	0.03
σ	Banks' minimum dimension relative to firms	4.0

Symbol	*Description*	*Value*
μ_1	Total credit supply parameter	20.0
μ_2	Minimal reserve requirement parameter	0.1
χ	Loan interest parameter	0.003
ι_l	Loans' probability parameter	0.2
ι_b	Bonds' probability parameter	0.1
τ_0	Initial tax rate	0.4
G_0	Initial public expenditure	0.4
i_{res}	Interest paid on banks' reserves	0.001
i_0^b	Initial interest rate on bonds	0.001
ζ	Deposit interest-discount rate ratio	0.1

Chapter 3

Technological Gaps and Distributive Shares in a Monetary Union: a Multi-Country Agent Based-Stock Flow Consistent Model

3.1 Introduction

The persistent declining pattern of aggregate wage share in advanced and developing countries has been identified as one of the main new stylized facts[1] about growth and distribution during the last decades. This evidence results in sharp contrast with the so-called 'Kaldor facts' (Kaldor 1957) claiming for the long-run constancy of distributive shares and capital-output ratio[2].
On this ground, after the sovereign debt crisis broke out in 2010 within the Eurozone, the different paces of wages and labor productivity growth (i.e. the relative Unit Labor Cost, ULC) across the member countries of the European Monetary Union (EMU) have been taken as the point of reference in order to build up a common economic narrative about the determinants of current account imbalances between 'core'

[1]See Stiglitz (2016), Jones (2015) about new stylized facts concerning growth, distribution and global inequality.

[2]The other 'Kaldor facts' are: exponential growth of aggregate labor productivity and real wages, increasing capital-labor ratio (i.e. the so-called 'capital deepening') and roughly stable long-run pattern for the average rate of profit.

(mainly Germany) and 'periphery' (Italy, Spain, Portugal, Ireland and Greece) countries so to purpose possible economic policies which were capable of restoring public finance sustainability (by complying euro convergence criteria, i.e. the so-called 'Maastricht criteria') as well as countries competitiveness (Giavazzi and Spaventa 2011, Jaumotte and Sodsriwiboon 2010). From this 'supply-side' interpretation of the persistent non-convergence between high-competitive and low-competitive countries mainly follow the so-called '*expansionary austerity*' (Giavazzi and Pagano 1990, and Reinhart and Rogoff 2010) and '*structural reforms*' [3] prescriptions for peripheral countries presenting higher and persistent public and external deficits.
The export-led growth strategy should have led low-competitive countries to catch-up with Germany and 'core' countries through the *internal devaluation* of wages (Stockhammer et al. 2014). However, this strategy has deeply exacerbated the effects of the crisis upon the asymmetric structure of EMU, characterized by an endogenous tendency of its member countries to diverge in terms of economic performance, by dampening the possibility for peripheral countries of investing in industrial and technological policies and in stimulating aggregate demand and economic growth (Storm and Naastepad 2015a).
Therefore, the austerity policies have permanently compromised the economic performance of peripheral countries by weakening their production capacity, the labor market structure and the ability of firms to innovate as well as the aggregate demand by dampening consumption and investment (IMF 2012, De Grauwe and Ji 2013, Caiani et al. 2017).
Moreover, there is no clear empirical evidence about the interplay between the output growth and the ULCs growth, as highlighted by the so-called 'Kaldor paradox' (Kaldor 1978) claiming for the predominance of non-price factors (for example product differentiation) during the competitive process among countries in terms of market shares and economic growth (Felipe and Kumar 2014).
Thus, following a 'demand-side' approach many scholars, especially within the Post-Keynesian tradition, have strongly criticized not only the economic and political consequences of austerity prescriptions but also the interpretation of persistent imbalances among European countries as a consequence of excessive public debt and labor market rigidity together with competitiveness-gaps due to excessively high wage shares, that is higher wages growth rates with respect to labor productivity growth, in low-competitive countries (Landesmann et al. 2015, Storm and Naastepad 2015).
For example, Stockhammer et al. (2008) propose a post-Kaleckian macroeconomic

[3] Structural reforms mainly concern labor markets reforms for low-competitive peripheral countries. See, for example, the so-called '*Jobs Act*' and '*Loi Travail*' adopted, respectively, in Italy and France as the only way to enhance firms and country competitiveness.

model by estimating different effects of an increase in the wage share upon the components of aggregate demand and Onaran and Obst (2016) recently present a multi-country demand-led growth model for the EU15 in order to stress how a decrease in the wage share negatively effects economic growth of EMU as a whole also providing empirical support for a wage-coordination strategy.

From a theoretical point of view, different explanations have been proposed within the economic literature for the declining pattern of aggregate wage share (OECD 2012, 2015 and IMF 2017), so that we can distinguish mainly between neoclassical (and classical) '*technological-based*' and post-Keynesian heterodox '*demand-side*' explanations. The latter, focuses on the central role played by the effect of *globalization* and *financialization* (Stockhammer and Lavoie 2012 and Stockhammer 2013), whereas the 'supply-side' and '*technological-based*' explanation mainly relies on the estimation of different values of the elasticity of substitution between production inputs (capital and labor). On this ground, Bentolila (2003), Bassanini (2012), Hutchinson and Persyn (2012) and Karabarbounis and Neiman (2014) trace back the increasing pattern of aggregate 'capital deepening' , affecting in turn the distributive shares, to the estimation of the elasticity of substitution greater than one, whereas Acemoglu (1998, 2002, 2003) proposes a model with endogenous *directed* and *input-* or *skill-biased* technical change together with an elasticity of substitution less than one in order to explain different distributive patterns observed during the last decades in US and European countries.

Moreover, some empirical and theoretical contributions also investigate the role played by the sectoral shift (from manufacturing to service sectors) in US and in European countries upon the dynamics of aggregate and sectoral wage shares (De Serres et al. 2002).

Following a two-sector approach, these contributions highlight how the long-run constancy of aggregate distributive shares, claimed by the standard 'Kaldor facts' , may be consistent with different patterns of sectoral wage shares (Kutznets 1957), so to have aggregate long-run 'balanced' growth and 'unbalanced' growth at sectoral level.

On this ground, Acemoglu and Guerrieri (2008) present a model of unbalanced growth based on different factor proportions and different values of the capital deepening across sectors where they propose a 'supply-side' explanation[4], mainly based on the so-called 'Baumol-Bowen effect' [5], for the slower growth of output and

[4]Another approach focuses the attention on the 'demand-side' , that is on the effects of different consumption compositions (*Engel's law*) on unbalanced growth patterns. Matsuyama (2008) provides a detailed literature review on this approach.

[5]We have the so-called 'Baumol-Bowen effect' (Baumol 1967) when the faster growth of productivity within the manufacturing sectors triggers the growth of wages while the slowdown of productivity within the service sectors cannot offset this raise of costs. This leads to an increase in

the faster growth of employment within those sectors characterized by lower capital intensity (i.e. service sectors) in the US.
Ngai and Pissarides (2007) propose a multisector general equilibrium model where the structural change leading to sectoral labor reallocation and balanced aggregate growth is due to different 'Total Factor Productivities' (TFP) across sectors.
Recently, Zuleta and Young (2013) try to exploit the *induced* technical change (ITC) hypothesis in order to account for the different patterns of aggregate and sectoral wage shares by implementing two different production functions for service (*Leontief* function) and manufacturing (*Cobb-Douglas* function) sectors. In line with the results presented by Acemoglu and Guerrieri (2008) and Ngai and Pissarides (2007), they show how an increasingly labor-saving technical change within the manufacturing sector leads to the reallocation of the labor input towards the service sector.
Beside these 'supply-side' and '*technological-based*' macroeconomic models a relatively new and promising stream of literature investigating the interplay between innovation process, economic growth, income distribution and aggregate demand comes from the *Complex Adaptive System* approach applied to economic systems, mainly through the *Agent-Based Computation Models* (ABM) (Arthur 1997, Kirman 2010 and Delli Gatti et al. 2007). Following this methodological approach, the so-called '*Keynes + Schumpeter*' (K+S) class of models (Dosi et al. 2010, 2013, 2017) deeply investigate the interplay between *Schumpeterian* evolutionary innovation processes and *Keynesian* aggregate demand in advanced capitalist economies (Dosi et al. 2017). Moreover, many recent contributions in this field try to extend the analysis within a multi-country framework so to exploit the AB bottom-up approach in order to analyze the micro, meso and macroeconomic issues related to the interaction among different countries. On this ground, Dosi et al. (2017) recently propose a multi-country extension of the K+S model in order to analyze the global divergence between different countries characterized by persistent growth and productivity gaps by analyzing the interplay between firms' evolutionary innovation process, industrial dynamics, macroeconomic growth and productivity patterns.
On similar grounds building on the Eurace@Unibi model Dawid et al. (2012), Dawid et al. (2017) propose a multi-country AB model by investigating the effects of fiscal transfers within the EMU highlighting how they may revert the persistent divergence between 'core'and 'periphery'countries.
Furthermore, building on the Agent-Based Stock-Flow Consistent (AB-SFC) macroeconomic benchmark model (Caiani et al. 2016) and its extensions (Caiani et al. 2018 and Caiani et al. 2018a), Caiani et al. (2017) and Caiani et al. (2017a) recently investigate the effect of, respectively, different fiscal targets and wage regimes within

the relative prices of service goods with respect to manufacturing goods.

the EMU by implementing a multicountry AB-SFC model. In particular, Caiani et al. (2017) analyze the negative effects of austerity policies, in the form of restrictive fiscal targets (i.e. the 'Maastricht criteria'), on the macroeconomic performance of different countries belonging to an artificial monetary union, whereas Caiani et al. (2017a) investigate the effect of different wage regimes by implementing an expansionary or a restrictive wage policy either in a single country and in the artificial monetary union as a whole, drawing attention to the positive effects that a wage-coordination strategy may have for the recovery of the EMU.

Built upon these two contributions, we propose a multi-country extension of the AB-SFC model of *induced* and *directed* technical change presented in Chapter 2. The model is aimed at analyzing the role of the induced and directed technical change process, biased towards an excessive labor-saving choice of techniques and emerging from the evolutionary innovation process engaged by (tradable and non-tradable)[6] consumption firms, upon distributive patterns, long-run growth and employment within an artificial monetary union.

As for the model presented in Chapter 2, this is an attempt to bridge[7] the evolutionary and *Schumpeterian* approach to innovation dynamics as a *localized* process (Dosi and Virgillito 2016) with the classical interpretation of the *induced*[8], *directed* and *biased* technical change.

Moreover, as within his ancestor models (Caiani et al. 2016, Caiani et al. 2018 and Caiani et al. 2017) we explicitly take into account the interplay between the supply-side and the demand-side of our artificial economy by analyzing the feedback mechanisms between the '*innovation bias*' and the dynamics of employment and aggregate demand. The model is able to confirm the main findings presented in its closed-economy version, that is the persistent declining pattern of aggregate wage share as a result of the interplay between the *directed* and *biased* innovation process, the dynamics of aggregate demand and the strength of workers bargaining power which is negatively affected by higher levels of aggregate unemployment exacerbated in turns by the excessive labor-saving technical change. Furthermore the two-sector specification also allows us to analyze different patterns of sectoral (tradable and non-tradable) wage shares, by highlighting how the faster capital-deepening within

[6]Thus, if we compare tradable sector with manufacturing sector and non-tradable sector with service sector, the present model overcomes the assumption made by Zuleta and Young (2013) about two different specifications of the production function between the two sectors and explicitly considers the innovation process and the adoption of different production techniques for both sectors.

[7]Acemoglu 2015 provides a detailed discussion about possible theoretical links between the *localized* innovation process (Atkinson and Stiglitz 1969) and the *induced* and *directed* innovation hypothesis.

[8]The ITC hypothesis stems from Hicks (1932) and has been then developed along *neoclassical* (Kennedy 1964, Samuelson 1965, Drandakis and Phepls 1966 and Young 2004), *classical* (Van Der Ploeg 1987, Foley and Michl 1999, Foley 2003,? and Zamparelli 2015), *classical/evolutionary* (Dumenil and Levy 2010) and *Keynesian* (Stiglitz 2015 and Stiglitz and Greenwald 2015) lines.

the tradable sector, due to the larger adoption of labor-saving innovations with respect to non-tradable sector, leads to a stronger declining pattern of the wage share for the tradable sector as well as a shift of the employment share from tradable to non-tradable sector. Moreover, the multi-country framework enables us to show how countries tend to orient their innovation effort on tradable sector, with faster labor productivity growth for tradable-good firms with respect to non tradable-good firms (Bernard et al. 2003, Bernard et al. 2007), and how the adoption of new production techniques and the endogenous '*innovation bias*' affects the emergence of persistent growth and productivity gaps among countries with a consequent club formation between high- and low-performing countries (Zeira 1998).

3.2 The Model

As stated above, I propose a multi-country extension of the model presented in Chapter 2 by describing an artificial monetary union composed by Z countries populated by different economic agents (as in Caiani et al. 2017 and Caiani et al. 2017a). We have a capital-good sector composed by K firms producing a homogeneous capital good by using only the labor input, whereas the consumption-good sector is composed by C^{NT} non-tradable good firms and C^{T} tradable good firms, producing a homogeneous consumption good over labor and capital input. Consumption-good firms try to innovate their production process by choosing both the *intensity*, that is the amount of resources to be invested in R&D activities, and the *direction* of the innovation process between labor or capital productivity improvements (Kennedy 1964, Acemoglu 2003, Van Der Ploeg 1987, Foley and Michl 1999 and Stiglitz and Greenwald 2015) and they discriminate among new production techniques depending on a classical *profitability criterion* (Okishio 1961 and Shaikh 2016). Consumption firms may also rely on both internal (i.e. their net worth) or external funds by applying for bank loans.
Thus we have B banks collecting deposits from firms and households, providing credit to consumption firms and purchasing government bills.
The household sector is composed by W workers, selling their labor force to capital and consumption firms, and M capitalist agents representing the equity investors and thus receiving dividends from the firms and banks they own. Workers and capitalists consume their income on tradable and non-tradable good markets with different propensities to consume. Each country has a government and a Central Bank. Government collects taxes from firms, banks and households and provides tax-exempt transfers to households, which is the public expenditure in our model (Caiani et al. 2017 and Caiani et al. 2017a). The desired level of public expenditure

and the desired tax rate are adaptively adjusted each period depending on a given fiscal target representing the 'Maastricht criterion' (Caiani et al. 2017 and Caiani et al. 2017a).
National Central Banks collect banks' reserves, accommodate their requests for cash advances and purchase the residual amount of bonds by governments (residual with respect to the quantity of bonds purchased by private banks).
Then, as in Caiani et al. (2017) and Caiani et al. (2017a), we have a Union Central Bank setting the discount rate on cash advances[9] by means of a 'Taylor Rule' .
As in Caiani et al. (2017), Caiani et al. (2017a) and Chapter 2, the entry/exit process of (capital- and consumption-good) firms and banks takes place endogenously through capitalists' equity investment. Thus, as in the SIM Model, that is the simplest Stock-Flow Consistent (SFC) model presented by Godley and Lavoie (2009), everything starts with public expenditure (i.e. the lump-sum transfers to households). Then, capitalist agents decide to invest in the creation of new firms, primarily within the capital sector, then within the consumption sector[10] and, eventually, they can invest in the creation of new commercial banks.
International transactions among agents populating different countries take place on different markets: consumers interact with tradable firms on tradable-good market, consumption-good firms interact with commercial banks on credit market, firms and consumers interact with commercial banks on deposit market and private banks interact with governments on bond market.
As in Riccetti et al. (2015) the heterogeneous agents interacting within each market by means of decentralized matching protocols. Each period, the demand-side agents observe a random subset of supplier, whose size depends on a (fixed) parameter Ψ indicating the degree of imperfect information, and they choose the cheapest one until the list of supplier is empty or the desired quantity has been satisfied.

3.2.1 The Simulation Schedule

The simulation schedule is the same presented in Chapter 2 with the addition of tradable-good firms and Union Central Bank activities.

1. Capital-good firms decide the wage to be offered and the selling price for their production;

2. Consumption firms determine the production planning by deciding the desired quantity of output, the desired quantity of labor input, wages, selling prices,

[9]Requested by private banks on order to fulfill mandatory liquidity constraints.
[10]Tradable good firms are created as a fixed share of the number of non-tradable good firms.

the desired amount of resources to be invested in R&D and, eventually, the demand for loans;

3. Commercial banks and consumption-firms interact on the credit market;

4. Consumption-good firms decide the accumulation plan by computing the desired growth rate of production capacity (and hence the desired quantity of capital goods);

5. Capital and consumption firms interact with workers on the labor market;

6. Capital firms interact with tradable and non-tradable firms on the capital goods market;

7. Workers receive their wages and are employed for production and R&D activities. Capitalist agents receive dividends generated in the previous period;

8. Consumption-good firms undertake the innovation process and compare the new random technique with the one inherited from the previous period. Then they produce the final good;

9. Governments decide the tax-rate and the public expenditure planning;

10. Bonds are issued by national Governments of each member country and then purchased by national and foreign commercial banks on the bonds market. The residual amount of bonds, not purchased by private banks, is absorbed by the National Central Banks;

11. Households pay taxes on their income and receive the tax-exempt transfers by the Government. Then, they compute the desired consumption and interact with tradable and non-tradable consumption-good firms;

12. Firms compute their profits and net worth and the taxes to be paid in the next period. Consumption firms also compute the dividends to be distributed in the next period to the equity investors (capitalists);

13. Union Central Bank sets the common discount rate for the artificial monetary union;

14. Entry/exit process. Capitalists invest and eventually create new firms and banks.

3.2.2 Capital-good Firms

The capital-good sector is populated by $k = 1, \ldots, K$ firms producing a homogeneous capital good, $y^K_{k,t}$, for tradable and non-tradable consumption-good firms only by means of labor input. Thus we have

$$y^K_{k,t} = a_k N^D_{k,t} \tag{3.1}$$

with a_K indicating the (constant) labor productivity for workers employed in the capital production process and $N^D_{k,t}$ indicating the desired quantity of labor needed in order to produce the capital output.
They compute the demand for labor input as follows

$$N^D_{k,t} = \frac{y^K_{k,t}}{a_K} \tag{3.2}$$

and decide the quantity of capital output to be produced, $y^K_{k,t}$, depending on the desired quantity requested by the consumption-good firms,

$$y^K_{k,t} = y^{KD}_{c,t}. \tag{3.3}$$

Each period, capital-good firms adaptively revise the wage offered in the previous period depending on the difference between the desired quantity of workers and the quantity of workers effectively hired (Caiani et al. 2017), as follows:

$$w_{k,t} = \begin{cases} w_{k,t-1}(1 - U[0, \delta]), & \text{if } N^D_{k,t-1} - N_{k,t-1} = 0 \text{ with } Pr(u_t) = 1 - e^{u_t v} \\ w_{k,t-1}(1 + U[0, \delta]), & \text{if } N^D_{k,t-1} - N_{k,t-1} > 0 \end{cases} \tag{3.4}$$

If the desired quantity of workers in $t-1$ has been fulfilled, capital firms have a positive probability, $Pr(u_t)$, of downward revising the offered wage. This probability is inversely related to the aggregate level of unemployment u_t, with a positive (fixed) parameter v indicating the strength of the relation, i.e. the lower v the higher the probability of reducing the offered wage.

Then, capital firms adopt a simple pricing rule

$$p_{k,t} = (1 + \mu_k)\frac{w_{k,t}}{a_k} \tag{3.5}$$

with a fixed mark-up, μ_k, over the unit labor costs.

3.2.3 Consumption-good Firms

Production, Prices and Wages

The consumption-good sector is composed by C^{NT} firms and C^{T} firms producing, respectively, a homogeneous non-tradable and tradable good over two inputs (labor and capital). We model the production process with a fixed coefficient Leontief production function, as follows

$$y_{c,t} = \min\{u_{c,t}\varphi_{kc,t}y^{K}_{c,t}; \varphi_{lc,t}N_{c,t}\} \tag{3.6}$$

where $u_{c,t}$ indicates the degree of capacity utilization, $\varphi_{kc,t}$ and $\varphi_{lc,t}$ are, respectively, capital and labor input productivity, whereas $y^{K}_{c,t}$ and $N_{c,t}$ represent the quantity of capital and labor input. Consumption firms may improve their input productivity ($\varphi_{kc,t}$ and $\varphi_{lc,t}$) by means of R&D activities and they discriminate among new production techniques depending on a *profitability criterion*, that is by adopting them only if the expected profit rate related to new innovations is greater than the actual one (see subsection 3.2.3).
Once the firm has chosen the production technique, it can compute the desired output and the desired quantity of labor[11] given, respectively, by

$$y_{c,t} = u_{c,t}\varphi_{Kc,t}y^{KD}_{c,t} = \varphi_{lc,t}N^{D}_{c,t} \tag{3.7}$$

and

$$N^{D}_{c,t} = u^{D}_{c,t}y^{K}_{c,t}\frac{\varphi_{kc,t}}{\varphi_{lc,t}}. \tag{3.8}$$

The desired quantity of output, $y^{D}_{c,t}$, depends on sales expectations, $y^{e}_{c,t}$, and on the level of inventories inherited from the previous period, $inv_{c,t}$[12], as follows:

$$y^{D}_{c,t} = y^{e}_{c,t}(1+\theta) - inv_{c,t}. \tag{3.9}$$

Then, each period consumption firms adaptively revise prices and sales expectations, as follows:

$$\text{if } \overline{y}_{c,t} \geq \overline{y}^{e}_{c,t-1} : \begin{cases} \overline{y}^{e}_{c,t} = \overline{y}^{e}_{c,t-1}(1+U[0,\delta]) \\ p_{c,t} = p_{c,t-1}(1+U[0,\delta]) \end{cases} \tag{3.10}$$

[11] These desired quantities could be lower then the effective ones, so we could have that $N^{D}_{c,t} \geq N_{c,t}$ and/or $y^{D}_{c,t} \geq y_{c,t}$.

[12] Firms decide th equantity of inventories to be accumulated as a share, θ, of expected sales. Thus inventories represent a buffer stock within our SFC framework (Steindl 1952 and Lavoie 1992).

$$\text{if } \overline{y}_{c,t} \leq \overline{y}^e_{c,t-1} \text{and } y^{tot}_{c,t-1} > \overline{y}_{c,t-1} : \begin{cases} \overline{y}^e_{c,t} = \overline{y}^e_{c,t-1}(1 - U[0,\delta]) \\ p_{c,t} = p_{c,t-1}(1 - U[0,\delta]) \end{cases} \tag{3.11}$$

$$\text{if } \overline{y}_{c,t} \leq \overline{y}^e_{c,t-1} \text{and } y^{tot}_{c,t-1} = \overline{y}_{c,t-1} : \begin{cases} \overline{y}^e_{c,t} = \overline{y}^e_{c,t-1} \\ p_{c,t} = p_{c,t-1} \end{cases} \tag{3.12}$$

where $\overline{y}_{c,t-1}$ represents the output sold in $t-1$ and $y^{tot}_{c,t} = y_{c,t-1} + inv_{c,t}$.

The desired quantity of (fixed) capital stock is computed depending on the accumulation decision (see subsection 3.2.3).
Moreover, the selling price cannot be less than the unit labor costs[13].

Then, as described for capital firms in section 3.2.2, consumption firms adopt an adaptive wage rule, as follows:

$$w_{c,t} = \begin{cases} w_{c,t-1}(1 - U[0,\delta]), & \text{if } N^D_{c,t-1} - N_{c,t-1} = 0 \text{ with } Pr(u_t) = 1 - e^{u_t v} \\ w_{c,t-1}(1 + U[0,\delta]), & \text{if } N^D_{c,t-1} - N_{c,t-1} > 0 \end{cases} \tag{3.13}$$

Innovation

Each period firms C producing tradable or non-tradable consumption goods, undertake an evolutionary innovation process in order to improve their input productivity. As in Chapter 2, they choose both the *intensity*, that is the amount of resources to be invested in R&D activities, and the *direction* of the innovation process towards labor or capital productivity improvements. Moreover, they decide to adopt the new random technique by comparing its expected profit rate with the actual one, that is by following a classical *profitability criterion* (Okishio 1961, Shaikh 1978, Nakatani 1979, Shaikh 1999, Park 2001 Shaikh 2016).
Once firm has decided the size of investment in R&D activity, represented by a (fixed) share γ of the expected wage bill[14], as follows:

$$IN^D_{c,t} = \gamma w_{c,t} N^D_{c,t} \tag{3.14}$$

then, the innovation process takes place in two steps as in the well established 'K+S' tradition Dosi et al. 2010). First, firms compute a Bernoulli experiment in order to determine whether the R&D activity has been successful. For non-tradable firms we have:

[13] That is, $p_{c,t} < (1+\mu_c)(\frac{w_{c,t}}{\varphi_{lc,t}})$, with μ_c indicating a (fixed) mark-up over the unit labor costs.

[14] Since R&D activity is made by workers also employed in production activities, R&D investment depends in turns on production planning and on sales expectations (as in Caiani et al. 2017 and Caiani et al. 2017a).

$$Pr^{NT}_{IN_t} = 1 - e^{\frac{-\nu IN_{c,t}}{\Phi^{NT}_t P^{NT}_t}} \tag{3.15}$$

where the probability of success, $Pr^{NT}_{IN_t}$, is directly affected by the amount of resources invested in the innovation activity, Φ^{NT}_t represents the national average labor productivity of non-tradable firms and P^{NT}_t is the average domestic price level of non-tradable goods (Caiani et al. 2017). For tradable firms we have:

$$Pr^{T}_{IN_t} = 1 - e^{\frac{-\nu IN_{c,t}}{\Phi^{T}_t P^{T}_t}}. \tag{3.16}$$

with Φ^T_t representing the average labor productivity of tradable firms and P^{NT}_t is the average level of tradable goods within the Monetary Union. Then, we have a second step where new production technique is obtained by computing two different random draws respectively for the growth rate of capital and for the growth rate of labor productivity, as follows:

$$\varphi^{+}_{kc,t+1} = \varphi_{kc,t}(1 + \hat{\varphi}_k) \tag{3.17}$$

and

$$\varphi^{+}_{lc,t+1} = \varphi_{lc,t}(1 + \hat{\varphi}_l) \tag{3.18}$$

with $\hat{\varphi}_k \sim U[-\delta, \delta]$ and $\hat{\varphi}_l \sim U[-\delta, \delta]$.
Thus, we have a symmetric support for the random draws of labor and capital productivity improvements. This allows us to let the '*innovation bias*' emerge from the evolutionary innovation process with no imposition of analytical trade-offs between labor or capital productivity improvements, i.e. without an explicit 'Invention Possibility Frontier' á-la-Kennedy.
As stated above, the adoption of new production techniques depends on a classical *profitability criterion*, i.e. the adoption takes place only if:

$$r^{+}_{c,t+1} > r_{c,t}. \tag{3.19}$$

The profit rate is given by the ratio between firm's profit[15] and the capital stock, as follows:

$$\frac{\Pi^*_{c,t}}{K_{c,t}} \equiv r_{c,t} = \frac{p_{c,t}y_{c,t} - w_{c,t}N_{c,t} - p_{kc,t}y^K_{c,t} - IN_{c,t} - i^l_{c,t}L_{c,t}}{p_{kc,t}y^K_{c,t}} \tag{3.20}$$

with $p_{c,t}y_{c,t}$ representing revenues obtained from sales in the previous period, $w_{c,t}N_{c,t}$ and $p_{kc,t}y^K_{c,t}$ indicate, respectively, production inputs costs and $i^l_{c,t}L_{c,t}$ is the

[15]As in Caiani et al. (2016) and Caiani et al. (2018), we refer to $\Pi^*_{c,t}$ as the Operating Cash Flow, that is the firm's profit excluding the variation of the inventories (see subsection 3.2.3).

repayment for loans obtained in $t-1$ (see subsection 3.2.3).
After some substitution we obtain the profit rate inherited from t and the potential profit rate expected from the adoption of the new random technique $(\varphi^{+}_{kc}, \varphi^{+}_{lc})$ in $t+1$, as follows

$$r_{c,t} = \frac{u_{c,t}\varphi_{kc,t}[p_{c,t} - \frac{w_{c,t}}{\varphi_{lc,t}}(1+\gamma)]}{p_{kc,t}} - 1 - \frac{i^{l}_{c,t}L_{c,t}}{p_{kc,t}y^{K}_{c,t}} \tag{3.21}$$

and

$$r^{+}_{c,t+1} = \frac{u^{D}_{c,t+1}\varphi^{+}_{kc}[p_{c,t} - \frac{w_{c,t}}{\varphi^{+}_{lc}}(1+\gamma)]}{p_{kc,t}} - 1 - \frac{i^{l}_{c,t}L_{c,t}}{p_{kc,t}y^{K}_{c,t}}. \tag{3.22}$$

Thus, firms compare (eq. 2.17) the old and the '*transient*' profit rate within a 'real competition' framework (Shaikh 1999, Park 2001 and Shaikh 2016).

Moreover, both tradable and non-tradable firms presenting productivity gaps with respect to the sectoral average (Φ_x) may try to catch-up by imitating the leading competitors, as follows:

$$\varphi_{xc,t+1} = \varphi_{xc,t} + U[0, \Phi^{NT}_{x,t} - \varphi_{xc,t}] \text{ if } \varphi_{xc,t} < \Phi^{NT}_{x,t} \tag{3.23}$$

$$\varphi_{xc,t+1} = \varphi_{xc,t} + U[0, \Phi^{T}_{x,t} - \varphi_{xc,t}] \text{ if } \varphi_{xc,t} < \Phi^{T}_{x,t} \tag{3.24}$$

with $x = \{l, k\}$.

Investment and Capital Accumulation

Each period, consumption-good firms compute their desired rate of growth of production capacity depending on their profitability and on their desired degree of capacity utilization by comparing them to the (exogenous) 'normal' rates for the overall economy (as in Caiani et al. 2016, Caiani et al. 2018), as follows:

$$g^{D}_{c,t} = \delta_1 \frac{r_{c,t-1} - \overline{r}}{\overline{r}} + \delta_2 \frac{u^{D}_{c,t} - \overline{u}}{\overline{u}} \tag{3.25}$$

with δ_1 and δ_2 indicate, respectively, the sensitivity of investment to the profit rate and to the desired degree of capacity utilization, $u^{D}_{c,t}$[16], and $\overline{r}$ and $\overline{u}$ represent, respectively, the 'normal' profit rate and capacity utilization rate[17]. Thus we have both a 'classical' and a 'Kaleckian' engine shaping the investment decision undertaken

[16] Depending on the desired output $y^{D}_{c,t}$, that is $u^{D}_{c,t} = min(1, \frac{y^{D}_{c,t}}{y^{K}_{c,t}\varphi_{kc,t}})$.

[17] Assumed to be constant and equal across firms. Caiani et al. (2018) and Caiani et al. (2017) calibrate the values for these 'normal' rates by computing the steady-state solution of the aggregate model preceding the simulation.

by consumption firms depending, respectively, on the weight given to the profit rate and on the weight given to the desired degree of capacity utilization.
After the accumulation decision, c computes the desired nominal investment, $i^D_{c,t}$, as the additional capital stock needed due to the obsolescence of capital (given a fixed depreciation rate δ and a given life span for machineries, see 3.5) and/or in order to fill the possible gap between the current and the desired production capacity. Then, the desired real investment will be $I^D_{c,t} = i^D_{c,t} p_{kc,t}$.

Financing Demand, Profits and Net Worth

In order to finance their production activity, consumption firms may rely on *internal funds*, that is the disposable net worth $A_{c,t}$, and/or, if necessary, on *external funds*, that is a certain desired quantity of loans[18], $L^D_{c,t}$, by paying an interest rate $i^l_{c,t}$ (see subsection 3.2.5).
The desired demand for loans to the banking sector depends on the cost of the desired quantity of productive inputs and on the disposable internal funds, as follows:

$$L^D_{c,t} = \begin{cases} w_{c,t} N^D_{c,t} + p_{kc,t} y^{KD}_{c,t} - A_{c,t}, & \text{if } w_{c,t} N^D_{c,t} + p_{kc,t} y^{KD}_{c,t} > A_{c,t} \\ 0, & \text{otherwise.} \end{cases} \tag{3.26}$$

and it could differ from the amount of loans effectively obtained, that is we could have $L^D_{c,t} \geq L_{c,d}$, due to an unsatisfactory amount of loans to be supplied by the commercial banks or due to an individual credit rationing (as production activity has the priority on the R&D expenditure).
Firms' profits are given by the difference between revenues and expenditure:

$$\Pi_{c,t} = p_{c,t} \overline{y}_{c,t} + \Delta INV_{c,t} - w_{c,t} N_{c,t} - p_{kc,t} y^K_{c,t} - IN_{c,t} - i^l_{c,t} L_{c,t}. \tag{3.27}$$

where $\Delta INV_{c,t}$ indicates the variation of inventories, and firms' net worth evolves according to the following law of motion:

$$NW_{c,t} = NW_{c,t-1} + \Pi^*_{c,t-1} - T^\pi_{c,t} - DIV_{c,t}. \tag{3.28}$$

When the operating cash flows are positive ($\Pi^*_{c,t-1} > 0$), firms pay taxes on their profits ($T^\pi_{c,t}$) and distribute dividends ($DIV_{c,t}$) to equity owners (capitalists), as follows

[18] For simplicity, we assume that each loans lasts only one period.

$$T^{\pi}_{c,t} = \begin{cases} \tau_t \Pi^*_{c,t}, & \text{if } \Pi^*_{c,t} > 0 \\ 0, & \text{otherwise.} \end{cases} \tag{3.29}$$

and

$$DIV_{c,t} = \begin{cases} \rho(\Pi^*_{c,t} - T^{\pi}_{c,t}), & \text{if } \Pi^*_{c,t} > 0 \\ 0, & \text{otherwise.} \end{cases} \tag{3.30}$$

with τ_t indicating the tax-rate decided by the government (see subsection 3.2.7).

3.2.4 Households

We have $h = 1, \dots, H$ households divided into two different types of agents, that is $w = 1, \dots, W$ workers and $m = 1, \dots, M$ capitalists, consuming their income on consumption goods market, saving in the form of bank deposits and paying taxes over their income. Workers sell their labor force to (tradable or non-tradable) consumption- and capital-good firms, whereas capitalists only own firms and banks by receiving dividends as a share of their profits.

Workers

Each period, workers revise their reservation wage as the mirror process of wage determination taking place for capital and consumption firms (see 3.4 and 3.13), depending on their occupational status in $t-1$, as follows

$$w_{w,t} = \begin{cases} w_{w,t-1}(1 + U[0,\delta]), & \text{if employed in } t-1 \text{ with } Pr(u_t) \\ w_{w,t-1}(1 - U[0,\delta]), & \text{if unemployed in } t-1 \end{cases} \tag{3.31}$$

with $Pr(u_t)$ indicating a positive probability of increasing the wage claims if they were occupied in the previous period depending on the aggregate level on unemployment.
Workers gross income is given by

$$y_{w,t} = w_{w,t} + i^d_{b,t} D_{w,t} + TF_t \tag{3.32}$$

with $i^d_{b,t} D_{w,t}$ indicating the interest rate obtained from bank deposits[19] and TF_t representing the tax-exempt transfer received by government.

[19] For simplicity we assume the same interest rate offered by the banking sector.

Capitalists

Capitalists gross income is given by

$$y_{m,t} = DIV_{m,t} + i^d_{b,t} D_{m,t} \tag{3.33}$$

with $DIV_{m,t}$ indicating the dividends received by the firms/banks they own and $i^d_{b,t} D_{m,t}$ being the interests on their deposits.
Capitalists may save their wealth ($NW_{m,t}$) either as deposit accounts $D_{m,t}$ or as investment in firms/banks' equity $A_{m,t}$. The choice between these two assets depends on a certain degree of liquidity preference ($LP_{m,t}$) [20]. Thus, capitalists compute the desired level of wealth depending on their disposable income and the desired consumption, as follows

$$NW^D_{m,t} = NW_{m,t-1} + y^{DISP}_{m,t} - C^D_{m,t} \tag{3.34}$$

then they obtain the desired level of deposits and equity as

$$D^D_{m,t} = NW^D_{m,t} - (A^D_{m,t} - A_{m,t-1}) \tag{3.35}$$

and

$$A^D_{m,t} = \max\{A_{m,t-1}, (1 - LP_{m,t})NW^D_{m,t}\} \tag{3.36}$$

with $A^D_{m,t} - A_{m,t-1}$ indicating the desired investment in equity, which is bounded to be non-negative (Caiani et al. 2017).
As for the other desired variables in the model, we may also have $C^D_{h,t} > C_{h,t}$ (with $h = m, w$), and for capitalist agents this means that $NW^D_{m,t} < NW_{m,t}$. In this case deposits act as a buffer stock variable with $A_{m,t}$ remaining at the planned level.

The disposable income for a generic agent within the household sector (worker or capitalist) is given by

$$y^{DISP}_{h,t} = (1 - \tau_t) y_{h,t} \tag{3.37}$$

with $h = w, m$ and τ_t indicating the tax-rate in the current period.

Each period, households also decide the desired quantity of consumption depending on their current disposable income and on their wealth (i.e. bank deposits), as

[20] See Caiani et al. (2017), for a detailed description related to how capitalists compute their liquidity preference. In the ancestor model (Caiani et al. 2017), the household sector is not divided into workers and capitalist agents so that households as a whole act as consumers, workers and equity owners. On the contrary, within the present model only capitalist agents may invest in equity asset.

follows

$$C^D_{h,t} = \alpha_{1h} y^{DISP}_{h,t} + \alpha_{2h} D_{h,t} \tag{3.38}$$

with $0 < \alpha_{1h} < 1$ and $0 < \alpha_{2h} < 1$ and $\alpha_w > \alpha_m$. Thus, the desired savings are

$$S^D_{h,t} = y^{DISP}_{h,t} - C^D_{h,t} \tag{3.39}$$

.

Consumers also decide whether to purchase tradable goods, $C^{DT}_{h,t}$, and non-tradable goods, $C^{DNT}_{h,t}$, respectively, as fixed proportions c^T and $1 - c^T$ of $C^D_{h,t}$, as follows:

$$C^{DT}_{h,t} = c^T C^D_{h,t} \tag{3.40}$$

$$C^{DNT}_{h,t} = (1 - c^T) C^D_{h,t}. \tag{3.41}$$

Moreover, as in Caiani et al. (2017) and Caiani et al. (2017a), we introduce a locational specification of consumers' preferences and firms' product varieties á-la-Hotelling (Hotelling 1929 and Salop 1979) by assuming that varieties and preferences are randomly located on a circle with diameter equal to one.

3.2.5 Banks

We leave the banking sector functioning as well as, Governments, national Central Banks and Union Central Bank behavior exactly as in Caiani et al. (2017) and Caiani et al. (2017a). Thus, we have $b = 1, \dots, B$ commercial banks collecting deposits from households and firms (i.e. capitalists' deposits), offering an interest rate $i^d_{b,t}$ (which is a constant fraction of the discount rate i_t fixed by the Union Central Bank), and endogenously creating means of payment by providing credit to consumption-good firms. Moreover, banks may also purchase bonds issued by any z country member belonging to the artificial Monetary Union.
The probability of receiving credit by banks depends on firms' leverage, as follows:

$$Pr(L_{c,t}) = e^{-\iota \frac{L^D_{i,t}}{A_{i,t}}} \tag{3.42}$$

$$i^l_{c,t} = \chi \frac{L^D_{c,t}}{A_{c,t}} + i_t \tag{3.43}$$

with i_t indicating the discount rate fixed by the Union Central Bank.
The desired supply of loans depends on banks' net worth:

$$L^{SD}_{b,t} = \mu_1 A_{b,t} \tag{3.44}$$

and the maximum amount that a bank may provide to each firm is represented by a maximum share of its supply ($\zeta L^{SD}_{b,t}$).
Commercial banks have a minimum amount of reserves to be held by the national Central Bank as a proportion of their deposits

$$R^{min}_{b,t} = \mu_2 D_{b,t} \tag{3.45}$$

by receiving a fixed interest rate i_{res}.
Then, banks may also spend the remaining amount of liquidity by purchasing governments' bonds $B_{bz,t}$, yielding an interest rate $i^b_{z,t}$ [21].
Thus, banks' profit is given by

$$\Pi_{b,t} = \sum\nolimits_{c=1}^{C_{z,t}} i_{c,t} L_{c,b,t} + \sum\nolimits_{z=1}^{Z} i^b_{z,t} B_{bz,t} + i_{res} R_{b,t} - BD_{c,b,t} - i^d_t D_{b,t} - i_t L^{cb}_{b,t} \tag{3.46}$$

with $BD_{c,b,t}$ indicating the 'bad debt', that is the non performing loans due to firms' default.
Also banks' profits are subject to taxation, and then net profit are eventually distributed to the equity owners as for firms (see equations 3.4 and 3.13).

3.2.6 Central Banks

National Central Banks of the z country members provide cash advances ($CA_{CBz,t}$) requested by commercial banks, collect their reserves ($R_{CBz,t}$), and eventually purchase the residual amount of governments' bonds ($B_{CBz,t}$).
Central Banks also compute their profits and we assume that they are automatically distributed to national governments, so to have:

$$\Pi_{CBz,t} = i^b_{z,t} B_{CBz,t} + i_t CA_{z,t} - i_{res} RCBz, t. \tag{3.47}$$

Moreover, as in Caiani et al. (2017) and Caiani et al. (2017a), we have a National Central Bank setting the common discount rate following a Taylor rule, that is depending on the average level of inflation across country members belonging to our artificial monetary union:

[21] As in Caiani et al. (2017) banks randomly access the bond market with a probability of purchase them, depending on the riskiness of the economy (i.e. the debt-on-GDP ratio): $Pr(b_t) = e^{-\iota \frac{B_t}{Y_t}}$.

$$i_t = \bar{i}(1-\xi) + \xi\ r_{t-1} + (1-\xi)\ \xi^{\Delta\ P}(\Delta\ P_{t-1} - \overline{\Delta\ P}). \tag{3.48}$$

3.2.7 Governments

Each Government receives taxes from household sector (capitalists and workers) and from firms and commercial banks, thus

$$T_{z,t} = \sum\nolimits_{h=1}^{H_z} \tau_{z,t} T^y_{h,t} + \sum\nolimits_{c,\pi^*>0}^{C_z} \tau_{z,t} T^\pi_{c,t-1} + \sum\nolimits_{b,\pi>0}^{B_z} \tau_{z,t} T^\pi_{b,t-1}. \tag{3.49}$$

Government public expenditure $G_{z,t}$ is represented by lump-sum tax-exempt transfers to household sector ($TF_{z,t}$).
Each period, government may achieve a budget surplus $SUR_{z,t}$ or deficit $DEF_{z,t}$, so we have

$$DEF_{z,t} = G_{z,t} + i^b_{z,t-1} B_{z,t-1} - T_{z,t} \tag{3.50}$$

with public debt defined as follows:

$$B_{z,t} = B_{z,t-1} + DEF_{z,t} - SUR_{z,t-1}. \tag{3.51}$$

Then, the interest rate on each country member public bonds depends on the country debt-on-GDP ratio and on the discount rate set by the Union Central Bank, as follows:

$$i^b_{z,t} = \chi_b \frac{B_{z,t}}{Y_{k,t}} + i_t. \tag{3.52}$$

Moreover, as in Caiani et al. (2017) and Caiani et al. (2017a), each period national governments adaptively revise their level of public expenditure, $G_{z,t}$, and their tax rate, $\tau_{z,t+1}$, depending on a given fiscal target, d^{max} , representing the so-called 'Maastricht criterion' related to the maximum deficit-GDP ratio allowed for each country member, as follows:

$$\text{if } d_{z,t} \geq d^{max} \text{and } G^D_{z,t} \leq G_{z,t-1} : \begin{cases} G_{z,t} = G_{z,t-1}(1 - U[0,\delta] \\ \tau_{z,t+1} = \tau_{z,t}(1 + U[0,\delta]) \end{cases} \tag{3.53}$$

$$\text{if } d_{z,t} \geq d^{max} \text{and } G^D_{z,t} > G_{z,t-1} : \begin{cases} G_{z,t} = G_{z,t-1} \\ \tau_{z,t+1} = \tau_{z,t}(1 + U[0,\delta]) \end{cases} \tag{3.54}$$

$$\text{if } d_{z,t} < d^{max} \text{and } G^D_{z,t} \leq G_{z,t-1} : \begin{cases} G_{z,t} = G_{z,t-1}(1 - U[0,\delta] \\ \tau_{z,t+1} = \tau_{z,t}(1 - U[0,\delta]) \end{cases} \tag{3.55}$$

$$\text{if } d_{z,t} < d^{max} \text{and } G^D_{z,t} > G_{z,t-1} : \begin{cases} G_{z,t} = G_{z,t-1}(1 + U[0,\delta] \\ \tau_{z,t+1} = \tau_{z,t} \end{cases} \tag{3.56}$$

where $G^D_{z,t}$ and $G_{z,t-1}$ indicate, respectively, the desired level of public expenditure and the effective public expenditure in $t-1$ for country z.

3.3 Simulation Results

We run the model for 1000 time periods[22] following a baseline calibration for the parameters (see Table 3.5). Moreover the baseline scenario has been run under two different specifications concerning the number of countries belonging to our artificial monetary union, that is under a two-country and a six-country scenario, as a robustness check for the dynamics of the model.

In order to check for the ability of the model to reproduce some macroeconomic stylized facts, we follow Dosi et al. (2010) and Caiani et al. (2016) by presenting a minimum empirical validation. Figure fig. 3.1 and 3.2 show the cross-correlation functions between the cyclical components of some key macroeconomic variable across 50 Monte Carlo runs, respectively, under the two countries and the six countries specification. As we can see, under both specifications we have that aggregate consumption, export and import are coincident[23] and strongly pro-cyclical whereas aggregate unemployment and public expenditure-GDP ratio are strongly counter-cyclical. These results confirm the results presented in Chapter 2 as well as the cross-correlations of aggregate export and import with respect to real output presented within its multi-country ancestor model (Caiani et al. 2017).

As we can see in figure 3.3, the model is able to reproduce a self-sustained endogenous growth process, with an exponential real growth pattern of both GDP and consumption and with persistent cyclical fluctuations characterized by boom-and-bust episodes during the overall simulation, due to the *out-of-equilibrium* dynamics of the model and the interplay between real and financial variables shaped by the

[22] Each time periods corresponds to a quarter, so that we have a time span of 250 years for our simulation.

[23] The left, centered or right position of the peak within the cross-correlation plots indicates whether the variable is, respectively, lagged, coincident or leading with respect to the other variable.

interactions among heterogeneous agents and countries within our artificial monetary union.
The model also reproduces the standard ‘Kaldor Facts’ as we have exponential growth of aggregate labor productivity, real wages (fig 3.4) and capital-labor ratio (i.e. the so-called ‘capital-deepening’) as shown in fig. 3.5. However, as in the closed-economy version of the model (Chapter 2), aggregate labor productivity and real wages grow at different paces and this results in a persistent fluctuations of the aggregate wage share (top panel in fig. 3.8).
As discussed in Chapter 2, this result is mainly driven by the predominance of two different economic forces shaping the process of growth and technical change. On the one hand, we have *Schumpeterian* ‘virtuous circles’ as (tradable and non-tradable) consumption-good firms are increasingly encouraged to improve their production techniques by investing in R&D and thus by hiring a greater amount of workers for both production and innovation activities, in order to gain persistent technological advantage over their competitors. On the other hand, we have a strong counter-force as firms tend to adopt labor-saving (capital-using) production techniques, so that they try to improve labor productivity (φ_l) to a greater extent than capital productivity (φ_k) (‘*innovation bias*’), thus also accelerating the process of capital accumulation, as highlighted by the artificial time series of aggregate output-labor ratio (Y/L) and capital-labor ratio (K/L) (fig. 3.4 and fig. 3.5). The excessive labor-saving pattern of technical change also negatively affects the unemployment rate[24] (fig. 3.9), as firms can produce a larger amount of output by using less workers, by further weakening the bargaining power of workers as it is negatively affected by higher levels of aggregate unemployment (see equation 2.28).

Furthermore, the two-sector framework enables us to analyze these aggregate macroeconomic variables at a sectoral level by analyzing how tradable and non-tradable firms behave during the technical change process (fig. 3.7), leading to different trends of sectoral wage shares (fig. 3.9), and how persistent growth and productivity gaps among countries (fig. 3.12 and 3.13) emerge due to different economic patterns between the two sectors and to the complex interactions between the supply and demand-side of the economy.
In line with the results presented by Caiani et al. (2017) and with a consolidated

[24]Within the present model we are not able to analyze the strength or the triggering of the so-called ‘compensation mechanisms’ identified within the economic literature analyzing the complex nexus between innovation and employment (Vivarelli 2015, Calvino and Virgillito 2018) . As discussed in Chapter 2, within the presented model the labor-saving profile of innovations adopted by consumption firms may be mitigated for example when capital-good firms try to hire a greater amount of workers in order to fulfill the increasing demand of machines coming from the consumption-good sector. However, as we will discuss, the two-sector framework here also enables us to analyze different patterns of the employment shares between tradable and non-tradable sectors.

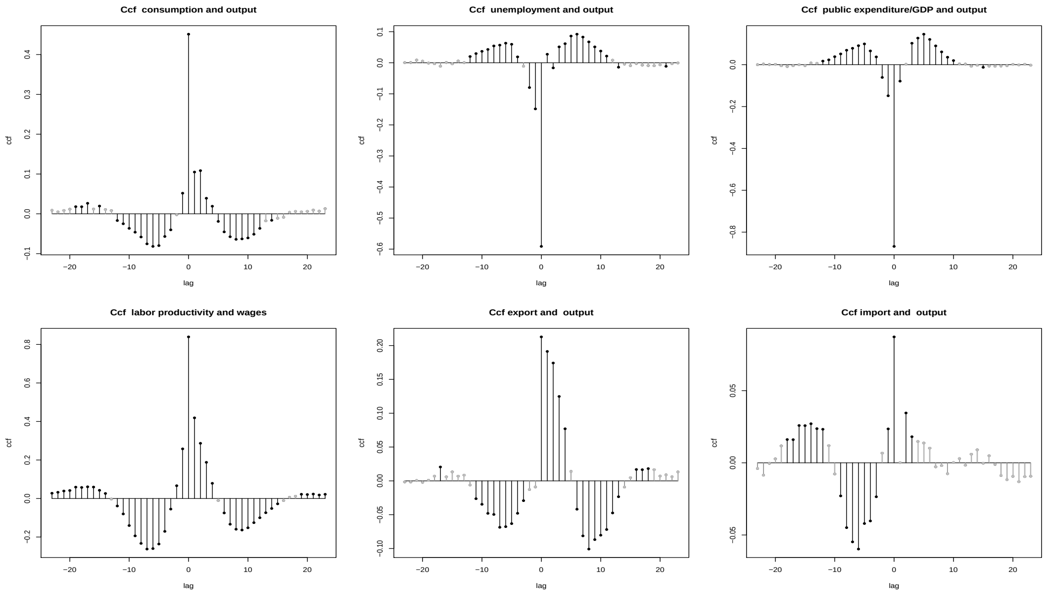

Figure 3.1. Average cross-correlations (across 50 Monte Carlo) of aggregate labor productivity, consumption, unemployment, public expenditure-GDP ratio, import and export with real GDP under the two countries specification.

empirical evidence about international trade (Bernard et al. 2003, Bernard et al. 2007), figure 3.6 shows how labor productivity grows faster for tradable firms with respect to non-tradable firms.
At a country level, the greater performance of tradable sector, leading to growing export flows absorbed by the demand for tradable-goods of the foreign consumers, also reflects in a relatively lower aggregate wage share within the high-performing countries (in terms of growth and productivity) with respect to low-performing countries (fig.3.8 and 3.9).

At a sectoral level, we can observe different patterns of the wage shares emerging from the simulation with a persistent declining trend of the wage share within the tradable good sector and an increasing, even if persistently fluctuating, trend within the non-tradable sector (fig.3.9).
We ascribe this result to the faster growth of ‘capital-deepening’ (i.e. the capital-labor ratio) within the tradable sector (fig. 3.10), due to the relatively larger adoption of increasingly labor-saving innovations made by tradable firms with respect to non-tradable firms. Moreover, this process leads to an endogenous structural change[25] characterized by the sectoral shift of the employment from tradable to non-tradable

[25] Dosi et al. (2017) propose a more sophisticated analysis of structural change, as they implement a multi-sector model with different industries, also accounting for the emergence of persistent technological and growth divergences among countries within their AB multi-country model.

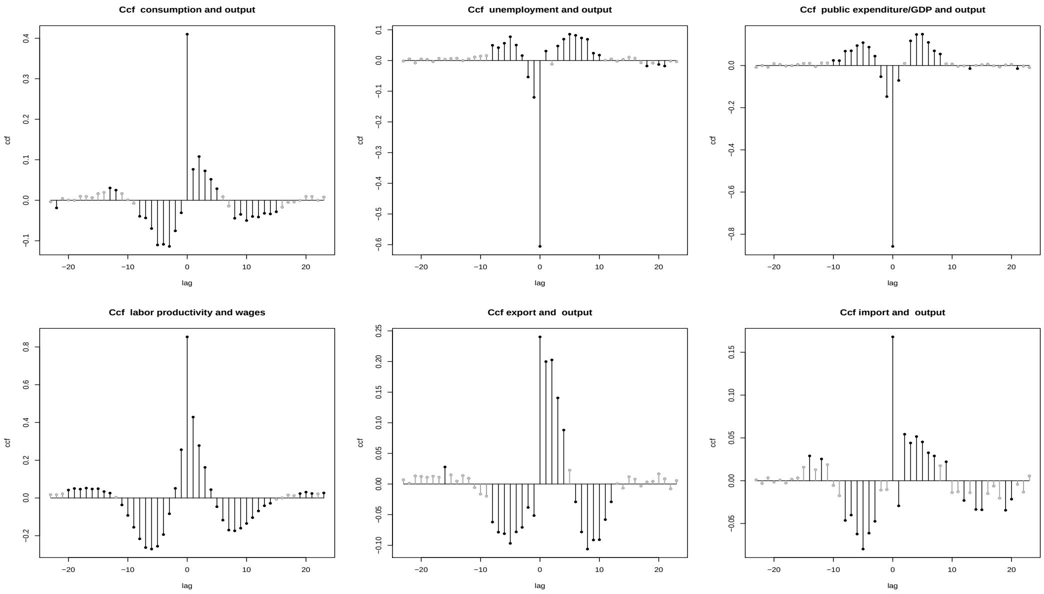

Figure 3.2. Average cross-correlations (across 50 Monte Carlo) of aggregate labor productivity, consumption, unemployment, public expenditure-GDP ratio, import and export with real GDP under the six countries specification.

sector with a persistent increase (decrease) of the non-tradable (tradable) sector employment share (fig. 3.11). This results are consistent with both theoretical (Acemoglu and Guerrieri 2008, Ngai and Pissarides 2007, Zuleta and Young 2013) and empirical (De Serres et al. 2002) contributions analyzing the different patterns of aggregate and sectoral wage shares from purely *supply-side* and *technological-based* perspectives, however our modeling framework also enable us to overcome some restrictive assumption, such as the possibility of innovation process only for one sector or the assumption of different production functions for each sector.

Moreover, our modeling framework is able to explicitly account for the effects of the interplay between the supply and demand-side of the economy as well as for the interaction between the real and financial side variables within and across a certain number of countries belonging to an artificial monetary union. Indeed, figures 3.12 and 3.13 show the percentage deviation of some macroeconomic variables for each country with respect to the cross-country average. As we can see, persistent growth, productivity and wage gaps among countries emerge from the simulation, leading to a club formation process between high- and low-performing countries. This divergence of the macroeconomic performance of different countries is driven by the interaction between the *Schumpeterian* innovation and imitation process and the competitive dynamics, characterized by an endogenous entry-exit process (Caiani et al. 2017), among heterogeneous credit-constrained firms and the *Keynesian/Kaldorian* dynamics of aggregate demand.

As discussed for example in Zeira (1998), different patterns of the induced and directed technical change process across countries have a strong impact on the persistent growth and productivity gaps across countries. Moreover, within the present model this process is driven by the choice made by consumption-good firms about both the *intensity* and the *direction* of the innovation effort, so that the innovation process is triggered not only by the input costs (as in the standard classical and neoclassical ITC models) but also by the amount of resources invested in R&D activities affected in turns by the firms sales expectations (Dosi et al. 2010).

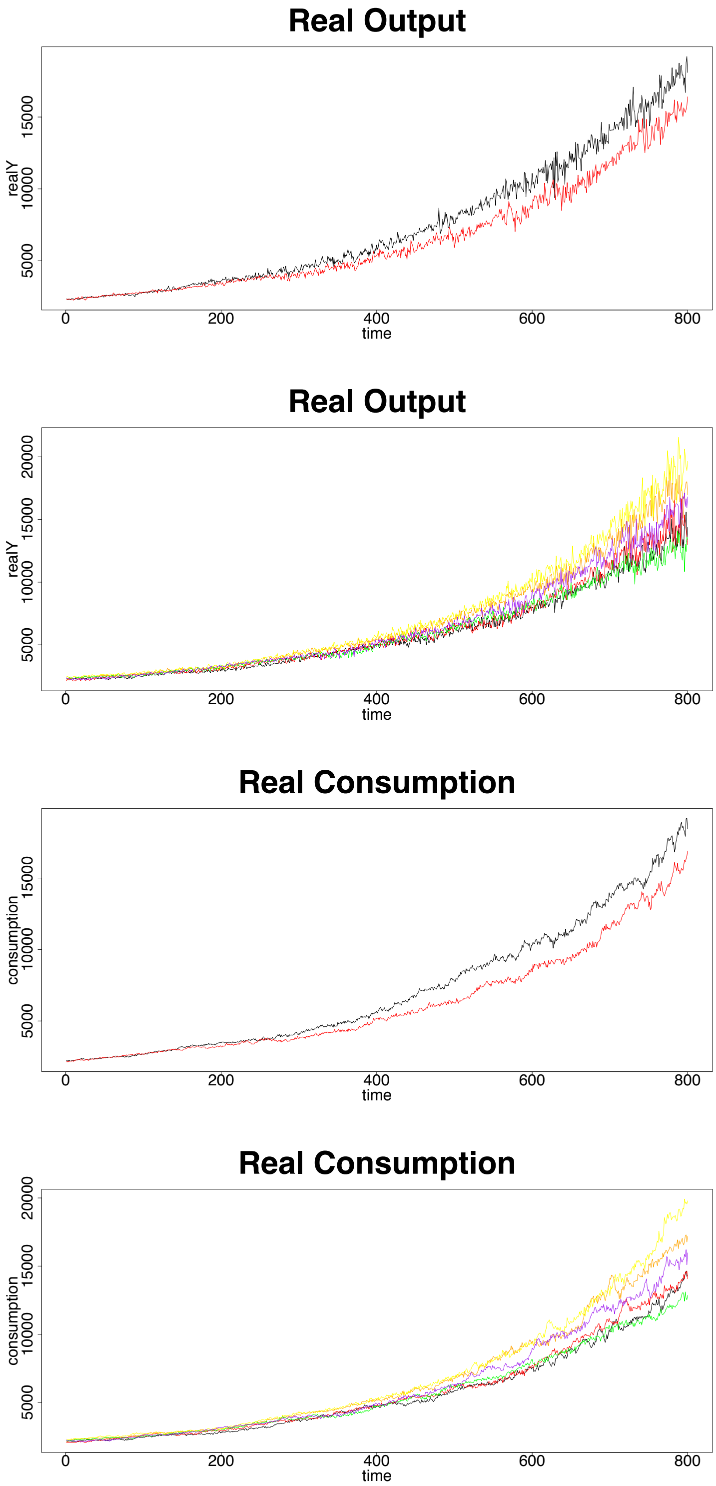

Figure 3.3. Artificial time series from time 100 to 1000 related to average real GDP and real consumption under the two baseline specifications, i.e. with two (left) and six (right) countries.

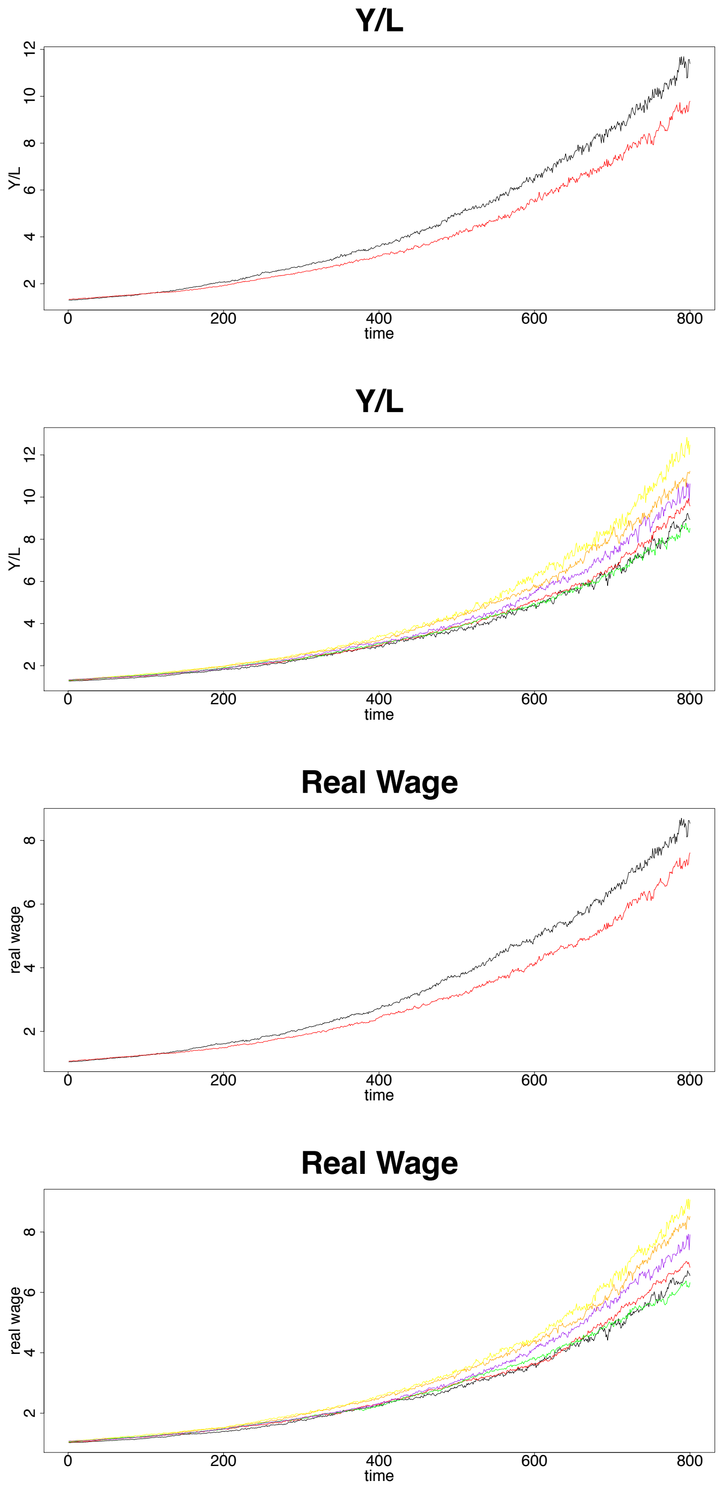

Figure 3.4. Artificial time series from time 100 to 1000 related to aggregate labor productivity and real wage under the two baseline specifications, i.e. with two (left) and six (right) countries.

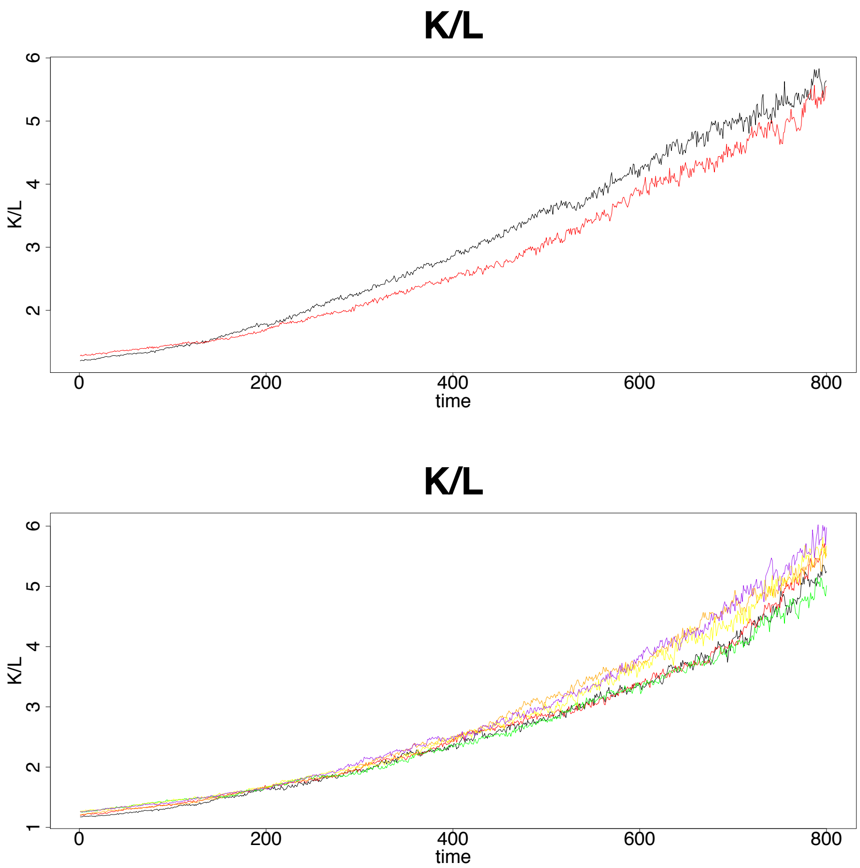

Figure 3.5. Artificial time series from time 100 to 1000 related to aggregate capital-labro ratio under the two baseline specifications, i.e. with two (left) and six (right) countries.

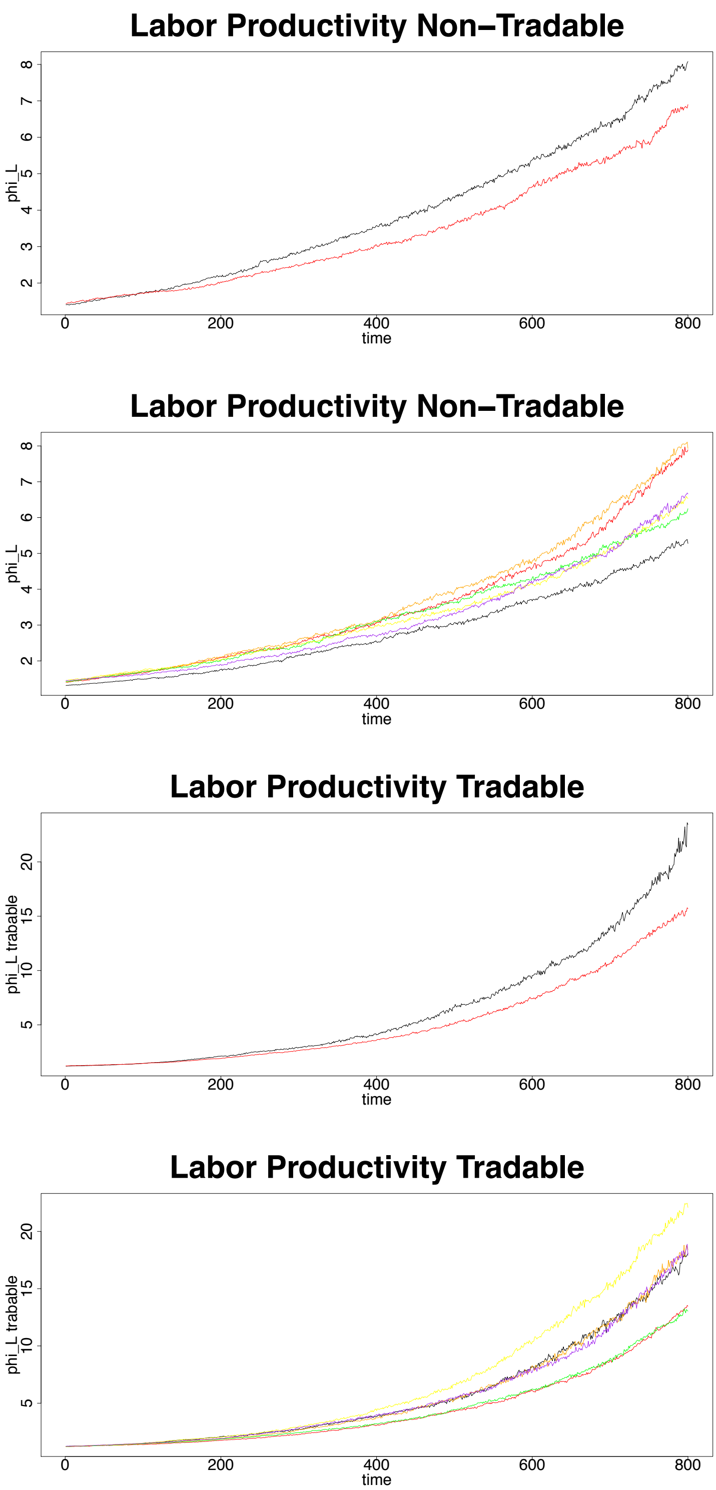

Figure 3.6. Artificial time series from time 100 to 1000 related to average labor productivity within tradable and non-tradable sector under the two baseline specifications, i.e. with two (left) and six (right) countries.

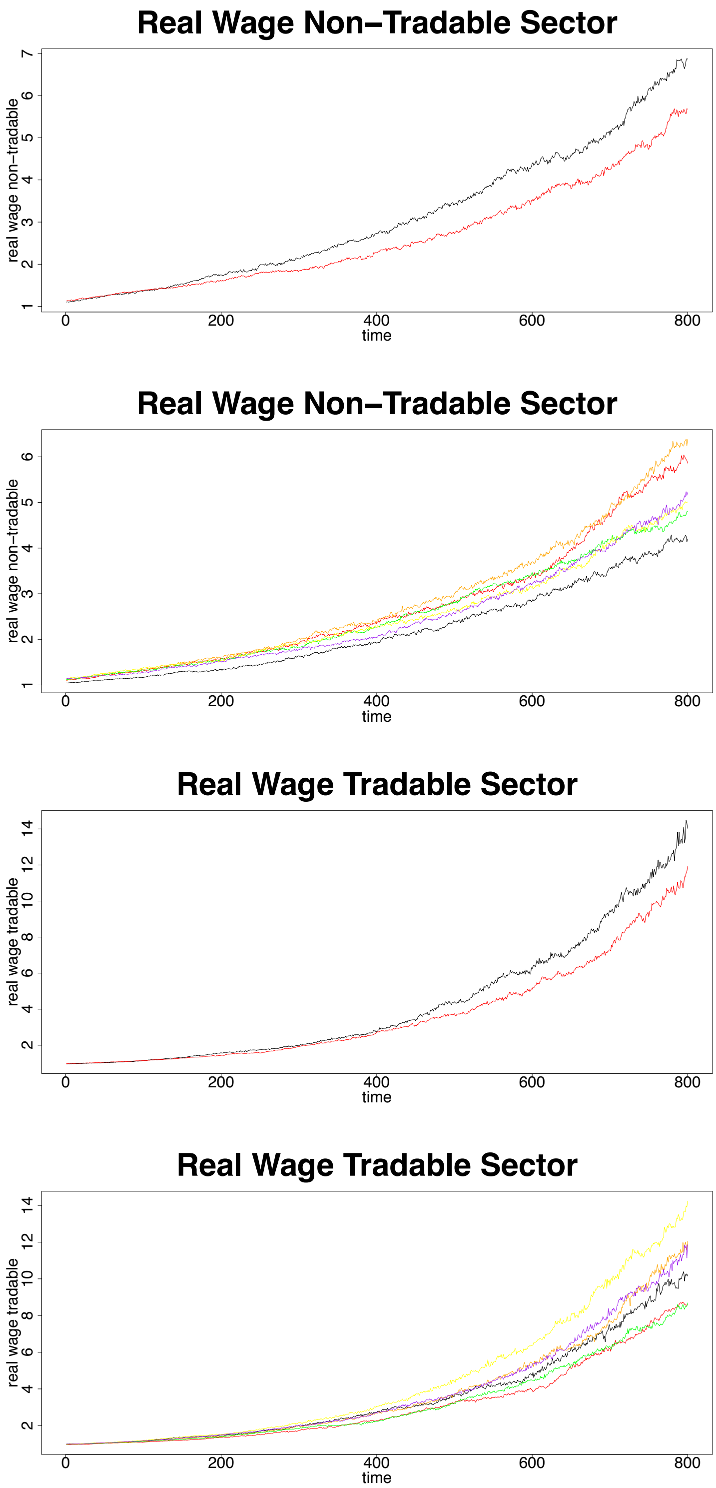

Figure 3.7. Artificial time series from time 100 to 1000 related to average real wage within tradable and non-tradable sector, under the two baseline specifications, i.e. with two (left) and six (right) countries.

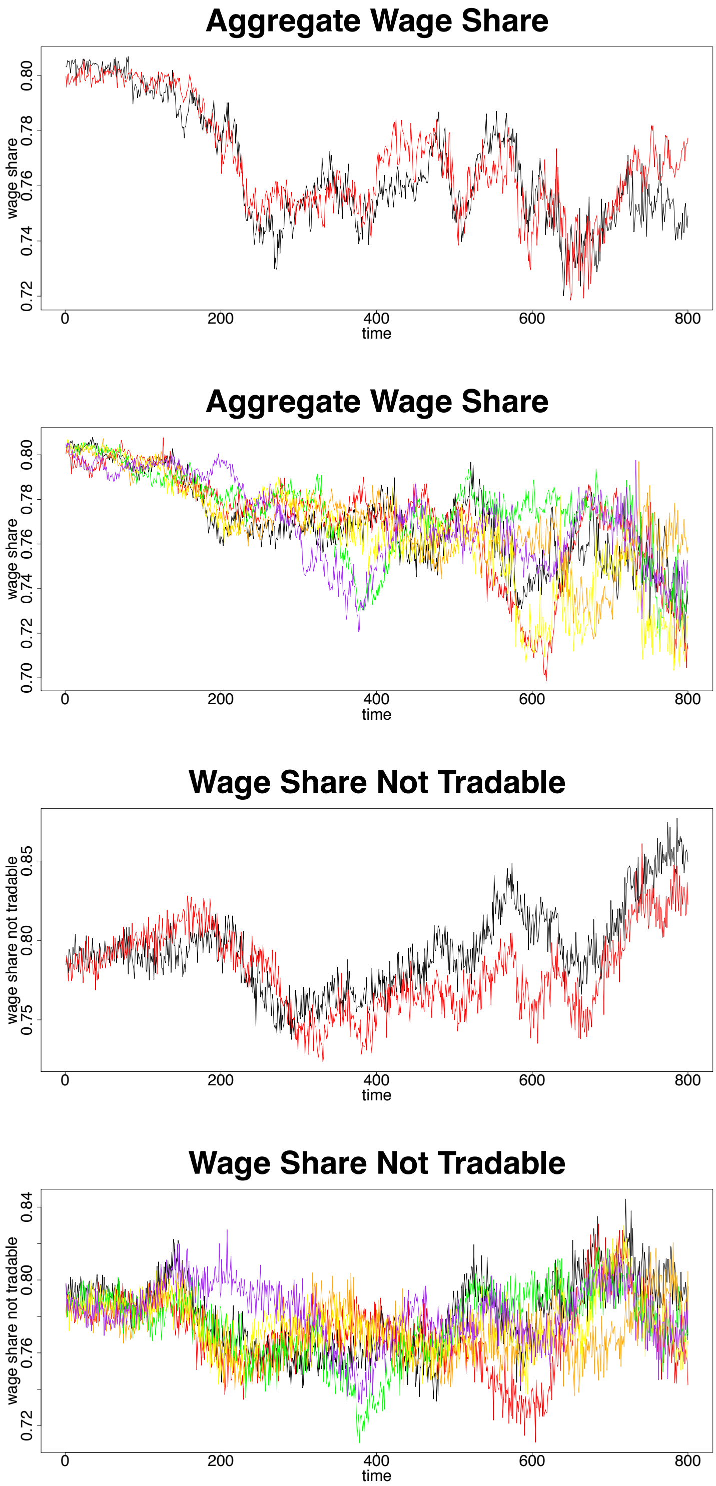

Figure 3.8. Artificial time series from time 100 to 1000 related to aggregate and non-tradable wage shares (computed as the ratio between real wage and labor productivity) under the two baseline specifications, i.e. with two (left) and six (right) countries.

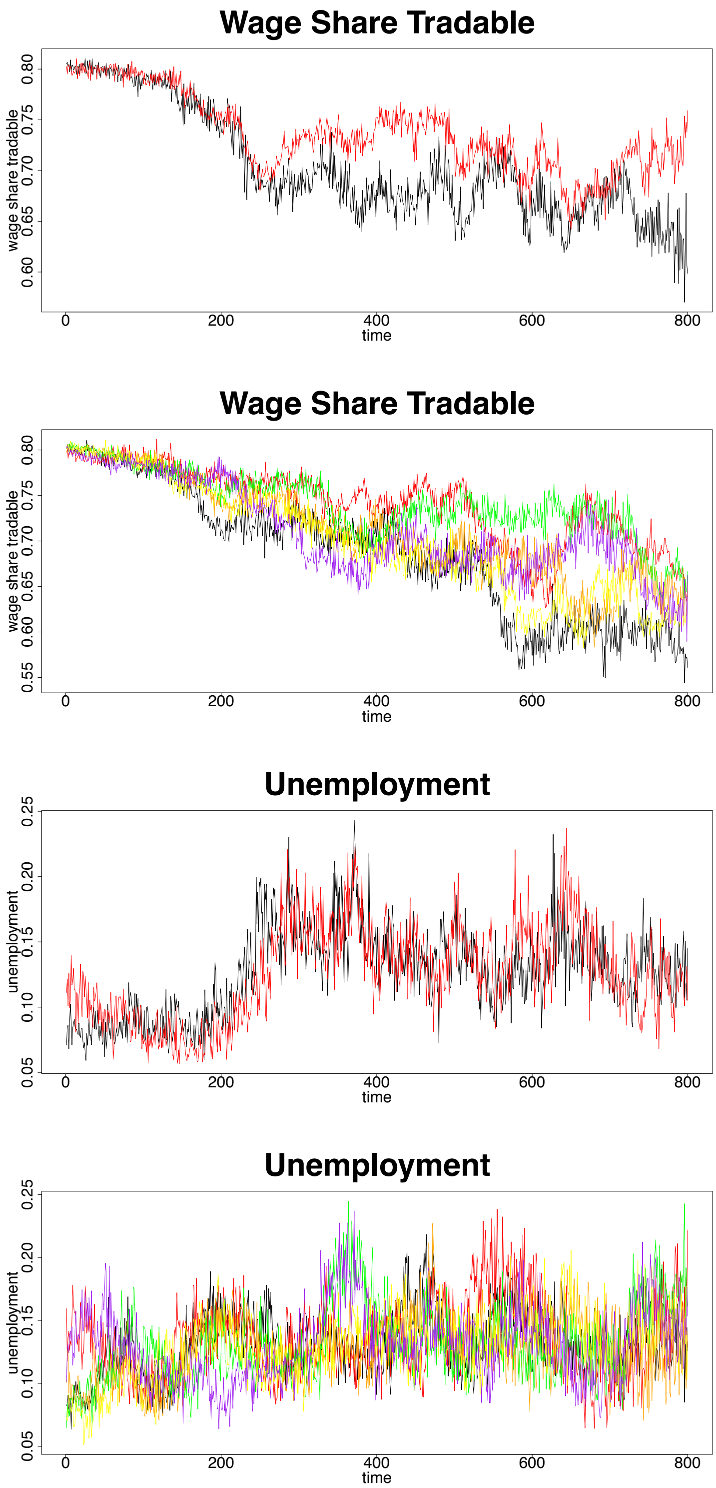

Figure 3.9. Artificial time series from time 100 to 1000 related to tradable wage share (computed as the ratio between real wage and labor productivity) and unemployment rate, under the two baseline specifications, i.e. with two (left) and six (right) countries.

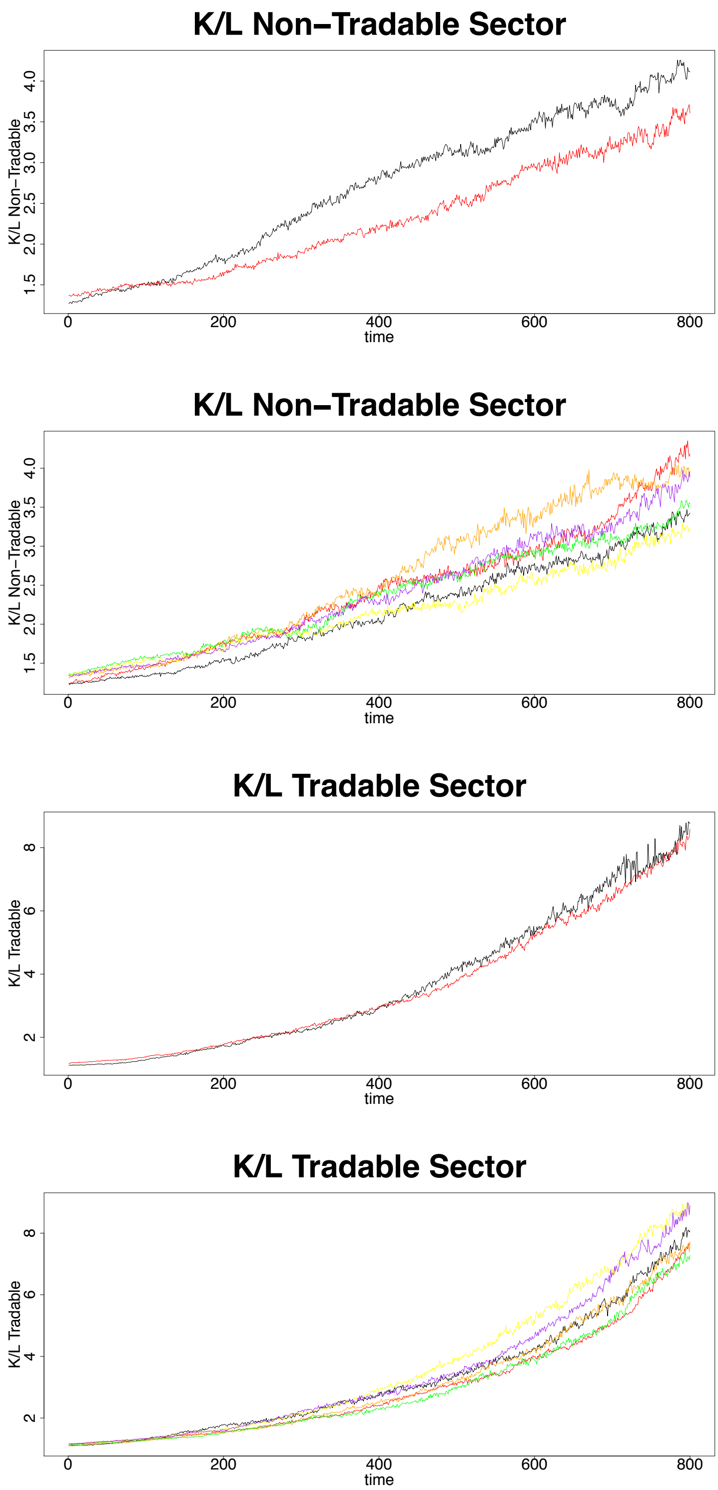

Figure 3.10. Artificial time series from time 100 to 1000 related to average labor productivity within tradable and non-tradable sector and average real wage within tradable and non-tradable sector, under the two baseline specifications, i.e. with two (left) and six (right) countries.

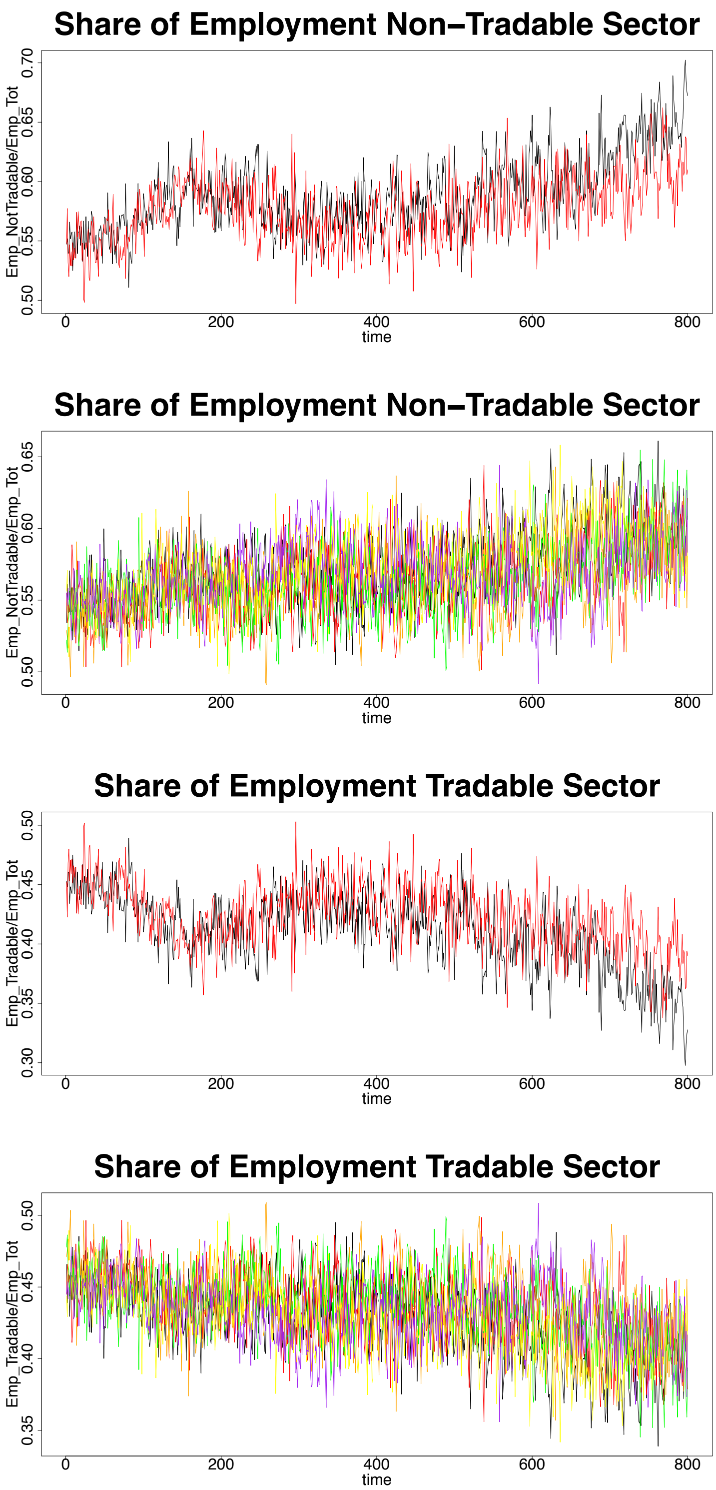

Figure 3.11. Artificial time series from time 100 to 1000 related to average labor productivity within tradable and non-tradable sector and average real wage within tradable and non-tradable sector, under the two baseline specifications, i.e. with two (left) and six (right) countries.

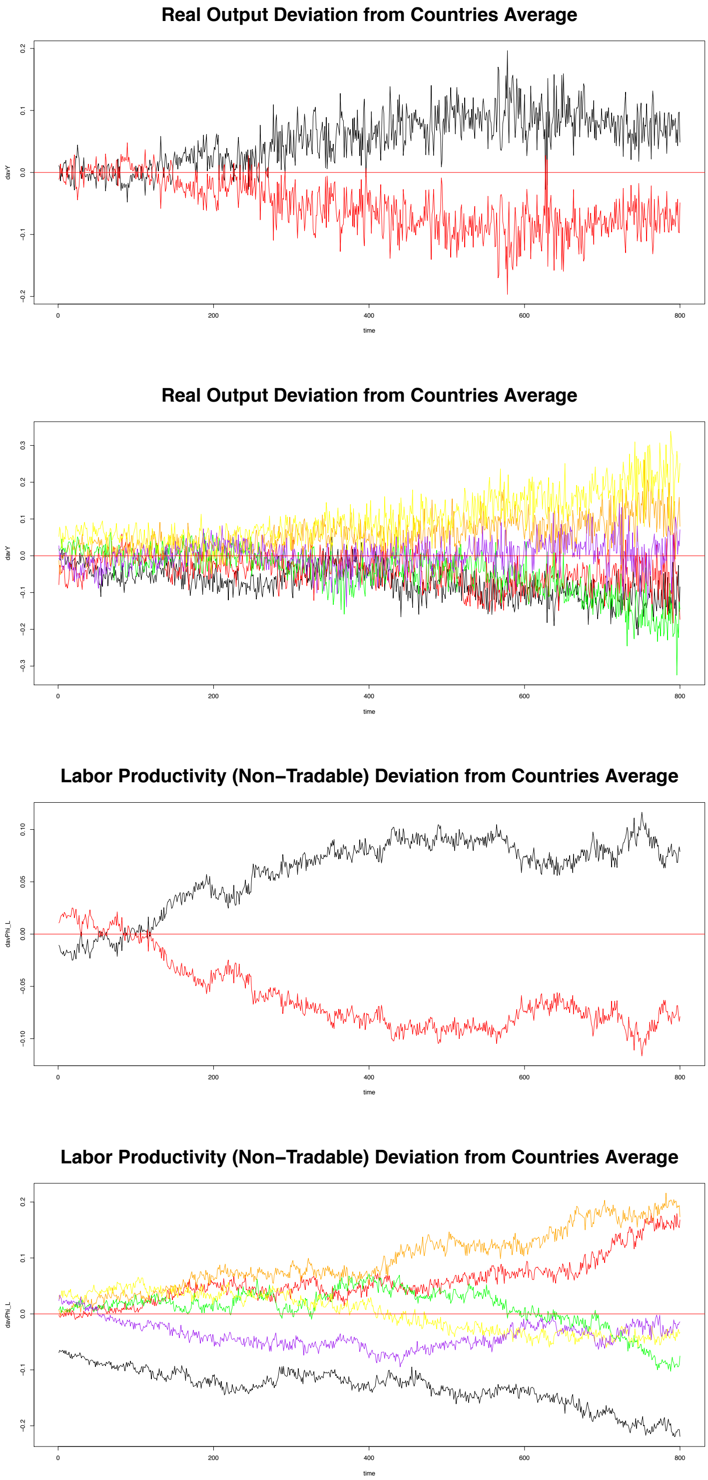

Figure 3.12. Artificial time series from time 100 to 1000 related to the percentage deviation with respect to the countries average of aggregate real output and labor productivity (within non-tradable sector) under the two baseline specifications, i.e. with two (left) and six (right) countries.

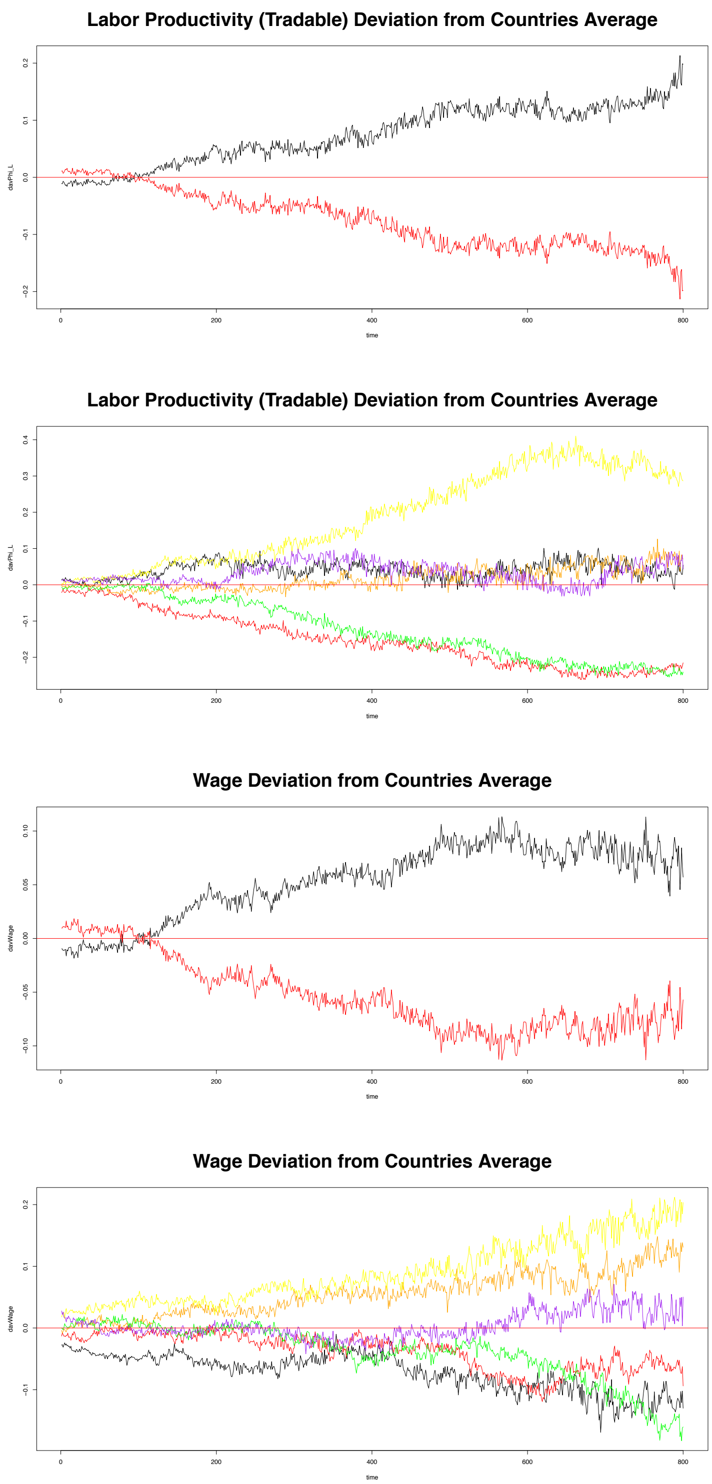

Figure 3.13. Artificial time series from time 100 to 1000 related to the percentage deviation with respect to the countries average of aggregate labor productivity (within tradable sector) and real wage under the two baseline specifications, i.e. with two (left) and six (right) countries.

3.4 Conclusions

Building on Caiani et al. (2017) and Caiani et al. (2017a), we present a multi-country Agent Based-Stock Flow Consistent (AB-SFC) model aimed at analyzing the effect of *induced* and *directed* technical change upon economic growth, functional income distribution and employment within an artificial monetary union. The simulation results show the emergence of persistent fluctuations of the aggregate wage share as in the closed-economy version presented in the first chapter. Moreover the two-sector specification, distinguishing between tradable and non-tradable firms, also enables us to discuss different trends of aggregate and sectoral wage shares. In particular, we observe from the artificial data an increasing trend of the wage share within the non-tradable sector and a persistent declining pattern of the wage share within the tradable sector.

These findings are mainly caused by the faster growth of capital-deepening within the tradable sector, due to the relatively larger adoption of labor-saving innovations by tradable firms, also leading to a sectoral shift of the employment from tradable to non-tradable sector with an increase (decrease) of the non-tradable (tradable) employment share. Furthermore, the model also shows the endogenous emergence of persistent technological and growth gaps among countries leading to club formations between high- and low-competitive countries.

However, many aspects related to the complex interplay between technical change, growth and distributive shares in a multi-country modeling framework should be further investigated by means of the present model.

First of all, some key parameter should be subjected to sensitivity analyses in order to check for the causal relation between relevant variables driving the economic phenomena here discussed. Then, we should account for the role of product innovations, following both a *Schumpeterian* and evolutionary microeconomic perspective and a *Kaldorian* macroeconomic perspective, given that we are only considering product innovations and disembodied technical change. Thus, an interesting extension of the present model should be focused on the analysis of the effect of product differentiation upon structural change and different growth and technological trajectories among countries.

3.5 Appendix: Baseline Calibration

Symbol	*Description*	*Value*
Z	Number of countries	2, 6
W	Number of workers	2000
M	Number of capitalists	100
Ψ	Matching parameter	10
c^T	Share of tradable firms	0.4
A_0	Firms' initial net worth	10
u	Wage revision probability parameter	0.8
φ_{l0}	Initial labor productivity (consumption firms)	1.0
φ_{k0}	Initial capital productivity (consumption firms)	1.0
a_K	Labor productivity (capital firms)	2.0
w_0	Initial wage	1.0
p_0	Initial consumption-good price	1.0
δ	Adaptive parameter	0.03
ρ	Share of dividends distributed	0.95
γ	Share of R&D expenditure	0.03
ν	R&D success probability parameter	0.8
$\mu_{c,0}$	Consumption firms' initial mark-up	0.25
$\mu_{k,0}$	Capital firms' initial mark-up	0.045
θ	Inventories share parameter	0.2
κ	Capital goods duration	20
δ_1	Investment function profit rate weight	0.25
δ_2	Investment function capacity utilization weight	0.25
$\overline{r}$	'Normal' profit rate	0.045
$\overline{u}$	'Normal' rate of capacity utilization	0.9
β	Hotelling's circle parameter	1.5
α_{1w}	Workers' propensity to consume out of income	0.95
α_{2w}	Workers' propensity to consume out of wealth	0.35
α_{1m}	Capitalists' propensity to consume out of income	0.65
α_{2m}	Capitalists' propensity to consume out of wealth	0.15
η	Banks-firms minimum proportion	0.03
σ	Banks' minimum dimension relative to firms	4.0
μ_1	Total credit supply parameter	20.0

Symbol	*Description*	*Value*
μ_2	Minimal reserve requirement parameter	0.1
χ	Loan interest parameter	0.003
ι_l	Loans' probability parameter	0.2
ι_b	Bonds' probability parameter	0.1
τ_0	Initial tax rate	0.4
G_0	Initial public expenditure	0.4
i_{res}	Interest paid on banks' reserves	0.001
i_0^b	Initial interest rate on bonds	0.001
ζ	Deposit interest-discount rate ratio	0.1

Chapter 4

Structural Change and the Wage Share: a Two-Sector Kaleckian Model

4.1 Introduction

At the onset of modern growth theory, Kaldor (1961) suggested that long-run stability of factors income shares is one of the main 'stylized facts' of market economies. Yet, recent contributions (Jayadev , 2007; Karabarbounis and Neiman, 2014; OECD, 2015) have shown that the labor share has declined over the past three decades in both developed and developing countries. While the possibility of short- and medium-run fluctuations in factors shares has long been acknowledged (Bentolila, 2003; Young, 2004), the prolonged decline in labor share seems to point to either a long-run negative trend in the labor share or a shift to a lower steady state wage share as more plausible descriptions of the evidence.

Several explanations for such a trend have been put forward and investigated both from theoretical and empirical standpoints. Economists working within the neoclassical framework have emphasized the importance of the shape of production function and the nature of technical change in determining factors shares trends. As is well known, a unitary elasticity of substitution (σ) between capital and labor, that is a Cobb-Douglas production function, necessarily implies constant factors shares. There are two possibilities to obtain a fall in the labor share: either capital deepening (in efficiency terms) when labor and capital are substitutes ($\sigma > 1$), or a reduction in the capital-labor ratio when the elasticity of substitution is less than one. Piketty and Zucman (2014) and Karabarbounis and Neiman (2014) support the first mechanism; but while Piketty and Zucman (2014) attributes capital deepening to negative shocks to the (exogenous) growth rate, Karabarbounis and Neiman (2014) find its determinant in the decline of the price of investment goods relative to consumption goods. Acemoglu (2003) analyzes the second possibility in the context of induced technical change, though he only applies it to deviations from the stable steady state wage share.

Other researchers (Berthold et al., 2002; Bental and Demougin , 2010; Checchi and García-Peñalosa , 2010) have investigated the relation between changes in labor market institutions and the labor share trend. Checchi and García-Peñalosa (2010), in particular, show that a reduction in unions' bargaining power might have played a role in reducing the share of income accruing to workers.

Multiple elements of globalization have also been singled out as factors behind the falling labor share. They range from trade (Brock and Dobbelaere , 2006; Doan and Wan , 2017), to offshoring (Elsby et al. , 2013), to capital account openess (Jayadev , 2007).

Finally, economists working withing the Post-Keynesian tradition (Dünhaupt , 2017; Stockhammer , 2017) have looked at the increasing size of the financial sector as an additional determinant of the decline in the wage share.

Relatively little attention, on the other hand, has been paid to the possible influence of structural change on functional income distribution. De Serres et al. (2001) show that changes in the sectoral structure of the economy help explaining the trend decline in the aggregate wage share observed in five European countries and in the US over the 1980s and 1990s. From a theoretical point of view, a recent paper by Alvarez-Cuadrado et al. (2018) explains the decline in the labor share in a two sector neoclassical growth model, where sectoral differences in productivities growth and factors' elasticities of substitution, and non-homotethic preferences produce an endogenous rise in the service sector relative to manufacturing. Their quantitative analysis shows that within-industries income shares dynamics rather than changes in the sectoral composition of output is mostly responsible for the fall in the aggregate wage share.

In this paper, we investigate the relation between structural change and functional income distribution within the Kaleckian theory of growth and distribution. We build on Dutt (1988) and Dutt (1990) to develop a two-sector Kaleckian model of growth and distribution, where the economy consists of the service and manufacturing sectors. The service good is only used for consumption while the manufacturing good is used both for consumption and the accumulation of capital stock. We assume that structural change is exogenous as it arises from shifts in consumers' preferences and in the saving rate. We study two versions of the model, with and without profit rates equalization across sector. Under both specifications we show that, when mark-ups are relatively higher in the service sector, a shift in the sectoral composition of demand in favor of the service sector generates a rise in the steady state profit share. The unique (non-trivial) steady state equilibrium is asymptotically stable. The crucial assumption that mark-ups are relatively higher in the service sector is motivated by recent empirical evidence. In particular, consistently with the results presented by Alvarez-Cuadrado et al. (2018), the analysis of aggregate and sectoral wage shares data from 1977 to 2010 for the US (fig. 4.1) shows that the labor share in the manufacturing sector is consistently higher than in the service sector.

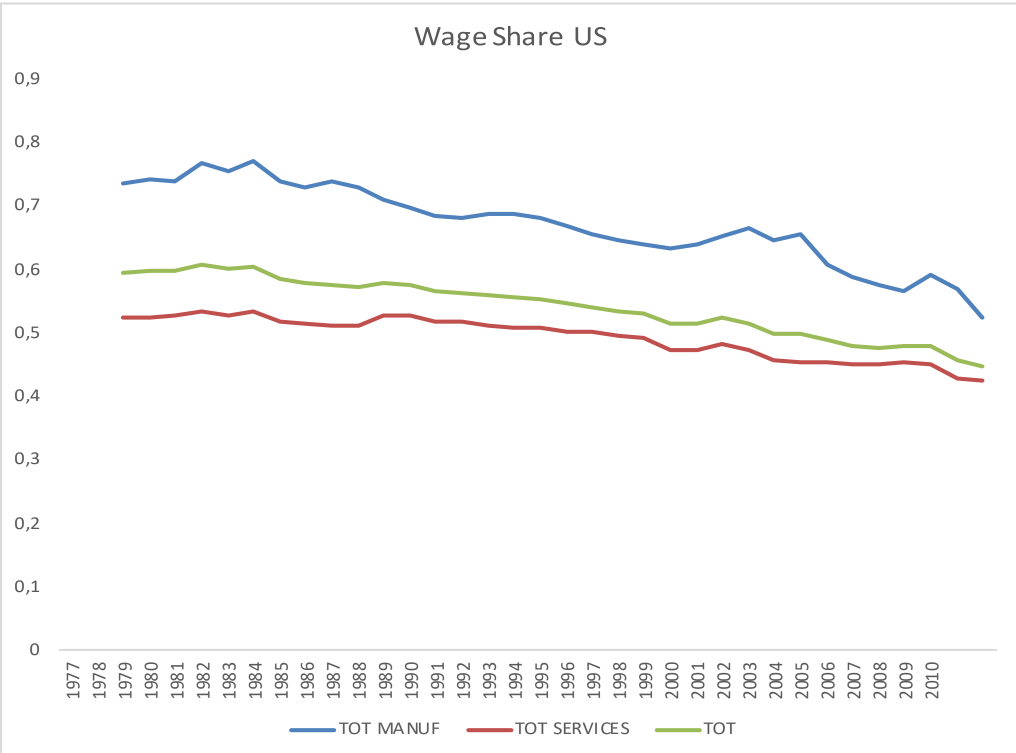

Figure 4.1. Authors' elaboration from 2012 EU-Klems data. The wage share is computed as the ratio between total labor compensation and total value added for the total industries (green line), manufacturing (blue line) and service (red line) sector.

Furthermore, figure 4.2 shows how, during the same period, we observe an increase (decrease) of the service (manufacturing) sector value added over the total value added in the US.

While seminal contributions by Dutt (1988, 1990); Park (1995); Dutt (1997); Lavoie and Ramirez-Gaston (1997); Franke (2000) laid the foundations of the two-sectors Keynesian-Kaleckian model growth and distribution, recent papers have generalized the model to investigate additional issues. Nishi (2018) analyzes the effects of introducing sectoral endogenous labor productivity growth on cyclical demand, growth and distribution. Fujita (2018) explores how changes in sectoral mark-ups affect sectoral and aggregate capacity utilization and capital accumulation. Murakami (2018) studies the effect of sectoral interactions on business cycles in a Keynesian model, without focusing on income distribution. None of these recent contributions, however, consider the role that changes in demand composition may produce on income distribution.

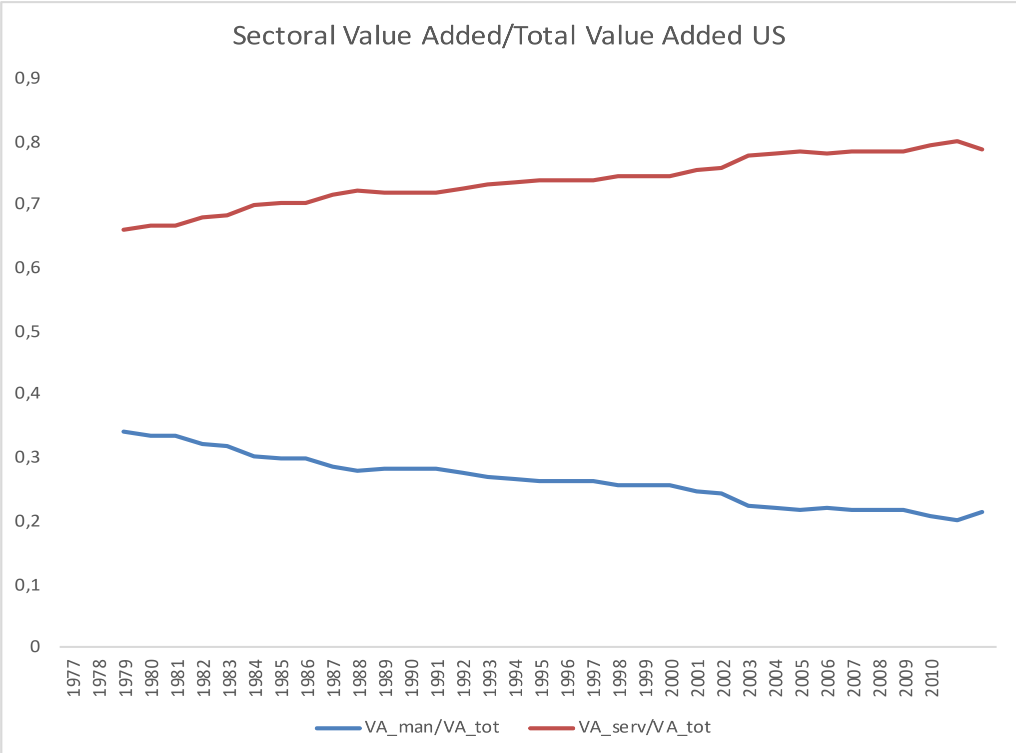

Figure 4.2. Authors' elaboration from 2012 EU-Klems data. The blue line indicates the share of manufacturing sector value added over the total value added whereas the red line indicates the share of service sector value added over the total value added.

The rest of the paper is organized as follows. Section 2 develops the model and states the theoretical results; Section 3 offer some concluding remarks while proofs of the propositions can be found in Section 4.

4.2 The Model

4.2.1 Production and technology

The economy consists of the service good (s) and the manufacturing good (m). Output in both sectors (X_i) is produced through a sector-specific Leontief production function:

$$X_i = min[u_i B_i K_i, A_i L_i], i = s, m \tag{4.1}$$

where B and A are capital and labor productivities, K is the capital stock, L is employment, and u is the degree of capacity utilization. We assume no depreciation of capital. Profit maximization ensures:

$$X_i = u_i B_i K_i = A_i L_i. \tag{4.2}$$

4.2.2 Society and preferences

There are two classes in society. Workers supply labor services and receive the wage rate w, uniform across sectors. They consume their whole income. Capitalists earn profits on the capital stock they own. Their propensity to save is $s > 0$.[1] Workers and capitalists share the same preferences, which are defined over the two goods. We assume that individual utility of agent j is:

$$U_j(c_s, c_m) = min[c_s, \alpha c_m],$$

where c_i is consumption of good i, and $\alpha > 0$. The fixed coefficient structure of preferences implies $c_s = \alpha c_m$. The same fixed proportion carries over to total demand:

$$C_s \equiv \sum_j c_s = \sum_j \alpha c_m = \alpha \sum\nolimits_j c_m \equiv \alpha C_m. \tag{4.3}$$

4.2.3 Mark-up prices

In line with the original Kaleckian literature, we assume that firms set prices by charging a constant mark-up (z_i) over unit labor cost. Mark-ups are sector specific and our crucial hypothesis is that they are relatively higher in the service sector, as this sector is less open to competition. If we let p_i be the price of good i, and we choose the service sector good as the numerarie we have $p_s = 1 = (1 + z_s)w/A_s$ and $p_m \equiv p = (1 + z_m)w/A_m$, with $z_s > z_m$. Accordingly

[1]We denote by s both the service sector and the saving rate. Given context no ambiguity should arise.

$$w = \frac{A_s}{1+z_s}, \tag{4.4}$$

$$p = \frac{1+z_m}{1+z_s}\frac{A_s}{A_m}. \tag{4.5}$$

4.2.4 Value added distribution

In each sector, value added is distributed as wages and profits to labor and capital employed in production. If we let r_i be the interest rate in sector i we have $p_i X_i = wL_i + r_i p_m K_i$, which, after using (4.2), (4.4), (4.5) and rearranging, yields

$$r_s = \frac{z_s}{1+z_m}\frac{A_m}{A_s}u_s B_s, \tag{4.6}$$

and

$$r_m = \frac{z_m}{1+z_m}u_m B_m. \tag{4.7}$$

4.2.5 Output uses

The service good is only used for consumption so that $X_s = C_s$. In what follows, it will be useful to distinguish consumption depending on its income source. We denote consumption out of wages as C_i^w, and consumption out of profits as C_i^π, so that

$$X_s = C_s = C_s^w + C_s^\pi. \tag{4.8}$$

Manufacturing output, on the contrary is used both for consumption and for investment (I) in the service and in the manufacturing sectors:

$$X_m = C_m + I. \tag{4.9}$$

4.2.6 Balanced growth under alternative closures

The discussion between Park (1995) and Dutt (1997) on the risk of overdetermination in the Kaleckian two sector growth model clarified that there are two possible consistent specifications of the model. In the first one, there is no sectoral capital mobility in the short run, so that K_s and K_m are given; we can specify sectoral growth rates, and profit rates will not be equalized unless by a fluke. The second version of the model assumes that the stock of capital moves between sectors to equate sectoral profit rates in the short run; in this framework, since the sectoral capital stocks are not state variables we can only specify the aggregate growth rate, rather than the sectoral ones.[2] We analyze the two specifications of the model in turn, and we show that the qualitative results on income distribution and structural change are independent of the model closure.

The model without profit rates equalization

Since workers do not save, the whole wage fund is spent as consumption out of wages. Using (4.3) and (4.2) we have

$$C_m^w + C_s^w = C_s^w/\alpha + C_s^w = w(L_s + L_m) = w\left(\frac{u_s B_s K_s}{A_s} + \frac{u_m B_m K_m}{A_m}\right).$$

Hence, factorizing C_s^w and substituting for the wage rate from (4.4) yields

$$C_s^w = \frac{\alpha}{1+\alpha}\frac{A_s}{1+z_s}\left(\frac{u_s B_s K_s}{A_s} + \frac{u_m B_m K_m}{A_m}\right) = \frac{\alpha}{1+\alpha}\frac{1}{1+z_s}\left(u_s B_s K_s + \gamma u_m B_m K_m\right), \tag{4.10}$$

where $\gamma \equiv A_s/A_m$.

On the other hand, capitalists' propensity to consume out of profits (Π) is $(1-s)$. Accordingly

$$C_m^\pi + C_s^\pi = C_s^\pi/\alpha + C_s^\pi = (1-s)\left(r_m p K_m + r_s p K_s\right),$$

which, using (4.5),(4.6) and (4.7) implies

$$C_s^\pi = \frac{\alpha}{1+\alpha}\frac{1-s}{1+z_s}\left(z_s u_s B_s K_s + z_m \gamma u_m B_m K_m\right).$$

Once we know consumption out of wages and profits in the service sector we can use equation (4.8) to find

$$X_s = \frac{\alpha}{1+\alpha}\frac{1}{1+z_s}\left(u_s B_s K_s(1+(1-s)z_s) + \gamma u_m B_m K_m(1+(1-s)z_m)\right).$$

Define $\delta \equiv K_s/K \in [0,1]$ as the share of the capital stock employed in the service sector, to be determined in equilibrium. Dividing both sides of the previous equation by K and rearranging yields

$$\delta u_s B_s = (1-\delta) u_m B_m \gamma \frac{\alpha(1+(1-s)z_m)}{1+z_s(1+\alpha s)} \equiv (1-\delta) u_m B_m \gamma \Gamma(\alpha, s). \tag{4.11}$$

[2] A variant of this version of the model assumes that profit rates equalization is a slow process. Sectoral capital stocks are given and sectoral investment depends on the profit rates differential. We explore this variant in the stability analysis.

It is easy to show that Γ is a positive function of α and negative of s, when $z_s > z_m$. Let us now turn to the equilibrium in the manufacturing sector. If we let g_i be the growth rate of sector i, under the assumption of no sectoral capital mobility, equation (4.9) becomes $X_m = C_s/\alpha + g_m K_m + g_s K_s = X_s/\alpha + g_m K_m + g_s K_s$, where we used (4.3). Using factors demand found in (4.2), and dividing both sides by K, the previous condition becomes

$$u_m B_m(1-\delta) = u_s B_s \delta/\alpha + g_m(1-\delta) + g_s\delta. \tag{4.12}$$

The Kaleckian tradition posits that investment depends on utilization of capacity as a measure of aggregate demand. In our case, the actual growth rate of capital in each sector (g_i) is a function of the sector's degree of capacity utilization:

$$g_m = g_m(u_m), \tag{4.13}$$

and

$$g_s = g_s(u_s). \tag{4.14}$$

Finally, balanced growth requires that sectoral growth rates be equalized

$$g_m = g_s. \tag{4.15}$$

We have a consistent system of five equations, (4.11),(4.12),(4.13),(4.14) and (4.15), in the five unknowns $\delta, u_m, u_s, g_m, g_s$. Our focus is on income distribution. The profit share π is the ratio between the value of total profits and value added. We can use (4.2), (4.5), (4.6), (4.7), (4.11) to calculate its equilibrium value

$$\pi^* = \frac{r_s p K_s + r_m p K_m}{X_s + pX_m} = p\frac{r_s\delta + r_m(1-\delta)}{\delta u_s B_s + (1-\delta)p u_m B_m} =$$

$$\frac{p}{1+z_m}\frac{u_s\delta/\gamma + z_m u_m(1-\delta)}{\delta u_s B_s + (1-\delta)p u_m B_m} = \frac{z_s\Gamma(\alpha,s) + z_m}{(1+z_s)\Gamma(\alpha,s) + (1+z_m)}. \tag{4.16}$$

Inspection of (4.16) shows that π^* is economically meaningful being bounded between zero and one. It is a function of the sectoral mark-ups, consumers' preferences between the two consumption goods, and the saving rate.

We are now in a position to state:

Proposition 1. *an increase in consumption demand of the service good relative to the manufacturing good (a rise in α) raises the equilibrium profit share.*

Proof. See the Appendix. □

Proposition 2. *a decrease in the saving rate raises the equilibrium profit share.*

Proof. See the Appendix. □

In both Proposition 1 and 2 the rise in the profit share follows the increase in Γ due to shocks to α and s. In order to understand the economic meaning of an increase in Γ we can re-write equation (4.11) as $X_s/(X_m\gamma) = L_s/L_m = \Gamma(\alpha, s)$. When Γ rises, employment in the service sector rises relative to the manufacturing one. Given labor producitivities and sectoral mark-ups, the change in relative employment carries over into relative sectoral value added. Therefore, the increase in the profit share depends on the change in the composition of production in favor of the sector with higher mark-up, which can be caused either by a change in consumers' preferences or by a reduction in the saving rate. Contrary to the standard one sector Kaleckian growth model, the profit share depends on savings.

The model with profit rates equalization

In the second version of the model, sectoral capital stocks are not state variables since capital adjusts in the short run to ensure profit rates equalization. Accordingly, there are no sectoral growth rates and we need to replace equation (4.12) with

$$u_m B_m(1-\delta) = u_s B_s \delta/\alpha + g. \tag{4.17}$$

Equation (4.11) is not affected by the new closure, whereas we need to drop (4.13) and (4.14) and replace them with a single equation for the growth rate of capital. We assume it depends on the degree of capacity utilization in both sectors:

$$g = g(u_s, u_m). \tag{4.18}$$

Next, we impose the equalization of profit rates across sectors, so that $r_s = r_m$. Using (4.6) and (4.7), the equalization yields:

$$u_s = \frac{A_s}{A_m}\frac{z_m}{z_s}\frac{B_m}{B_s}u_m. \tag{4.19}$$

We now have a consistent system of four equations, (4.11),(4.17),(4.18) and (4.19), in the four unknowns δ, u_m, u_s, g. In particular, use (4.19) into (4.11) to find

$$\delta^* = \frac{\Gamma(\alpha, s)}{\Gamma(\alpha, s) + z_m/z_s}. \tag{4.20}$$

Let us now turn to the profit share:

$$\pi^* = \frac{r_s p K_s + r_m p K_m}{X_s + pX_m} = \frac{rp}{\delta u_s B_s + (1-\delta) p u_m B_m} =$$

$$= \frac{z_m}{(1-\delta)\left((1+z_s)\,\Gamma(\alpha,s)+1+z_m\right)} = \frac{z_s\Gamma(\alpha,s)+z_m}{(1+z_s)\Gamma(\alpha,s)+(1+z_m)}, \tag{4.21}$$

where we used the equalization of profit rates, (4.2), (4.5), (4.6), (4.7), (4.11), and (4.20). Equations (4.13) and (4.21) show that the final expression for the profit share is the same irrespective of the model closure; therefore, a shift of consumers' preferences in favor of the service sector and a decrease in the saving rate bring about an increase in the profit share, whether we assume profit rates equalization or not.

4.2.7 Stability

We now turn to the stability analysis of the balanced growth path. In the model with profit rate equalization, however, the adjustment to the balanced growth equilibrium is instantaneous and there is no transitional dynamics. In order to introduce a dynamic adjustment in this version of the model, we assume that sectoral profit rates are different in the short run, but changes in sectoral investment bring about profit rates equalization in the long run. This is the process known as 'classical competition'. After this modification, the dynamics of the economy in both models is described by the slow adjustment in the the allocation of capital between sectors. To the purpose, we derive a differential equation for δ, the share of capital employed in the service sector. Given the definition of δ, taking time derivative and rearranging yields

$$\dot{\delta} = \delta(1-\delta)(g_s - g_m). \tag{4.22}$$

The model without profit rate equalization

In order to study the dynamic behavior of δ, we start by assuming explicit functional forms for sectoral growth rates. Equations (4.13) and (4.14) become

$$g_s = \vartheta_0 + \vartheta_1 u_s \tag{4.23}$$

and

$$g_m = \beta_0 + \beta_1 u_m. \tag{4.24}$$

We can use the two previous equations together with (4.11) and (4.12) to solve for utilization rates as functions of δ :

$$u_s(\delta) = \frac{\gamma\Gamma(\alpha,s)}{B_s\Theta}\left(\beta_0\frac{1-\delta}{\delta} + \vartheta_0\right) \tag{4.25}$$

and

$$u_m(\delta) = \left(\beta_0 + \vartheta_0 \frac{\delta}{1-\delta}\right) / \Theta, \tag{4.26}$$

where $\Theta = [1 - (\beta_1 + \gamma\Gamma(\alpha, s)(\vartheta_1/B_s + 1/\alpha))]$. Notice that economically meaningful (positive) solutions for u_m and u_s require $\Theta > 0$, that is $(\beta_1 + \gamma\Gamma(\alpha, s)(\vartheta_1/B_s + 1/\alpha)) < 1$. This condition is the equivalent of the standard Keynesian 'stability' condition in one-sector Kaleckain growth models, which states that investment need be less responsive than saving to economic activity. β_1 and ϑ_1 represent how sectoral invesment reacts to capacity utilization; the role of saving is captured by $\Gamma(\alpha, s)$, which is a negative function of the saving rate.

We can rewrite (4.22) as

$$\dot{\delta} = \delta(1-\delta)\left[g_s(\delta) - g_m(\delta)\right],$$

and state

Proposition 3. *The system has two locally unstable trivial steady states at $\delta = 0$ and $\delta = 1$. The system has one non-trivial steady state δ^*, which is asymptotically stable for $\delta \in (0, 1)$.*

Proof. see the Appendix. □

Proposition 3 shows that if the intial condition of the system is such that both sector exist, the economy will converge towards the non- trivial steady state. If, on the other hand, the economy consists of only one sector at the beginning of time, the two-sector structure will never appear. Notice, however, that $\delta = 1$ does not have economic meaning because there cannot be accumulation of capital without production of the manufacturing good. When $\delta = 0$, we are back to the standard one-sector model, where the only output is used for both consumption and investment.

The model with profit rates equalization

In order to introduce a dynamic adjustment in this version of the model, we assume that profit rates equalization is not instantaneous. Sectoral profit rates are different in the short run, but changes in sectoral investment bring about profit rates equalization in the long run. We follow Dutt (1997) in assuming that the difference in sectoral growth rates depends on the profit rates differential

$$g_s - g_m = \lambda(r_s - r_m), \lambda > 0. \tag{4.27}$$

On the other hand, firms choose the total rate of invesment based on the average degree of capacity utilization in the economy $\bar{u}$. Assuming a linear form for the investment function we have:

$$g = g(\bar{u}) = \mu_0 + \mu_1 \bar{u}, \tag{4.28}$$

where

$$\bar{u} = \frac{X_s + pX_m}{pK} = \frac{1 + z_m}{1 + z_s} \frac{u_s \delta B_s}{\gamma} + u_m(1 - \delta)B_m.$$

We can now use (4.11), (4.17), (4.6), (4.7) and (4.28) to solve for sectoral profit rates as functions of δ :

$$r_s(\delta) = \frac{z_s}{1 + z_m} \frac{1}{\gamma} B_s u_s(\delta) = \frac{z_s}{1 + z_m} \frac{\mu_0}{\Psi} \frac{1}{\delta}, \tag{4.29}$$

and

$$r_m(\delta) = \frac{z_m}{1 + z_m} B_m u_m(\delta) = \frac{z_m}{1 + z_m} \frac{\mu_0}{\Psi} \frac{1}{1 - \delta}, \tag{4.30}$$

where $\Psi = \left[1 - \gamma\Gamma(\alpha, s)/\alpha - \mu_1 \left(1 + \frac{1+z_m}{1+z_s}\Gamma(\alpha, s)\right)\right]$. Economically meaningful (positive) solutions for r_m and r_s require $\Psi > 0$. Similarly to the previous case, we can interpret it as the equivalent of the standard Keynesian 'stability' condition in one-sector Kaleckian growth models. Using the latest results and (4.27) in (4.22) we find

$$\dot{\delta} = \lambda\delta(1 - \delta)\left[r_s(\delta) - r_m(\delta).\right] \tag{4.31}$$

We can state

Proposition 4. *The system has two locally unstable trivial steady states at $\delta = 0$ and $\delta = 1$. The non trivial steady state $\delta^* = \frac{\Gamma(\alpha,s)}{\Gamma(\alpha,s)+z_m/z_s}$ is asymptotically stable over $\delta \in (0, 1)$.*

Proof. See the Appendix. □

Similarly to the comparative dynamics results found in Proposition 1 and 2, the comparison between Proposition 3 and 4 show that the stability properties of the model are independent of the model closure.

4.3 Conclusions

Evidence on the process of structural change shows that the share of the service sector in the total economy tends to rise as countries become richer (Herrendorf et al. , 2014). Since, as documented in Alvarez-Cuadrado et al. (2018), the wage share in the service sector is relatively low, growth and structural tranformation in mature economies necessarily bring about a reduction in the aggregate wage share, absent mitigating factors. As a consequence, changes in the composition of output and employment across sectors should be taken into account when investigating the ongoing negative trend in the wage share in most industrialized countries.

This paper has adopted the Kaleckian two-sector growth model of growth and distribution to analyze this process. We have shown that there is one (non trivial) unique asymptotically stable balanced growth path. The steady state functional income distribution depends on the composition of output, which, in turn, changes with consumers' preferences over the two consumption goods and with the saving rate. When the size of the service sector rises the profit share increases.

4.4 Appendix

4.4.1 Proof of Proposition 1

$$\frac{d\pi^*}{d\alpha} = \frac{(z_s - z_m)\Gamma'_\alpha(\alpha, s)}{((1+z_s)\Gamma(\alpha, s) + (1+z_m)\gamma)^2} > 0,$$

since $z_s > z$ and $\Gamma'_\alpha(\alpha, s) = \frac{\alpha(1+(1-s)z_m)(1+z_s)}{(1+z_s(1+\alpha s))^2} > 0$.

4.4.2 Proof of Proposition 2

$$\frac{d\pi^*}{ds} = \frac{(z_s - z_m)\Gamma'_s(\alpha, s)}{((1+z_s)\Gamma(\alpha, s) + (1+z_m)\gamma)^2} < 0,$$

since $z_s > z$ and $\Gamma'_s(\alpha, s) = \frac{-\alpha(z_m+\alpha z_s+z_m z_s(1+\alpha))}{(1+z_s(1+\alpha s))^2} < 0$.

4.4.3 Proof of Proposition 3

Let us start with the two trivial steady state. Inspection of (4.22) shows that $\dot{\delta} = 0$ at $\delta = 0$, and $\delta = 1$. Turning to stability, we have $\frac{d\dot{\delta}}{d\delta} = (1-\delta)\left[g_s(\delta) - g_m(\delta)\right] - \delta\left[g_s(\delta) - g_m(\delta)\right] + \delta(1-\delta)\left[g'_s(\delta) - g'_m(\delta)\right]$. At $\delta = 0$, $g_s(0)$ is not defined but $lim_{\delta\to 0}\frac{d\dot{\delta}}{d\delta} = lim_{\delta\to 0}\left[g_s(\delta) - g_m(\delta)\right] \to \infty > 0$, so that the first trivial steady state is locally unstable. At $\delta = 1$, $g_m(1)$ is not defined but $lim_{\delta\to 1}\frac{d\dot{\delta}}{d\delta} = lim_{\delta\to 1} - \left[g_s(\delta) - g_m(\delta)\right] \to \infty > 0$, so that the second trivial steady state is locally unstable.Let us now to turn to prove the existence and stability of the non-trivial steady state. Plug 4.25 and (4.26) into (4.22) to find

$$\dot{\delta} = \delta(1-\delta)\left[\vartheta_0 + \vartheta_1\frac{\gamma\Gamma(\alpha,s)}{B_s\Theta}\left(\beta_0\frac{1-\delta}{\delta} + \vartheta_0\right) - \beta_0 - \beta_1\left(\beta_0 + \vartheta_0\frac{\delta}{1-\delta}\right)/\Theta\right]$$
$$= \delta(1-\delta)\left[\vartheta_0 - \beta_0 + \vartheta_1\frac{\gamma\Gamma(\alpha,s)}{B_s\Theta}\vartheta_0 - \beta_1\beta_0/\Theta\right] + (1-\delta)^2\vartheta_1\frac{\gamma\Gamma(\alpha,s)}{B_s\Theta}\beta_0 - \delta^2\beta_1\vartheta_0/\Theta$$

$= \delta^2(K_2 - K_1 - K_3) + \delta(K_1 - 2K_2) + K_2$, where $K_1 = \vartheta_0 - \beta_0 + \vartheta_1 \frac{\gamma\Gamma(\alpha,s)}{B_s\Theta}\vartheta_0 - \beta_1\beta_0/\Theta$, $K_2 = \vartheta_1 \frac{\gamma\Gamma(\alpha,s)}{B_s\Theta}\beta_0$, and $K_3 = \beta_1\vartheta_0/\Theta$. Therefore $\dot{\delta}(\delta)$ is a quadratic function. As a first step, notice that $\dot{\delta}(0) = K_2 > 0$, and $\dot{\delta}(1) = -K_3 < 0$. Since $\dot{\delta}$ is continuous, over the domain $\delta \in [0,1]$, it must cross the horizontal axis from above at least once in order to move from positive to negative values, according to Bolzano's theorem for continuous functions defined over a compact set. In principle, there could be a second root since the function is quadratic, but that cannot be the case or there would need to be a third real root for the function to approach a negative value as $\delta \to 1$. Therefore, for $\delta \in (0,1)$ there can only be one steady state δ^*. It is asymptoticall stable as $\dot{\delta} < 0$ for $\delta > \delta^*$ and $\dot{\delta} > 0$ for $\delta < \delta^*$.

4.4.4 Proof of proposition 4

The analysis of two trivial steady states is analogous to the proof of proposition 3. Inspection of (4.31) shows that $\dot{\delta} = 0$ at $\delta = 0$ and $\delta = 1$. Turning to stability, we have $\frac{d\dot{\delta}}{d\delta} = \lambda(1-\delta)\left[r_s(\delta) - r_m(\delta)\right] - \lambda\delta\left[r_s(\delta) - r_m(\delta)\right] + \lambda\delta(1-\delta)\left[r_s'(\delta) - r_m'(\delta)\right]$. At $\delta = 0$, $r_s(0)$ is not defined but $lim_{\delta\to 0}\frac{d\dot{\delta}}{d\delta} = lim_{\delta\to 0}\left[r_s(\delta) - r_m(\delta)\right] \to \infty > 0$, so that the first trivial steady state is locally unstable. At $\delta = 1$, $r_m(1)$ is not defined but $lim_{\delta\to 1}\frac{d\dot{\delta}}{d\delta} = lim_{\delta\to 1} - \left[r_s(\delta) - r_m(\delta)\right] \to \infty > 0$, so that the second trivial steady state is locally unstable.

Let us now to turn to prove stability of the non-trivial steady state. $\forall\delta \in (0,1)$ we have $d\dot{\delta}/d\delta = -\frac{\lambda}{1+z_m}\frac{\mu_0}{\Psi}\delta(1-\delta)\left(z_s\frac{\Gamma(\alpha,s)}{\alpha}\frac{1}{\delta^2} - +z\frac{1}{(1-\delta)^2}\right) < 0$. Hence $\delta^* = \frac{\Gamma(\alpha,s)}{\Gamma(\alpha,s)+z_m/z_s}$ is asymptotically stable over $\forall\delta \in (0,1)$.

Chapter 5

Conclusions

The three essays presented in this thesis aim to explore different causes shaping the persistent declining pattern of aggregate wage share observed during the last decades in many advanced and developing countries. This evidence results in sharp contrast with the standard 'Kaldor facts' about growth and distribution and different theoretical explanations have been proposed within the economic literature following different perspectives. In Chapter 2 and Chapter 3 I analyze the role of *induced* and *directed* innovations, biased towards the adoption of excessive labor-saving production techniques, upon long-run growth and functional income distribution by implementing a closed-economy (Chapter 2) and a multi-country (Chapter 3) Agent Based-Stock Flow Consistent (SFC) model following a *Schumpeterian* and *Keynesian* theoretical approach.
The AB-SFC modeling approach enables us to analyze the *innovation bias* as an emergent property from the *evolutionary* technical change process engaged by heterogeneous consumption-good firms choosing both the *intensity* and the *direction* of innovations towards labor- or capital-saving production techniques. In both simulation models a persistent declining pattern of aggregate wage share emerges. This result is mainly driven by the complex interaction between biased innovation process, the dynamics of aggregate demand and the strength of workers bargaining power, which is negatively affected by higher levels of aggregate unemployment exacerbated in turns by the adoption of excessive labor-saving technical change. Moreover, the two-sector model specification presented in Chapter 3 also allows for the possibility of analyzing different patterns of sectoral (tradable and non-tradable) wage shares. In particular, the simulation results highlight how the faster capital-deepening within the tradable sector, due to the larger adoption of labor-saving innovations with respect to non-tradable sector, leads to a stronger declining pattern of the wage share for the tradable sector as well as a shift of the employment share from tradable to non-tradable sector. In additon, the multi-country framework

sheds a light on the emergence of persistent growth and productivity gaps among countries, with a consequent club formation between high- and low-performing countries, and shows how countries tend to orient their innovation effort on tradable sector consistently with a well-consolidated empirical evidence about international trade. In Chapter 4 I focus the attention on structural change as another important economic force driving the pattern of wage share. To the purpose I implement a two-sector Kaleckian analytical growth model in order to show how the sectoral shift of output and employment composition from manufacturing to service sector is also able to account for the persistent declining trend in the wage share in advanced capitalist economies. Focusing on the effects caused by different mark-ups values across sectors upon the composition of demand, this result is consistent with the simulations presented in Chapter 3 wherein the sectoral shift in the employment composition is endogenously driven by the relatively faster capital-deepening and the excessive innovation bias within the tradable sector with respect to non-tradable sector.

Bibliography

Acemoglu, D. (1998). 'Why Do New Technologies Complement Skills? Directed Technical Change and Wage Inequality', Quarterly Journal of Economics, 113(4): 1055-1089.

Acemoglu, D. (2002). 'Directed Technical Change', Review of Economic Studies, 69(4): 781-809.

Acemoglu, D. (2003). 'Labor- and Capital- Augmenting Technical Change', Journal of the European Economic Association, 1(1): 1-37.

Acemoglu, D. and V. Guerrieri (2008). 'Capital Deepening and Nonbalanced Economic Growth', Journal of Political Economy, 116(3): 467-498.

Acemoglu, D. (2015). 'Localized and Biased Technologies: Atkinson and Stiglitz's New View, Induced Innovations, and Directed Technological Change', The Economic Journal, 125(583): 443-463.

Alvarez-Cuadrado F., N. Van Long and M. Poschke (2018). 'Capital-Labor Substitution, Structural Change and the Labor Income Share', Journal of Economic Dynamics and Control, 87: 206-231.

Arrow, K. (1962). Economic Welfare and the Allocation of Resources for Invention. In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, 609-626, National Bureau of Economic Research, Inc.

Arthur, B. (1997). *The Economy as an Evolving Complex System II*, Addison-Wesley Reading, MA.

Atkinson, A. and J. Stiglitz (1969). 'A New View of Technological Change', The Economic Journal, 79(315): 573-578.

Badhuri, A. and S. Marglin (1990). 'Unemployment and the Real Wage: the Economic Basis for Contesting Political Ideologies', Oxford University Press, 4(14): 375-393.

Bassanini, A. and T. Manfredi (2012). 'Capital's Grabbing Hand? A Cross-Country/Cross-Industry Analysis of the Decline of the Labour Share', Eurasian Business Review, 4(1): 3-30.

Baumol, W. J. (1967). 'Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis', American Economic Review, 57: 415-26.

Baumol, W. and W. Bowen (1966). 'Performing Arts, The Economic Dilemma: a Study of Problems Common to Theater, Opera, Music, and Dance'. New York: Twentieth Century Fund.

Bental, B. and D. Demougin (2010). 'Declining Labor Shares and Bargaining Power: An Institutional Explanation', Journal of Macroeconomics, 32(1): 443-456.

Bentolila, S. and G. Saint-Paul (2003). 'Explaining Movements in the Labor Share', The B.E. Journal of Macroeconomics, 3(1): 1-33.

Bernard, A. B., J. J. Eaton, B. J. Jensen and S. Kortum (2003). 'Plants and Productivity in International Trade', American Economic Review, 93(4): 1268–1290.

Bernard, A. B., B. J. Jensen, S. J. Redding and P. K. Schott (2007). 'Firms in International Trade', Journal of Economic Perspectives, 21(3): 105–130.

Berthold, N., R. Fehn and E. Thode (2002). 'Falling Labour Share and Rising Unemployment: Long-Run Consequences of Institutional Shocks?', German Economic Review, 3(4): 431-59.

Blanchard, O. (1997). 'The Medium Run', Brookings Papers on Economic Activity, 28(2): 89-158.

Brock, E. and S. Dobbelaere (2006). 'Has international trade affected workers bargaining power?', Review of World Economics 142(2): 233-266.

Caiani, A., A. Godin, E. Caverzasi, M. Gallegati, S. Kinsella and J. E. Stiglitz (2016). 'Agent Based-Stock Flow Consistent Macroeconomics: Towards a Benchmark Model', Journal of Economic Dynamics and Control, 69(C): 375-408.

Caiani, A., E. Catullo, and M. Gallegati (2017). 'The Effects of Fiscal Targets in a Currency Union: A Multi-Country Agent Based-Stock Flow Consistent Model', Industrial and Corporate Change, dty016.

Caiani, A., E. Catullo, and M. Gallegati (2017). 'The Effects of Alternative Wage Regimes in a Monetary Union: A Multi-Country Agent Based-Stock Flow Consistent Model', SSNR.

Caiani, A., A. Russo, and M. Gallegati (2018). 'Does Inequality Hamper Innovation and Growth?', Journal of Evolutionary Economics, 28: 1-52.

Caiani, A., A. Russo, and M. Gallegati (2018). 'Are Higher Wages Good for Business? An Assessment Under Alternative Innovation and Investment Scenarios', Macroeconomic Dynamics, 1-40.

Calvino, F. and M. E. Virgillito (2018). 'The Innovation-Employment Nexus: a Critical Survey of Theory and Empirics', Journal of Economic Surveys, 32(1).

Cardinale, I., D. Coffman and R. Scazzieri (2017). *The Political Economy of the Eurozone*, Cambridge University Press.

Cass, D. (1965). 'Optimum Growth in an Aggregative Model of Capital Accumulation', Review of Economic Studies, 32(3): 233-240.

Cetrulo, A., V. Cirillo and D. Guarascio (2018). 'Weaker Jobs, Weaker Innovation. Exploring the Temporary Employment-Product Innovation Nexus', Laboratory of Economics and Management (LEM), Sant'Anna School of Advanced Studies, Pisa, Italy, LEM Papers Series, 2018/06.

Checchi, D. and C. Garcìa-Peñalosa (2010). 'Labour Market Institutions and the Personal Distribution of Income in the OECD', Economica, 77 (307): 413-450.

Dawid, H. (2006). Agent-based Models of Innovation and Technological Change. In Tesfatsion, L. and Judd, K. eds. *Handbook of Computational Economics,* Agent-Based Computational Economics, 2: 1235-1272.

Dawid, H., S. Gemkow, P. Harting, S. Van Der Hoog and M. Neugart (2012). 'The Eurace@Unibi Model: an Agent-Based Macroeconomic Model for Economic Policy Design.', Bielefeld Working Papers in Economics and Management, 5.

Dawid, H., P. Harting, and M. Neugart (2017). 'Fiscal Transfers and Regional Economic Growth', Review of International Economics.

De Grauwe, P. and Y. Ji (2013). 'Self-fulfilling crises in the Eurozone: An empirical test', Journal of International Money and Finance, 34(C): 15-36.

Delli Gatti, D., M. Gallegati and A. Russo (2006). Technological Innovation, Financial Fragility and Complex Dynamics. In Salvadori, N. Ed. *Economic Growth and Distribution: on the Nature and Causes of the Wealth of Nations,* Edward Elgar, Cheltenham, UK, 311-330.

Delli Gatti, D., E. Gaffeo, M. Gallegati, G. Giulioni and A. Palestrini (2007). *Emergent Macroeconomics: an Agent-Based Model of Business Fluctuations*, Springer.

De Serres, A., S. Scarpetta and C. Maisonneuve (2001). 'Falling Wage Shares in Europe and the United States: How Important is Aggregation Bias?', Empirica, 28(4): 375-401.

De Serres, A., S. Scarpetta and C. De La Maisonneuve (2002). 'Sectoral shifts in Europe and the United States: how they affect aggregate labour shares and the properties of wage equations', OECD, OECD Economics Department Working Papers, 2002/326.

Doan, Ha Thi Thanh & Wan, Guanghua (2017). 'Globalization and the Labor Share in National Income', ADBI Working Papers 639, Asian Development Bank Institute.

Dosi, G., G. Fagiolo and A. Roventini (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., and M. E. Virgillito (2015). 'Profit-Driven and Demand-Driven Investment Growth and Fluctuations in Different Accumulation Regimes', Journal of Evolutionary Economics, 707-728.

Dosi, G., G. Fagiolo, M. Napoletano and A. Roventini (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., M. E. Virgillito (2016). 'The Schumpeterian and the Keynesian Stiglitz: Learning, Coordination Hurdles and Growth Trajectories', Laboratory of Economics and Management (LEM), Sant'Anna School of Advanced Studies, Pisa, Italy, LEM Papers Series, 2016/20.

Dosi, G., M. Napoletano, A. Roventini and T. Treibich (2016). The Short- and Long-Run Damages of Fiscal Austerity: Keynes beyond Schumpeter. In Stiglitz J.E., Guzman M. eds. *Contemporary Issues in Macroeconomics,* Palgrave Macmillan, London.

Dosi, G., M. Pereira, A. Roventini and M. E. Virgillito (2017). 'When more Flexibility Yields more Fragility : the Microfoundations of Keynesian Aggregate Unemployment', Journal of Economic Dynamics and Control, 81:162-186.

Dosi, G., A. Roventini and E. Russo (2017). 'Endogenous growth and global divergence in a multi-country agent-based model', Laboratory of Economics and Management (LEM), Sant'Anna School of Advanced Studies, Pisa, Italy, LEM Papers Series, 2017/32.

Dosi, G. and M. E. Virgillito (2017). 'In Order to Stand Up You Must Keep Cycling: Change and Coordination in Complex Evolving Economies', Structural Change and Economic Dynamics.

Drandakis, E. M. and E. S. Phelps (1966). 'A Model of Induced Invention, Growth and Distribution', Economic Journal, 76(304): 823-840.

Dumenil, G. and D. Levy (1993). *The Economics of the Profit Rate. Competition, Crisis and Historical Tendencies in Capitalism*, Edward Elgar Publishing, Brookfield.

Dumenil, G. and D. Levy (1966). 'Being Keynesian in the Short Term and Classical in the Long Term: The Traverse to Classical Long-Term Equilibrium', Manchester School, 67(6): 684-716.

Dumenil, G. and D. Levy (2010). 'Technology and Distribution: Historical Trajectories a la Marx', Journal of Economic Behavior and Organization, 52(2): 201-233.

Dünhaupt, P. (2017). 'Determinants of Labour's Income Share in the Era of Financialisation,' Cambridge Journal of Economics, 41(1): 283-306.

Dutt, A. K. (1988). 'Convergence and Equilibrium in Two Sector Models of Growth, Distribution and Prices', Journal of Economics, 48: 2, 135–158.

Dutt, A. K. (1990). *Growth, Distribution and Uneven Development*, Cambridge, UK: Cambridge University Press.

Dutt, A. K. (1997). 'Profit-rate Equalization in the Kalecki-Steindl Model and the 'Over-Determination' Problem', The Manchester School, 65(4): 443-451.

Elsby, M., B. Hobjin, and A. Sahin (2013). 'The Decline of the U.S. Labor Share', Brookings Papers on Economic Activity, September 2013.

Fagiolo, G., G. Dosi and G. Roberto (2004). 'Matching, Bargaining and Wage Settingin an Evolutionary Model of Labor Market and Output Dynamics', Advances in Complex Systems, 14: 237-273.

Fanti, L. (2004). 'An AB-SFC Model of Induced Technical Change along Classical and Keynesian Lines', Department Social Sciences and Economics (DSSE), DSSE Papers Series, 3/2018.

Felipe, J. and U. Kumar (2014). 'Unit Labor Costs in the Eurozone: the Competitiveness Debate Again', Review of Keynesian Economics, 2(4):490-507.

Fellner, W. (2014). 'Two Propositions in the Theory of Induced Innovations', Economic Journal, 71(282): 305-308.

Foley, D. K. (2003). *Unholy Trinity: Labor, Capital and Land in the New Economy*, Routeledge.

Foley, D. K. (2003). 'Endogenous Technical Change with Externalities in a Classical Growth Model', Journal of Economic Behavior & Organization, 52(2): 167-189.

Foley, D. K. and T. R. Michl (1999). *Growth and Distribution*, Harvard University Press.

Franke, R. (2000). 'Optimal Utilization of Capital and a Financial Sector in a Classical Gravitation Process', Metroeconomica, 51 (1): 40-66.

Fujita, S. (2018). 'Mark-Up Pricing, Sectoral Dynamics, and the Traverse Process in a Two-Sector Kaleckian Economy', Cambridge Journal of Economics, https://doi.org/10.1093/cje/bey024.

Funk, P. (2002). 'Induced Innovation Revisited', Economica, 69(273):155-171.

Giavazzi, F. and M. Pagano (1990). 'Can Severe Fiscal Contractions Be Expansionary? Tales of Two Small European Countries', NBER Macroeconomics Annual, 5: 75-111.

Giavazzi, F. and L. Spaventa (2011). 'Why the Current Account May Matter in a Monetary Union. Lesson From the Financial Crisis in the Euro Area', IGIER (Innocenzo Gasparini Institute for Economic Research), Bocconi University, Working Paper, 426.

Godley, W. and M. Lavoie (2009). *Monetary Economics: an Integrated Approach to Credit,Money, Income, Production and Wealth*, Palgrave Macmillan.

Gollin, D. (2002). 'Getting Income Shares Right', Journal of Political Economy, 110(2): 458-74.

Goodwin, R. (1967). *A Growth Cycle*, Cambridge University Press.

Greenwald, B. C. and J. E. Stiglitz (1993). 'Financial Market Imperfections and Business Cycles', The Quarterly Journal of Economics, 108(1): 77-114.

Grossman, G. M. and E. Helpman (1991). 'Trade, Knowledge Spillovers, and Growth', European Economic Review, 35(2).

Habakkuk, J. H. (1962). *American and British Technology in the Nineteenth Century*, Cambridge University Press.

Herrendorf, B., R. Richard and A. Valentinyi (2014). 'Growth and Structural Transformation', in: Handbook of Economic Growth, volume 2, ch.(6),pp. 855-941.

Hicks, J. (1932). *Theory of Wages*, Macmillan.

Hicks, J. (1937). 'Mr Keynes and the 'Classics', a Suggested Interpretation', Econometrica, 5(2): 147-159.

Hotelling, H. (1929). 'Stability in Competition', Economic Journal, 39(153): 41-57.

Howitt, P. and P. Aghion (1998). 'Capital Accumulation and Innovation as Complementary Factors in Long-Run Growth', Journal of Economic Growth, 3(2): 111-130.

Hutchinson, J. and D. Persyn (2012). 'Globalisation, Concentration and Footloose Firms: in Search of the Main Cause of the Declining Labour Share', Review of World Economics, 148(1): 17-43.

IMF (2012). 'World Economic Outlook: Coping with High Debt and Sluggish Growth', International Monetary Fund (IMF), Chapter 3.

IMF (2017). 'World Economic Outlook, April 2017: Gaining Momentum?', International Monetary Fund (IMF).

Jaumotte, F. and P. Sodsriwiboon (2010). 'Current Account Imbalances in the Southern Euro Area', International Monetary Fund (IMF), IMF Working Paper Series, 10: 139-49.

Jayadev, A. (2007). 'Capital Account Openness and the Labour Share of Income', Cambridge Journal of Economics, 31(3): 423–443.

Jones, C. (2005). 'The Shape of Production Functions and the Direction of Technical Change', The Quarterly Journal of Economics, 120(2): 517-549.

Jones, C. (2015). 'The Facts of Economic Growth', The National Bureau of Economic Research, Inc, NBER Working Papers.

Jones, A. J. (2005). 'Steady-State Growth and Distribution with an Endogenous Direction of Technical Change', Metroeconomica, 56(1): 101-125.

Kaldor, N. (1957). 'A Model of Economic Growth', The Economic Journal, 67(268): 591-624.

Kaldor, N. (1961). Capital accumulation and economic growth. In F. A. Lutz and D. C. Hague, eds. *The Theory of Capital,* St. Martins Press.

Kaldor, N. (1970). 'The Case for Regional Policies', Scottish Journal of Political Economy, 17(3): 337-348.

Kaldor, N. (1978). The Effect of Devaluations on Trade in Manufactures. In *Further Essays on Applied Economics,* Duckworth, London.

Kaldor, N. (1981). 'The Role of Technical Progress and Cumulative Causation in the Theoryof International Trade and Economic Growth', Economie Applique, 34(3): 593-617.

Kalecki, M. (1971). *Selected Essays on the Dynamics of the Capitalist Economy*, Cambridge University Press.

Karabarbounis, L. and B. Neiman (2014). 'The Global Decline of the Labor Share', Quarterly Journal of Economics, 129(1): 61-103.

Kennedy, C. (1964). 'Induced Bias in Innovation and the Theory of Distribution', The Economic Journal, 74(295): 541-547.

Keynes, J. M. (1936). *The General Theory of Employment, Interest and Money*, Palgrave Macmillan.

Kirman, A. (2010). *Complex Economics. Individual and Collective Rationality*, Routledge.

Kongsamut, P. , S. Rebelo and D. Xie (2001). 'Beyond Balanced Growth', The Review of Economic Studies, 68(4): 869-882.

Koopmans, T. C. (1963). 'On the Concept of Optimal Economic Growth', Cowles Foundation for Research in Economics, Yale University, Cowles Foundation Discussion Papers.

Kutznets, S. (1957). 'Quantitative Aspects of the Economic Growth of Nations: II. Industrial Distribution of National Product and Labor Force', Econ. Development and Cultural Change, 5(4): 1-112.

Landesmann, M., S. Leiter and R. Stehrer (2015). 'Competitiveness of the European economy', European Investment Bank (EIB), EIB Working Papers, 2015/01.

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

Lavoie, M. and P. Ramirez-Gaston (1997). 'Travers in a Two-Sector Kaleckian Model of Growth with Target-Return Pricing', The Manchester School, 65 (2): 145-169.

Lavoie, M. and E. Stockhammer (2013). Wage-led Growth: Concept, Theories and Policies. In M. Lavoie and E. Stockhammer eds. *Wage-led Growth. Advances in Labour Studies,* Palgrave Macmillan, London.

Luca, R. J. (1988). 'On the Mechanics of Economic Development', Journal of Monetary Economics, 22(1): 3-42.

Matsuyama, K. (2008). Structural Change. In Steven N. Durlauf and Lawrence Blume eds. *The New Palgrave Dictionary of Economics,* New York.

Murakami, H. (2018). 'A Two-Sector Keynesian Model of Business Cycles', Metroeconomica, 69(2): 444-472.

Nakatani, T. (1979). 'Price Competition and Technical Choice', Kobe University Economic Review, 25: 66-77.

Napoletano, M., G. Dosi, G. Fagiolo and A. Roventini (2012). 'Wage Formation, Investment Behavior and Growth Regimes: An Agent-Based Analysis', Revue de l'OFCE, 0(5): 235-261.

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

Ngai, L. R. and C. Pissarides (2007). 'Structural Change in a Multisector Model of Growth', American Economic Review, 97(1): 429–443.

Nordhaus, W. D. (1973). 'Some Skeptical Thoughts on the Theory of Induced Innovation', The Quarterly Journal of Economics, 87(2): 208-219.

OECD (2012). 'Labour Losing to Capital: What explains the declining Labour Share?', Employment Outlook, Paris, Working Paper.

OECD (2015). 'The Labor Share in G20 Economies', International Labour Organization (ILO) and Organisation for Economic Co-operation and Development (OECD), Working Paper.

Okishio, N. (1961). 'Technical Changes and the Rate of Profit', Kobe University Economic Review, 7: 86-99.

Okishio, N. (2001). 'Competition and Production Prices', Cambridge Journal of Economics, 25(4): 493-501.

Onaran, Ö and T. Obst (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.

Park, M. S. (1995). 'A Note on the 'Kalecki-Steindl' Steady-state Approach to Growth and Income Distribution', The Manchester School, 63(3): 297-310.

Park, C. (2001). 'Criteria of Technical Choice and Evolution of Technical Change', Research in Political Economy, 19: 87-106.

Pasinetti, L. L. (1962). 'Rate of Profit and Income Distribution in Relation to the Rate of Economic Growth', Review of Economic Studies, 29(4): 267-279.

Pasinetti, L. L. (1981). *Structural Change and Economic Growth*, Cambridge University Press.

Pasinetti, L. L. (2006). *Keynes e i Keynesiani di Cambridge, Editori Laterza.*

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

Piketty T. , Zucman G. (2014). 'Capital is back: wealth-income ratios in rich countries 1700-2010', Quarterly Journal of Economics, 129 (3): 1255-1310.

Ramsey, F. (1928). 'A Mathematical Theory of Saving', Economic Journal, 38(152): 543-559.

Reinhart, C. and K. Rogoff (2010). 'Growth in a Time of Debt', American Economic Review Papers and Proceedings, 100: 537-578.

Riccetti, L., A. Russo and M. Gallegati (2012). 'An Agent Based Decentralized Matching Macroeconomic Model', Journal of Economic Interaction and Coordination, 10(2): 305-332.

Rober, P. M. (1989). Capital Accumulation In The Theory Of Long Run Growth. In Barro, J., Ed. *Modern Business Cycle Theory,* Harvard University Press, New York, 51-127.

Romer, P. M. (2016). 'The Trouble with Macroeconomics', Stern School of Business Working Paper.

Salop, S. C. (1979). 'Monopolistic Competition with Outside Goods', The Bell Journal of Economics, 10(1): 141-156.

Salter, W. E. G. (1962). *Productivity and Technical Change*, Cambridge University Press.

Samuelson, P. (1965). 'A Theory of Induced Innovation along Kennedy-Weiszäcker Lines', Review of Economics and Statistics, 47(4): 343-356.

Shaikh, A. (1978). 'Political Economy and Capitalism: Notes on Dobb's Theory of Crisis', Cambridge Journal of Economics, 2: 233-251.

Shaikh, A. (1999). 'Explaining the Global Economic Crisis: a Critique of Brenner', Historical Materialis, 5: 103-144.

Shaikh, A. (2016). *Capitalism. Competition, Conflict and Crises*, Oxford University Press.

Solow, R. (1956). 'A Contribution to the Theory of Economic Growth', Quarterly Journal of Economics, 70(1): 65-94.

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

Stiglitz, J. E. (1967). *A Two-Sector Two Class Model of Economic Growth*', Review of Economic Studies, 34(2): 227-238.

Stiglitz, J. E. (2012). *The Price of Inequality: How Today's Divided Society Endangers Our Future*, W.W. Norton Company.

Stiglitz, J. E. (2015). 'Unemployment and Innovation', Institute for New Economic Thinking, Working Papers Series, 1.

Stiglitz, J. E. and B. Greenwald (2015). *Creating a Learning Society. A New Approach to Growth, Development and Social Progress*, Columbia University Press.

Stiglitz, J. E. (2016). New Theoretical Perspectives on the Distribution of Income and Wealth Among Individuals, In Basu K., Stiglitz J.E. (eds), *Inequality and Growth: Patterns and Policy,*Palgrave Macmillan, London.

Stiglitz, J. E. (2018). 'Where Macroeconomics Went Wrong', Oxford Review of Economic Policy, 34(1-2): 70-106.

Stockhammer, E., Ö. Onaran and S. Ederer (2008). 'Functional Income Distribution and Aggregate Demand in the Euro Area', Cambridge Journal of Economics, 33(1): 139-159.

Stockhammer, E. (2013). 'Why Have Wage Shares Fallen? A Panel Analysis of the Determinants of Functional Income Distribution: for the International Labour Organisation (ILO) project "New Perspectives on Wages and Economy', International Labour Organization, ILO Working Papers, 994709133402676.

Stockhammer, E. and D. P. Sotiropoulos (2014). 'Rebalancing the Euro Area: The Costs of Internal Devaluation', Review of Political Economy, 26(2): 210-233.

Stockhammer, E. and M. Lavoie (2012). 'Wage-led Growth : Concepts, Theories and Policies', International Labour Organization, ILO Working Papers, 41.

Stockhammer, E. (2017). 'Determinants of the Wage Share: A Panel Analysis of Advanced and Developing Economies', British Journal of Industrial Relations, 55(1): 3-33.

Storm, E S. and C. W. M. Naastepad (2015). 'Europe's Hunger Games: Income Distribution, Cost Competitiveness and Crisis', Cambridge Journal of Economics, 39(3): 959-986.

Storm, E S. and C. W. M. Naastepad (2015). 'NAIRU Economics and the Eurozone Crisis', International Review of Applied Economics, 29(6): 843-877.

Nishi, H. (2018). 'A Dynamic Analysis of Demand and Productivity Growth in a Two-sector Kaleckian Model', MPRA Paper 86778, University Library of Munich, Germany.

Sylos Labini, P. (1957). *Oligopolio e Progresso Tecnico*, Rubbettino Editore.

Sylos Labini, P. (2015). 'Factors Affecting Changes in Productivity', Journal of Post Keynesian Economics, 6(2): 161-179.

Tavani, D. and L. Zamparelli (2018). 'Endogenous Technical Change in Alternative Theories of Growth and Distribution', Journal of Economic Surveys, 31(5): 1272-1303.

Uzawa, H. (1965). 'Optimum Technical Change in an Aggregative Model of Economic Growth', International Economic Review, 6(1): 18-31.

Van Der Ploeg, F. (1987). 'Growth Cycles, Induced Technical Change, and Perpetual Conflict Over the Distribution of Income', Journal of Macroeconomics, 9(1): 1-12.

Vivarelli, M. (2015). 'Innovation and employment', IZA World of Labor, 154.

Young, A. T. (2004). 'Labor's Share Fluctuations, Biased Technical Change and the Business Cycle', Review of Economic Studies, 7(4): 916-931.

Zamparelli, L. (2015). 'Induced Innovation, Endogenous Technical Change and Income Distribution in a Labor-Constrained Model of Classical Growth', Metroeconomica, 66(2): 243-262.

Zeira, J. (1998). 'Workers, Machines, and Economic Growth', The Quarterly Journal of Economics, 113(4): 1091-1117.

Zuleta, H. and A. T. Young (2013). ‘Labor Shares in a Model of Induced Innovation’, Structural Change and Economic Dynamics, 24(C): 112-122.