UNIVERSIDADE ESTADUAL DE CAMPINAS
INSTITUTO DE ECONOMIA

LILIAN NOGUEIRA ROLIM

INCOME INEQUALITY, ECONOMIC ACTIVITY, AND ECONOMIC POLICY IN AN AGENT-BASED MACROECONOMIC MODEL

DESIGUALDADE DE RENDA, ATIVIDADE ECONÔMICA E POLÍTICA ECONÔMICA EM UM MODELO MACROECONÔMICO BASEADO EM AGENTES

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Supervisor: Prof. Dr. Carolina Troncoso Baltar
Co-supervisor: Prof. Dr. Gilberto Tadeu Lima

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Profa. Dra. Carolina Troncoso Baltar - Presidente e Orientadora

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A Ata da Defesa, assinada pelos membros da Comissão Examinadora, consta no SIGA/Sistema de Fluxo de Dissertação/Tese e na Secretaria do Programa da Unidade.

O que é *liberté*? A liberdade. Que liberdade? A liberdade, igual para todos, de fazer o que bem se entender, dentro dos limites da lei. Mas quando é que se pode fazer o que bem se entender? Quando se possui um milhão. A liberdade concede acaso um milhão a cada um? Não. O que é um homem desprovido de milhão? O homem desprovido de milhão não é aquele que faz o que bem entende, mas aquele com quem fazem o que bem entendem.
F. Dostoiévski, Notas de inverno sobre impressões de verão

Entendamo-nos a respeito da igualdade, porque se a liberdade é o ápice, a igualdade é a base.
V. Hugo, Os miseráveis

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Resumo

Esta tese investiga as dimensões macroeconômicas da desigualdade de renda, explorando as implicações distributivas de fatores econômicos e os efeitos bidirecionais entre distribuição de renda e variáveis macroeconômicas, como crescimento econômico e inflação. A principal questão de pesquisa diz respeito às condições sob as quais crescimento econômico inclusivo pode ser alcançado. Para investigar essa questão de pesquisa, cada capítulo trata de uma questão mais específica, explorando, assim, as diferentes camadas que formam a complexa e bidirecional relação entre distribuição de renda e atividade econômica. O capítulo 1 trata da interação entre poder de barganha dos trabalhadores e crescimento da produtividade, explorando suas implicações para a distribuição de renda e crescimento econômico. Para isso, um novo modelo baseado em agentes com características kaleckianas é construído. As principais novidades do modelo são um novo e mais detalhado processo de barganha salarial entre empresas e trabalhadores capturando o conflito sobre os salários nominais, um novo componente estratégico para a margem de lucro das empresas e uma estrutura social de três classes. O modelo é empregado para analisar a interação entre crescimento da produtividade, que potencialmente beneficia as empresas ao reduzir custos unitários, e poder de barganha dos trabalhadores, que potencialmente beneficia os trabalhadores ao afetar os salários nominais. O capítulo mostra que a relação entre distribuição de renda e crescimento do produto depende da força relativa dos principais parâmetros que determinam suas dinâmicas e identifica um dilema de política quando há um *trade-off* entre estimular a atividade econômica e o crescimento da produtividade e promover mais igualdade, que pode, contudo, ser atenuado por políticas protegendo os trabalhadores. O capítulo 2 investiga o efeito de choques externos na distribuição de renda, atividade econômica e inflação em uma economia aberta, estendendo, assim, o modelo baseado em agentes apresentado no capítulo anterior para uma economia aberta ao comércio internacional de bens de consumo. São investigados choques externos de demanda e de preços e os resultados sugerem que o tipo de choque, sinal, magnitude e duração são de importância primordial para o efeito sobre a distribuição de renda. Ademais, o tipo de choque importa para a relação entre crescimento econômico e distribuição de renda, bem como para a relação entre crescimento econômico e taxa de câmbio real e para a natureza da inflação. Finalmente, o capítulo 3 investiga o que poderia ser feito para reduzir as desigualdades de renda. Os experimentos são baseados no modelo do capítulo 2 e exploram o efeito e a interação de regulamentações no mercado de trabalho e políticas redistributivas. A combinação destes instrumentos é eficaz para alcançar mais igualdade e exerce efeito positivo na dinâmica do produto e do emprego. Além disso, o capítulo destaca a natureza complexa da relação bidirecional entre estes instrumentos e a distribuição de renda, bem como entre distribuição de renda e variáveis macroeconômicas como crescimento econômico e inflação. Um cenário pró-trabalhar é caracterizado por mais igualdade e maiores taxas de crescimento econômico mas requer um desenho cuidadoso e avaliação dos efeitos e interações entre estes instrumentos.

Palavras-chave: modelos baseados em agentes, distribuição de renda, parcela salarial, crescimento econômico, inflação, choques externos, política econômica

Abstract

This dissertation investigates the macroeconomic dimensions of income inequality by exploring the distributive implications of economic factors and the feedback effects between income distribution and macroeconomic variables, such as output growth and inflation rates. The main research question concerns the conditions under which inclusive economic growth can be achieved. To investigate this research question, each chapter deals with a more specific and derived research question, thus exploring the different layers that form the complex and two-way relationship between income distribution and economic activity. Chapter 1 deals with the interplay between workers' bargaining power and productivity growth and explores its implications for income distribution and output growth. In order to do so, a novel agent-based model with Kaleckian features is set forth. The main novelties of the model are a new and more inclusive wage bargaining process between firms and workers capturing the conflict over nominal wages, a new strategic component to firms' mark-up rates, and a three-class social structure. The model is employed to analyze the interaction between productivity growth, which potentially benefits firms by reducing unit costs, and workers' bargaining power, which potentially benefits workers by affecting nominal wages. The chapter shows that the relationship between income distribution and output growth largely depends on the relative strength of the key parameters determining the dynamics of these variables and identifies a policy dilemma when there is a trade-off between stimulating economic activity and productivity growth and promoting more equality in the income distribution, which can, nonetheless, be attenuated by policies protecting workers. Chapter 2 investigates the effect of foreign shocks on income distribution, economic activity, and inflation in an open economy, thus extending the agent-based model set forth in the preceding chapter to an economy open to international trade of consumption goods. The effects of a foreign demand and a foreign price shock are investigated and simulation results suggest that the type of shock, sign, magnitude, and length are of primary importance for understanding how income distribution is affected. Also, the type of shock matters for the relationship between output growth and income distribution, as well as for the relationship between output growth and the real exchange rate and for the nature of inflation. Finally, chapter 3 investigates what could be done to reduce income inequalities. The experiments are based on the model presented in chapter 2 and explore the effect and interaction of labor market regulations and redistributive policies. The combination of these policy tools is effective to achieve more equality, while also exerting a positive effect on the output dynamics and employment levels. Moreover, the chapter highlights the complex nature of the two-way relationship between these regulations and policies and income distribution, as well as between income distribution and macroeconomic variables such as output growth and inflation. Thus, while a pro-labor scenario is characterized by more equality and higher output growth rates, careful design and evaluation of the effects and interactions between these policy tools are also recommended.

Keywords: agent-based models, income distribution, wage share, economic growth, inflation, foreign shocks, economic policy

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List of Acronyms

AB	Agent-based
AMW	Active minimum wage
DNWR	Downward nominal wage rigidity
DoE	Design of experiments
FT	Flat taxation
HWBP	High workers' bargaining power
LWBP	Low workers' bargaining power
NOLH	Nearly Orthogonal Latin Hypercube
PMW	Passive minimum wage
PT	Progressive taxation
UBP	Unemployment benefit periods
US	United States

List of Symbols

Latin letters

b	payback rule threshold
$b_{m,t}$	payback period for machine m
c_1	real consumption persistence
c_2^j	propensity to consume out of income for class j
c_3	propensity to consume out of deposits
c_x	propensity to consume in foreign sector
$C_{H,t}^{\$}$	aggregate nominal consumption
$C_{h,t}^{D,\$}$	consumption demand
cpi_t	consumers price index
$D_{f,t}^{\$,*}$	deposits held by firms in the beginning of the period
$D_{f,t}^{\$}$	deposits held by firms
$D_{h,t}^{\$}$	deposits held by households
$d_{h,t}^{\$}$	unemployment benefit
$\bar{E}_t$	average competitiveness in consumption goods market
$E_{c,t}$	firm's competitiveness
g_t	output growth rate
g_x	growth rate of foreign sector's output
h	sensitivity of productivity to unfilled demand for managers and supervisors
i	fixed nominal interest rate
i_t	interest nominal rate (inflation targeting regime)
i^{min}	minimum interest rate
i_x	interest rate of foreign sector
$I_{c,t}$	realized investment
$I_{C,t}^{\$}$	aggregate nominal investment
$I_{c,t}^{D}$	investment demand
i_t^{dif}	interest rate differential
$I_{c,t}^{fc}$	expansion investment
$I_{c,t}^{r}$	replacement investment
$IM_t^{\$}$	aggregate imports denominated in domestic currency
$IM_t^{D,\$}$	aggregate imports demand denominated in domestic currency
k	degree of pricing to market

$L_{f,t}^{D,j}$	number of workers of type j demanded by firm f
$L_{c,t}^{dir,fc}$	number of direct workers at full capacity production level
$L_{f,t}^{j}$	number of workers of type j employed at firm f
L_{g}^{j}	number of workers of type j hired by public sector
$l_{c,t}^{n}$	normalized unfilled demand level
$m_{c,t}$	mark-up rate deviation due to unit costs dynamics
$m_{c,t}^{'}$	mark-up rate deviation due to exports dynamics
$ms_{c,t}$	domestic firms' market share of consumption goods market
$ms_{x,t}$	foreign sector's market share of consumption goods market
$ms_{c,t}^{'}$	domestic firms' market share of foreign consumption goods market
ms^{exp}	minimum market share of the domestic consumption goods market access the foreign market
ms^{min}	minimum market share to stay in consumption goods market
N^{c}	number of consumption goods firms
n^{g}	share of public servants in total initial employment (direct workers)
N^{h}	number of households
n^{IN}	desired inventories as a share of expected demand
N^{j}	number of households of type j
n^{j}	participation of class j in total of households
n^{mw}	threshold for income taxed at high tax rate (as multiples of minimum wage)
$n^{s,j}$	percentage of demanded workers for wage survey
n^{w}	number of hiring rounds per open position
$\hat{p}_{t}$	inflation rate
$\hat{p}^{T}$	inflation rate target
$\hat{p}_{x}$	inflation rate in foreign sector
$p_{f,t}^{\$}$	price of good sold by firm f
$p_{x,t}^{\$}$	price of good sold by foreign sector denominated in domestic currency
$\bar{p}_{t}^{C,*,\$}$	average price level of domestic consumption goods firms
$\bar{p}_{t}^{C,\$}$	average price level in consumption goods market
$\bar{p}_{t}^{C,e,\$}$	expected average price level in consumption goods market
$p_{c,t}^{n}$	normalized price level
$p_{x,t}^{x}$	price of good sold by foreign sector denominated in foreign currency
$Q_{f,t}$	production at firm f
$Q_{c,t}^{D,e,t}$	expected demand for period t
$Q_{c,t}^{D}$	demand for consumption goods
$Q_{f,t}^{d}$	desired production level
$Q_{c,t}^{e,t+1}$	expected production for period $t+1$
$Q_{c,t}^{fc}$	full capacity utilization production level

$Q^{fc}_{m,t}$	maximum production level per machine
$Q^{IN}_{c,t}$	inventories
$Q^{s}_{c,t}$	sales of consumption goods
R	maximum interest payments to average revenue
s	sensitivity of probability of on-the-job search to difference in wages
T^{c}	number of periods before an entrant firm can exit the market
$T^{w}_{h,t}$	periods of unemployment since last employment
T^{e}	number of periods in the exchange rate adjustment to changes in interest rate differential
T^{k}	machines lifetime
T^{p}	periods considered in inflation targeting regime
T^{u}	maximum number periods that unemployed workers receive unemployment benefit
u^{d}	desired capacity utilization rate
v	expansion investment adjustment speed
$w^{\$}_{h,t}$	wage received by workers
$W^{\$}_{t}$	aggregate nominal wages
$w^{d,*,\$}_{h,t}$	inflation-adjusted wage
$w^{d,\$}_{h,t}$	desired wage by workers
$w^{f,\$}_{f,t}$	wage desired by firm f for workers of type j
$w^{j,\$}_{f,t}$	wage payed by firm f to workers of type j
$w^{j,s,\$}_{f,t}$	average wage from survey
$\hat{w}^{max}$	maximum desired wage real growth rate
$w^{min,\$}_{t}$	minimum wage
$w^{r,\$}_{h,t}$	worker's reservation wage
$X_{c,t}$	exports
$X^{D}_{c,t}$	exports demand
x^{c}_{t}	change in direct workers' labor productivity of new machines
x^{k}_{t}	change in direct workers' labor productivity in capital goods sector
x	Beta distribution support parameter (innovation process)
$Y_{x,t}$	output level of foreign sector
$\bar{y}^{c,*}_{c,t}$	average direct workers' labor productivity at desired production level
$\bar{y}^{c}_{c,t}$	average direct workers' labor productivity at current production level
$y^{c,\star}_{t}$	direct workers' labor productivity of new machines currently produced
$y^{c,in}_{t}$	direct workers' labor productivity of new machines from innovation
$y^{k,in}_{t}$	direct workers' labor productivity of capital goods firm from innovation
y^{k}_{t}	direct workers' labor productivity of capital goods firm
$Y^{\$}_{H,t}$	aggregate nominal wages and profits
$Y^{high,\$}_{H,t}$	aggregate profit and labor incomes taxed at high tax rate

$Y_{H,t}^{low,\$}$	aggregate profit and labor incomes taxed at low tax rate

Greek letters

α	Beta distribution parameter (innovation process)
β	Beta distribution parameter (innovation process)
$\Gamma_{c,t}^{\$}$	total production costs (C firms)
$\Gamma_{c,t}^{u,\$}$	unit production costs (C firms)
$\Gamma_{c,t}^{e,\$}$	production budget (C firms)
γ_1	sensitivity of worker's desired wage to previous inflation rate
γ_2	sensitivity employed workers' desired wage to output growth rate
γ_3	sensitivity of workers' reservation wage to periods of unemployment
γ_4	minimum difference between desired and reservation wages
γ_5	sensitivity of unemployed workers' desired wage to periods of unemployment
γ_6	sensitivity of firms' desired wage to change in unemployment rate
γ_7	adjustment in offered wage in case of unfilled job positions
δ	proportion of average capital stock of established firms for entrant firms' investment demand
ϵ_t	nominal exchange rate
ϵ_t^r	real exchange rate
ζ	capital goods firm's search capabilities (innovation easiness)
η_t	employment rate
θ_t	probability of success in innovating
ϑ	employees turnover share
ι_1	sensitivity of probability to export to firms' market share of domestic market
ι_2	domestic firms' maximum market share of foreign market
ι_3	price sensitivity of domestic firms' market share of foreign market
ι_4	foreign sector's maximum market share of domestic consumption goods market
ι_5	price sensitivity of foreign sector's market share of domestic consumption goods market
$\Lambda_{c,t}^{\$}$	loan
$\Lambda_{c,t}^{D,\$}$	new loan demand
λ_1	smoothing parameter of nominal interest rate
λ_2	sensitivity of nominal interest rate to inflation gap
λ_3	sensitivity of nominal exchange rate to trade balance
λ_4	sensitivity of nominal exchange rate to interest rate differential
$\mu_{f,t}$	mark-up rate at firm f

$\mu^*_{c,t}$	mark-up rate component due to competitiveness with other firms
ν_1	sensitivity of mark-up rate to evolution of market share
ν_2	mark-up deviation persistence
ν_3	sensitivity of mark-up deviation to change in unit costs
ν_4	sensitivity of market share to competitiveness
ν_5	sensitivity of mark-up deviation to exports growth
$\Pi^{dist,\$}_{f,t}$	distributed profits by firm f
$\Pi^{h,\$}_{h,t}$	profit dividends received by households
$\Pi^{gross,\$}_{f,t}$	gross profits at firm f
$\Pi^{net,\$}_{f,t}$	net profits at firm f
ρ_1	number of capitalists per firm
ρ_2	proportion of revenue to R&D in K firm
ρ_3	managers per direct workers in K firm
ρ_4	indirect workers per direct worker demanded in C firms
ρ_5	indirect workers per direct worker at full capacity production in C firms
ϱ_1	initial ratio between direct workers' wage and minimum wage
ϱ_2	initial ratio between indirect workers' wage and direct workers' wage
ϱ_3	initial productivity difference between vintages
$\mathcal{T}^{\$}_{H,t}$	aggregate nominal profits
τ	tax rate on income
τ^{dif}	difference between high and low tax rates
τ^{high}_t	high-income households tax rate
τ^i	tax rate on interest on deposits
τ^{low}_t	low-income households tax rate
ϕ	sensitivity of workers' bargaining power to employment rate
ω_i	sensitivity of expected demand to actual demand in period $t-i$

Contents

Introduction

Income inequality is the collective inheritance of a society divided into classes, in which power is used to extract income from the less powerful classes in favor of the more powerful ones. It is transmitted across generations through multiple forms of capital, that is, the private and unequal inheritance of the economic, cultural, and social capitals (Bourdieu, 1986). It bespeaks the history of each society, in particular its racists and patriarchal bases, which historically have determined who belongs to the more powerful classes. It manifests itself in our daily lives through the combination of numerous mechanisms that translate power and capital into income and income disparities.

This dissertation investigates the macroeconomic dimensions of income inequality by exploring the effect of different economic mechanisms. In this sense, it explores some of the economic determinants of inequality in a society divided into classes, wherein one's position in the social structure determines one's opportunities and power. Accordingly, we emphasize the importance of the functional income distribution to understanding the personal income distribution (Atkinson, 2009, Giovannoni, 2010). The analysis of the macroeconomic determinants of income distribution in such a structure provides information concerning their role in reproducing existing inequalities and generating new ones and indicates how economic policies can potentially attenuate the income disparities generated by the economic system.

Our analysis of the macroeconomic determinants of income inequality is largely inspired by the post-Keynesian literature - mostly of the Kaleckian variety - and its understanding that income distribution in capitalist societies results from the class conflict. Indeed, it is especially inspired by Michal Kalecki's work and the more recent Kaleckian literature that explores theoretically and empirically the determinants of income distribution and its two-way relationship with economic growth. Thus, such theoretical framework also motivates the analysis of the feedback effects between income inequality and three important macroeconomic indicators: employment, output growth, and inflation. More specifically, the post-Keynesian approach emphasizes the intrinsic relation between the bargaining process over nominal wages and pricing decisions by firms, which determines real wages and the wage share. Therefore, income distribution and inflation result from the same economic processes and should be analyzed in tandem (Rowthorn, 1977). In addition, the level of economic activity and the employment rate are closely related to the income distribution, either by altering the relative bargaining power of each class, and thus generating changes in the income distribution, or by responding to changes in income distribution that alter the level of aggregate demand (Bhaduri and Marglin, 1990, Blecker, 1989, Dutt, 1984, Lavoie and Stockhammer, 2012, Rowthorn, 1981).

Considering these different dimensions, the main research question of this dissertation concerns the conditions under which inclusive economic growth can be achieved or, in other words, more income equality can be more favorably conciliated with economic growth. To investigate this research question, a novel agent-based (AB) model with Kaleckian features is set forth and each chapter makes use of (and, in some cases, extends) this model to deal with a more specific and derived research question, thus exploring the different layers that form the two-way relationship between income distribution and economic activity. Indeed, the structure of this dissertation is organized to explore endogenous mechanisms determining the relative strength of each class (chapter 1), exogenous factors altering the international trade relations and the social conflict over the income distribution (chapter 2), and the effect of regulations and policies aiming to reduce the inequalities generated by the economic system (chapter 3). The combination of these different layers of analysis provides new insights into the macroeconomic determinants of income distribution, as well as into the feedback effects between income distribution and output growth. Given the complex nature of these two-way relationships, the dissertation also offers a detailed analysis of the possibilities of achieving inclusive economic growth in different economic contexts.

The use of AB models for macroeconomic analyses has been increasing since the availability of modern digital computers, which have made it possible to build complex and encompassing models (Simon, 1959). The complexity of these models stems from the inclusion of heterogeneous agents, detailed behavioral and exceptional rules, interaction protocols, and non-linearities. In addition to providing empirically-based microfoundations to macroeconomic models, these features allow them to incorporate a large number of endogenous variables and to generate emergent properties without the need of (or not available through) analytical solutions (Haldane and Turrell, 2018). While the first AB macroeconomic models date back to the 1970s, this literature started to attract more attention from the 2000s onward. Nowadays, there are many research groups contributing to build a diverse set of AB macroeconomic models (Dawid and Delli Gatti, 2018, Fagiolo and Roventini, 2017). Indeed, as the field flourishes, it can be argued that it offers a robust alternative to the more standard macroeconomic models based on representative agents, which fail to account for the complex and evolving nature of economic systems (Dosi and Roventini, 2019).

The complex nature of the relationship between income distribution and economic activity would already motivate the use of an AB model in this dissertation, but there are also some specific advantages of such a framework that are worthwhile emphasizing. The inclusion of heterogeneous households enables us to consider agents that belong to different classes, thus having specific roles in the production process and earning different types (and levels) of income. Combined with the heterogeneity at the level of the firms, this means that each type of shock affects the agents differently depending on their class, employment status, and other agent-specific characteristics, which leads to heterogeneous and endogenously time-varying wage and price levels. As the distribution of profits within the capitalist class and of wages

within the managers and workers classes change, a more nuanced and granulated relationship between the endogenously-generated functional and the personal income distribution can be captured. Moreover, the detailed structure of an AB model provides qualitative information with respect to the distributive effect of specific shocks, policies, and institutions. Thus, we are able to discuss not only their effect on the overall income distribution, but also how this effect is obtained by identifying the transmission mechanisms and discriminating the groups that are affected the most in each case.

Overall, the main structural novelties of the model set forth in this dissertation relative to other AB macroeconomic models (Dawid and Delli Gatti, 2018, Fagiolo and Roventini, 2017) are a new and more inclusive wage bargaining process between firms and workers capturing the conflict over nominal wages, a new strategic component in the mark-up rates of firms linking the evolution of nominal costs to the functional income distribution, and a three-class structure based on Mohun's (2016) work that connects the functional and personal income distribution. While these are the main structural novelties of the model, the entire model structure was developed in this dissertation, so many of the equations and relations are specific and different from other models or have been adapted from models in the literature. Given these features of the model, we undertake a different approach relative to the vast majority of the recent literature on increasing income inequality, which has focused on individual labor market earnings due to the strong influence from human capital theory (Berg, 2015). Similarly to numerous models in the AB macroeconomic literature, economic growth is determined through the interaction between supply and demand factors in a coevolutionary process.

The model structure is presented in chapter 1, wherein we also employ it to discuss key determinants of the income distribution and of its relationship with economic activity. More specifically, we analyze the interaction between productivity growth, which potentially benefits firms by reducing unit costs, and workers' bargaining power, which potentially benefits workers by affecting the nominal wages and offering a countervailing power to that of employers. In this sense, the experiments presented in chapter 1 are closely related to numerous empirical analyses investigating the increase in income inequality in many economies, in particular studies that stress the role of the erosion of institutions and policies that used to protect workers in a context of productivity growth (Mishel and Bivens, 2021, Setterfield, 2021, Setterfield and Blecker, 2022, Stansbury and Summers, 2020). Since the model incorporates several features of the conflicting-claims inflation model in the post-Keynesian literature, inflation emerges endogenously through the interaction between heterogeneous firms and workers. By exploring the key intuition that productivity growth may provide the *potential* for changes in the income distribution while its *actual* effect is mediated by the labor market, the chapter shows that the two-way relationship between income distribution and output growth largely depends on the relative strength of the key parameters determining the dynamics of these variables. It also identifies the possibility of a policy dilemma when there is a trade-off between stimulating economic activity and productivity

growth and promoting a more equal income distribution, which can, nonetheless, be attenuated by policies protecting workers.

Chapter 2 investigates the effect of foreign demand and price shocks on income distribution, economic activity, and inflation in a small open economy, thus introducing a new and unexplored dimension to the class conflict over the income distribution. In order to do so, the AB model put forward in chapter 1 is extended to an economy open to international trade of consumption goods. The chapter analyzes the dynamics of such an economy when subject to temporary external shocks of different types, signs, magnitudes, and lengths that affect its international trade relations and have implications for output growth, income distribution, and inflation. Two types of shocks, which have not been explored so far in the AB models literature, are investigated: a shock on the foreign output growth rate (a demand shock) and a shock on the foreign inflation rate (a price shock). The simulation results suggest that the type of shock, sign, magnitude, and length are of primary importance for understanding how income distribution is affected by foreign shocks that operate through international trade. These characteristics are also key for understanding how the dynamics of income distribution is related to that of output since shocks that stimulate export growth and output have very different effects on distribution depending on these characteristics. They also highlight that income distribution is an important mechanism through which foreign shocks influence the domestic economy dynamics. Similarly, the results indicate that the two-way relationship between output growth and the real exchange rate varies depending on the type of shock and is influenced by the interplay between income distribution and international competitiveness. The open economy framework also leads to a connection between the foreign and domestic inflation rate and, consequently, to a more realistic approach to the determinants of inflation (Bobeica and Jarocinski, 2019, Borio and Filardo, 2007).

Finally, chapter 3 intends to investigate what could be done policy-wise to tackle the expressive income inequality levels that characterize many contemporaneous capitalist economies. The analysis is based on the open economy AB model outlined in chapter 2 in order to capture the complex two-way relationship between income distribution and output growth given the possibility of a loss in international competitiveness that may result from nominal wage increases (Blecker, 1989). The experiments explore the effect and interaction of labor market regulations and redistributive policies. The chapter starts by discussing the transition from the pro-market scenario, wherein the government does not rely on any policy tools to influence the income distribution, towards the redistributive scenario, wherein redistributive policies (unemployment benefits and progressive taxation) are progressively added with the aim of reducing the inequality levels generated by the (unregulated) bargaining process between agents in the labor market. Yet, in such redistributive scenario, the government still does not rely on labor market regulations possibly to avoid efficiency losses. The analysis then moves from the redistributive scenario towards the pro-labor scenario, wherein in addition to the redistributive policies, there are also more regulations protecting workers in the wage bargaining process (downward nominal wage

rigidity, an active minimum wage policy, and higher workers' bargaining power independently from the employment level). Since our analysis deals with the effects of each type of labor market regulation and redistributive policy, the results also provide new insights into the interaction between the policies and their contribution to the main macroeconomic and distributive variables.

Chapter 1

Income distribution, productivity growth, and workers' bargaining power

1.1 Introduction

In the past decades, the economic debate on income distribution has been strongly revived. This has been the case due to the growing understanding that inequality has reached unprecedented high levels and that this dynamics has potential undesirable economic and social consequences. Indeed, different measures show that inequality has worsened in a number of countries in the past years, such as the lower wage shares (ILO, 2008, Stockhammer, 2017), the higher top wages relative to lower wages ratios (Atkinson, 1970, Baker et al., 2019, Piketty and Saez, 2006), or the higher supervisors' wage shares (Mohun, 2014). In an effort to explain this dynamics, the literature highlights that it results from a combination of different factors, such as skilled-biased technological change (combined with job polarization), globalization, financialization, and labor market institutions (Mishel and Bivens, 2021, Karanassou and Sala, 2010, Machin, 2008, Stockhammer, 2017).

This chapter deals with two of those factors: technological change and institutions that support workers' bargaining power. Our aim is to understand how these factors affect (individually and jointly) the inequality dynamics. Indeed, one of the key aspects related to the increase in income inequality is the increasing wage-productivity gap and increasing mark-up levels (De Loecker et al., 2020). In the case of the US, for instance, numerous authors draw attention to a contrast between fairly stagnant real wages and the continuous labor productivity growth (Karanassou and Sala, 2010, Mohun, 2006). This means that the median workers' living standards lagged behind the economy's potential, with this gap being directed to highly paid managers through an increase in earnings inequality and to capital owners through an increase in the profit share (Bivens and Mishel, 2015). Interestingly, while the increase in productivity in the US was much more intense in the period between 1948 and 1973 than in the period between 1973 and 2014, it was only in the latter period that the dynamics of real wages and productivity strikingly diverged (Bivens and Mishel, 2015). The additional factor explaining the increasing wage-productivity gap in the latter period is to be found in the labor market dynamics, in particular a shift in power relations that undercut the ability of workers to obtain

real wage growth in line with productivity. This resulted from intentional policy decisions that led to the erosion of institutions and policies that used to provide a countervailing power to that of employers (Mishel and Bivens, 2021), so the resulting increased labor market flexibility and "worker insecurity" replaced unemployment as a discipline device that moderates workers' bargaining power (Setterfield, 2021). This interpretation seems to hold for other OECD countries as well, as there is evidence that the reduction in workers' bargaining power is a key factor in the decline in the wage share (Guschanski and Onaran, 2021).[1] Therefore, if productivity growth may provide the *potential* for changes in the income distribution, its *actual* effect is mediated by the labor market and, in particular, the relative power of employers *vis-à-vis* workers.

From a theoretical perspective, these relations are strongly related to the post-Keynesian literature, in particular its approach to the functional income distribution inspired by Michal Kalecki's work. This literature has long emphasized that the wage share results from the class conflict between workers and firms over the income distribution (Kalecki, 1971, ch. 14), an idea that was later related to the inflation dynamics (Rowthorn, 1977). The factors discussed above influence how this conflict plays out and the resulting wage share, which is negatively related to the mark-up over unit costs. Indeed, in the case of a simple mark-up pricing equation with labor as the main production input, the wage share will remain constant as long as the mark-up remains constant. Accordingly, nominal wage increases that are proportionally passed on to prices simply lead to higher price levels, whereas productivity increases that are not accompanied by higher mark-up rates will not lead to more inequality in the functional income distribution (a lower wage share).[2] Thus, if changes in the wage share are observed, something is happening to firms' mark-up rates as well, which can suffer a downward pressure from higher nominal wages or increase in face of productivity gains that decrease costs.[3] In other words, in a context of growing labor productivity, increasing (decreasing) workers' bargaining power can counteract (reinforce) the evolution of mark-ups and the wage share.

The dynamics of the wage share also entails implications for the personal income and wealth distribution. Indeed, profits become income for capital owners when they are distributed and these households tend to be part of the rich class. If profits are more unequally distributed

[1] Stansbury and Summers (2020) have named this the "bargaining power hypothesis". As argued in their paper, this hypothesis is coherent with many phenomena observed in the US economy. Also Setterfield and Blecker (2022) emphasize the role of lower workers' bargaining power in increasing income inequality and relate it to the inflation dynamics.

[2] Nevertheless, labor-saving technology can lead to lower employment rates, which can worsen the personal income distribution as unemployed workers tend to earn lower incomes (e.g. unemployment benefits). It can also increase the earnings inequality if it increases education wage differentials by reducing the relative demand for low-skilled workers relative to other workers (the so-called skill-biased technological change).

[3] It is worthwhile mentioning that changes in the wage share observed in real data can also be associated with cyclical effects due to overhead labor or with changes in the composition of employed workers (e.g., changes in the share of self-employment in total employment depending on how this income is treated in the national accounts). While the former effect is considered in what follows, it mainly leads to cyclical fluctuations in the wage share, that can be observed even if the mark-up rate is fixed depending on the pricing rule adopted (see Lavoie (2014, ch. 3)). The latter effect is not considered in this chapter, so our discussion pertains to the division of income between employees and firms.

than wages, this composition effect is a channel through which higher profit shares lead to more inequality in the personal income distribution (Daudey and García-Peñalosa, 2007). Also, changes in the profit share can affect the personal income distribution through changes in the inter-class inequality (Wolff and Zacharias, 2013). This is reflected in the recent data for the US, for example, which show both an increase in the profit share and an increase in the top wages income share (Mohun, 2014).[4] Additionally, as a higher personal income inequality is associated with increases in the wealth inequality, the mechanisms driving the former can also be relevant to the dynamics of the latter (Tippet et al., 2021).

In order to further investigate the interplay between productivity growth and workers' bargaining power, we build a novel agent-based (AB) macroeconomic model. Our main objective is to provide a theoretical framework that incorporates the class conflict over the income distribution, which can be influenced by different elements that affect the relative strength of each class in the conflict. More specifically, the proposed framework allows this conflict to be influenced by the extent to which firms take advantage of productivity growth and workers' bargaining power affects the nominal wage dynamics. The combination of these features of the model allows workers' and firms' strengths to endogenously affect the real wage level and the wage share and offers new insights into how technological innovation and labor strength affect inequality. In this sense, the model follows the tradition in macrodynamic AB models that aims to reproduce macroeconomic features that emerge from decentralized interactions among heterogeneous agents in a bottom-up approach (Dawid and Delli Gatti, 2018). In addition to reproducing a broad range of stylized facts at the macro and micro levels, a key feature of the model is the reproduction of empirical regularities regarding the income distribution dynamics, which indicates that the model structure is well-suited for our purpose. Our experiments explore the interplay between productivity growth and workers' strength, which are further discussed in the sensitivity analysis. We show the importance of firms' and workers' strength in determining the outcome of the class conflict over the income distribution, with the former increasing with productivity growth and the latter increasing with institutional factors that support workers in the wage bargaining process. With respect to the macroeconomic implications of this interaction, in addition to exploring the conditions under which positive inflation rates arise, we show that the relation between income inequality and output depends on the source of changes in the income distribution, giving rise to a policy dilemma when there is a trade-off between stimulating economic activity and productivity growth and promoting a more equal income distribution.

The remaining of this chapter is organized as follows. In section 1.2 the related literature is discussed. In section 1.3 the main features of the model are summarized. In section 1.4 the model structure is presented. Then, the baseline specification and the model's validation

[4]With respect to the US case, it should be noted that while Wolff and Zacharias (2013) argue that inter-class inequality was the main cause of the overall increase in inequality from 1989 to 2000, Piketty and Saez (2006) suggest that increases in top wages are the main explanation for the higher top income shares in the post-1970 period. Nevertheless, both factors operate to decrease the income share of the working poor, as discussed by Rolim (2019).

are discussed in section 1.5, while the experiment results are presented in section 1.6. Section 1.7 presents the sensitivity analysis, where we investigate the interaction between key model parameters. Concluding remarks follow in section 1.8.

1.2 Related literature

Our work relates to a growing AB literature that deals with income distribution issues from different perspectives. The wage bargaining process relates to and considerably extends that presented by Fagiolo et al. (2004), wherein firms set wages as a linear combination of the average satisficing wage of workers who applied for the open positions and their own satisficing wage, with the weight of each component depending on firms' (exogenous) bargaining strength. The authors show that the model is able to reproduce key labor market stylized facts, such as the Beveridge, Wage, and Okun curves. In addition, the authors find that higher firms' bargaining strength is associated with lower growth rates. Similarly, a wage bargaining model is presented in the labor-augmented version of the "Schumpeter meeting Keynes" (KS) model (Dosi et al., 2017, 2018). The authors compare two systems representing the "Fordist regime", in which wages are not bargained for and are unilaterally set by firms, and the "Competitive regime", in which firms offer the minimum amount that satisfies enough workers in their applicants queues. In general, the competitive scenarios lead to higher unemployment rates, higher mark-up rates, higher standard deviation of wages, and higher inequality.

There are also various contributions that discuss the relation between income distribution and productivity growth. For instance, Carvalho and Di Guilmi (2020) show how productivity growth can lead to changes in income distribution by considering labor-saving technological progress. In their model, productivity growth is associated with higher unemployment rates, which have a detrimental effect on the wage dynamics and a positive effect on the mark-up set by the firm sector (represented as an aggregate sector in the model), thus altering both the functional and personal income distribution. The relation between inequality and productivity growth is also analyzed in Ciarli et al. (2010), who deal with the relation between technological progress, firms' organizational structure and wages and earnings structure. In addition, Caiani et al. (2019b) deal with the link between productivity growth and inequality by focusing on how different distribution regimes affect the innovation dynamics. In their model, households are also split into different classes and a dynamics in the personal income inequality emerges from differences between the income groups. An alternative relation between productivity and inequality is explored by Caiani et al. (2019a), who assume an adaptive behavior of firms, which adjust prices depending on their sales and wages depending on whether they could fill all vacant

job positions. In this sense, mark-ups are residually determined by the difference between prices and unit costs (which are also affected by productivity growth).[5]

An alternative analysis of the link between innovation and inequality is offered by models that focus on market concentration dynamics. These works draw on contributions documenting the increase in product market concentration associated with technological change and the existence of higher entry barriers. As the higher concentration benefits firms with higher mark-up rates, it is associated with the observed decreases in the wage share (Autor et al., 2020, De Loecker et al., 2020). In line with these works, Terranova and Turco (2022) explore how market concentration is affected by technical change and what are the implications for income inequality. The authors show that the dynamics can be markedly different depending on whether there are legal entry barriers (which affect concentration in the long run) and that economic policies can attenuate the tendency towards concentration or alter the macroeconomic results. Similarly, Dawid and Hepp (2021) capture the role of firms in shaping inequality dynamics in different technological regimes in a model where workers are heterogeneous with respect to their skills. They show that the effect of productivity growth on inequality strongly depends on how the technological regime changes and that the effect of market concentration on wage inequality can be ambiguous.

Inspired by these works, this chapter contributes to the literature by linking the wage bargaining process based on firms' and workers' interaction to productivity growth. As this framework avoids the oversimplifications that lead to a superficial or absent interaction between firms and workers in the wage bargaining process that are commonly adopted in the literature, it allows for an endogenous determination of income distribution as an emergent property. In sum, the main implication of our proposed framework is to allow the study of the functional and personal income inequality dynamics in an economy intrinsically characterized by a class conflict over the distribution of income, in which the relative evolution over time of wages and productivity is simultaneously an expression and a determinant of the bargaining power of each class.

1.3 Key features of the model

The model's basic structure is inspired by key contributions in the macroeconomic AB literature, such as the KS model (Dosi et al., 2010, 2013, 2018), the micro-macro multisectoral model (Dweck, 2006, Dweck et al., 2020, Melo et al., 2016), as well as the models developed by Caiani et al. (2016, 2019a,b), Ciarli et al. (2010, 2019), Carvalho and Di Guilmi (2020), and Oliveira et al. (2020). Its main contribution is to incorporate three aspects relevant to the recent changes in the functional and personal income distribution, which are particularly related to the

[5]Thus, while productivity growth is also interpreted as an opportunity to increase profit margins in Caiani et al. (2019a), this results from an adaptive behavior of firms, rather than being determined strategically by firms following a mark-up pricing rule as proposed in our model.

Kaleckian approach. These features are also the major novelties of the model in comparison with the existing literature.

Firstly, we model a novel and fuller specified wage bargaining process in which the interaction between workers and firms is key to the wage determination. In our proposed model, workers can influence the nominal wage adjustment by firms through their bargaining power, which is assumed to reflect the institutional framework supporting workers and the macroeconomic context (captured by the employment rate). This approach intends to provide a broader and more detailed wage setting mechanism, rather than assuming that wages are unilaterally determined by one agent (firms or workers) and just accepted (or rejected) by the other agent. As such, our model provides a novel conflicting-claims approach to modeling wage negotiations that has not yet been undertaken in the literature.

Secondly, firms' mark-up adjustment rule is assumed to depend on a strategic evaluation of their positions *vis-à-vis* their competitors and *vis-à-vis* the working class, which are summarized by the evolution of their market shares and unit production costs respectively. This latter variable captures the interplay between productivity and nominal wage growth rates and signals to firms if they may increase or maintain higher mark-up levels to take advantage of productivity growth, or if they should keep their mark-ups at lower levels in order to prevent nominal wage increases from passing on entirely to prices and harming their competitiveness. Therefore, in addition to the commonly adopted assumption that firms seek to become more efficient in order to lower costs and prices with the objective of achieving higher market shares, we assume that productivity growth is a strategy to increase profit margins and rates without increasing prices. As mark-ups are an expression of firms' power (the extent to which prices can be set above costs), this framework incorporates productivity growth as another facet of the class conflict over income distribution.

Finally, we link this class conflict dynamics and its effects on the functional income distribution to the personal income distribution through a class structure for households. We incorporate the sociological class division described by Mohun (2016), according to which capitalists receive non-labor income, the working class is characterized by being powerless (is compelled to sell its labor power and is supervised by someone else), and the managerial class exercises supervisory functions, but, as the working class, does not have sufficient non-labor income. Accordingly, in our model households are split into three heterogeneous classes that perform different functions and earn different income levels. With respect to the capitalist class specifically, we assume that each capitalist owns a fixed share of a firm, so each firm is owned by a fixed number of capitalists. Therefore, despite of a fixed distribution of profits within each firm, the income distribution in the capitalist class is endogenously determined by the goods market dynamics (as well as by the evolution of firms' prices and costs). This is an important feature for the relation between the functional and personal income distribution, as capital income tends to be more unequally distributed than labor income (Daudey and García-Peñalosa, 2007).

1.4 The model

The model is composed of five types of agents:[6]

- A monopolist **capital goods firm**, which produces machines using direct labor and employs indirect workers to supervise the production process and to engage in research and development (R&D) activities.[7] This firm is responsible for the innovation activity in the economy, with the new technologies being embodied in its production technique and in the new machines. It distributes to its owners all its net profits.

- A set of N^c **consumption goods firms**, which produce a homogeneous good using direct labor and machines. These firms also hire indirect workers to perform management and supervision activities. They invest in capital goods and may ask for a loan to finance production and/or investment. Net profits are distributed to the capitalist households who own them.

- A monopolist **bank**, which grants loans to consumption goods firms, buys bonds from the government and holds firms' and households' deposits. For simplicity, the bank does not hire any worker to perform its activities and it is not owned by any capitalist household, so its profits (if any) are simply added to its net worth.

- A set of N^h **households** divided in N^{cap} capitalists, N^{dir} direct workers, and N^{ind} indirect workers. Workers sell their labor to firms and receive wages in return, while capitalists own the firms and receive profit dividends (each firm is owned by ρ_1 capitalist households). Unemployed workers receive a tax-exempted benefit from the government. Households buy consumption goods and keep their savings as deposits at the bank. They also pay taxes on profit dividends and wages.

- A **public sector** composed by a central bank and a government. The government employs a fixed number of direct and indirect workers, pays unemployment benefits to unemployed workers, collects taxes, and issues bonds to cover its fiscal deficits. It is also responsible for setting the minimum wage. The central bank holds the government's reserves account and government bonds and sets the base interest rate (at a fixed level i).

[6] The following subscripts are used throughout this dissertation: h for households, c for consumption goods firms, m for machines, k for the capital goods firm, f for both firms, b for the bank, and g for the public sector. The superscripts res, man, ind, dir, and cap refer to researchers, managers, indirect workers, direct workers, and capitalists, respectively, while j refers to households from all classes. The superscripts \$, D, d , and e identify nominal, demand, desired, and expected variables, respectively. Note that variables that are defined as expected or desired are so defined because they may not be equal to the respective actual value and even to each other. Finally, the subscript t identifies the time period, which encompasses the production, commercialization, and investment periods. Parameters that do not change in a given simulation are referred to as fixed parameters and, as such, are not accompanied by t.

[7] The assumption of monopolist agents is adopted in other models in the literature (Cardaci and Saraceno, 2018, Dawid et al., 2019, Carvalho and Di Guilmi, 2020, Dweck et al., 2020, Oliveira et al., 2020) and is consistent with the idea of keeping the model as simple as possible in the elements that are less essential to the main relations under analysis.

The model structure and the interactions between the agents are represented in figure 1.1 and a detailed matrix presenting the transaction flows between the agents is reported in Appendix A. The next sections present the decision rules for all agents and interaction protocols.[8]

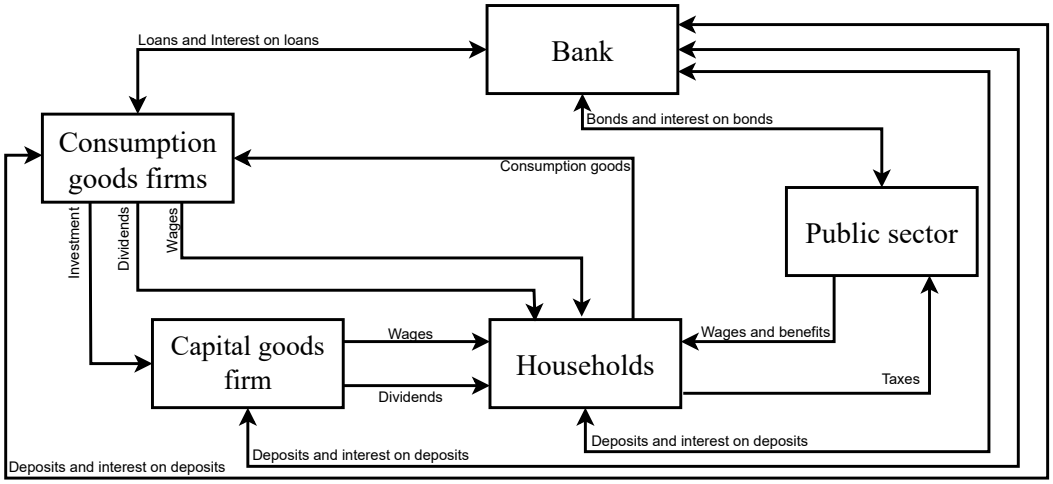


Figure 1.1: Model structure

Note: arrows point from paying sector to receiver sector. Source: author's own elaboration.

1.4.1 Capital goods firm

The capital goods firm sector is represented by a monopolist firm, which produces a homogeneous capital good characterized by direct labor productivity $y_t^{c,\star}$. The firm uses direct labor as the sole production input and employs a production technique characterized by direct labor productivity y_t^k. These workers are supervised by indirect workers hired as managers. The capital goods firm is responsible for the innovation process, which is undertaken by indirect workers hired as researchers. This is the sole source of increase in the productivity of direct labor in the economy and may create an additional demand for the capital goods firm. In the beginning of each period, the firm receives orders of new machines from the consumption goods firms (aggregate investment demand), which are delivered in the end of the period.

1.4.1.1 Innovation

Innovation is modeled as a three steps process, whose outcome depends on two successive random draws (Dosi et al., 2010, Nelson and Winter, 1982). In case the firm is successful in innovating, the new values of labor productivity in the capital goods sector (y_t^k) and embodied in the new machines ($y_t^{c,\star}$) depend on a comparison with the previous state-of-the-art.

In the first step, the firm decides how much to spend in R&D. This amount depends on a fixed fraction $\rho_2 < 1$ of the current period nominal investment demand. The R&D budget

[8]The model presented in this Ph.D. dissertation was implemented and simulated in the Laboratory for Simulation Development (LSD) software with the assistance of the Purpurea program (see Appendix E). The data analysis was undertaken in R and greatly benefited from R scripts available in model examples in LSD.

determines the number of researchers the firm demands in the period (section 1.4.1.2), while the actual number of employed researchers ($L_{k,t}^{res}$) is determined in the labor market.

Then, a random draw determines whether the firm is successful in innovating. More specifically, the firm's access to innovation is determined by a Bernoulli draw with the probability of success being a function of the number of researchers employed:

$$\theta_t = 1 - e^{-\zeta L_{k,t}^{res}} \tag{1.1}$$

where $1 > \zeta > 0$ is a parameter that reflects the firm's search capabilities.

If this first random draw is successful, the new technology is characterized by the pair $y_t^{c,in}$ and $y_t^{k,in}$:

$$y_t^{c,in} = y_t^{c,\star}(1 + x_t^c) \tag{1.2}$$

$$y_t^{k,in} = y_t^{k}(1 + x_t^k) \tag{1.3}$$

where x_t^c and x_t^k are random draws from a $Beta(\alpha, \beta)$ distribution over the $[-x, x]$ support.

The firm then decides whether it adopts the new technology ($y_t^{c,in}$ and $y_t^{k,in}$) or continues with the previous technology ($y_{t-1}^{c,\star}$ and y_{t-1}^{k}) . Similarly to Dosi et al. (2010), this decision is based on the trade-off between the price (higher y_t^k leads to a lower price, *ceteris paribus*) and efficiency (which increases with $y_t^{c,\star}$) of the machine. More specifically, when the firm observes that the new technology renders a higher price and lower efficiency or when it renders a lower price and higher efficiency, it automatically chooses the best alternative (stay with old technology or adopt new technology respectively). Whenever that is not the case, it has to evaluate whether the (lower or higher) efficiency associated with new technology compensates the (higher or lower) price of the machines, since the consumption goods firms adopt this type of evaluation when deciding to replace old machines by new ones. Consequently, the decision rule followed by the capital goods firm to decide between the two technologies is to adopt the technology that minimizes the sum of the price of the machine and the total production cost at the consumption goods firms' desired capacity utilization rate (u^d) times a payback factor:

$$min[p_k(y_{t-1}^k) + b\Gamma^{\$}(y_{t-1}^{c,\star}, u^d),\ p_k(y_{t-1}^{k,in}) + b\Gamma^{\$}(y_{t-1}^{c,in}, u^d)] \tag{1.4}$$

where p_k is the capital goods price function (see section 1.4.1.3), b is the exogenous payback factor, and $\Gamma^{\$}$ is the consumption goods firms' total cost function (see section 1.4.2.5).[9]

[9] As the average wage level in the current period is not yet known when the capital goods firm is undertaking this decision, it calculates the consumption goods firms' costs by assuming that the previous period average wage in the economy grew at the same rate as wages in the capital goods sector.

1.4.1.2 Labor demand

The capital goods firm hires both direct and indirect workers. Direct workers are directly involved with the production process, so the demand for direct workers is the ceiling of (i.e., the smallest integer that is not smaller than) the division of the consumption goods firms' investment demand in the period ($\sum_{c=1}^{N^c} I_{c,t}^{D}$) by the direct workers' productivity, as follows:

$$L_{k,t}^{D,dir} = \left\lceil \frac{\sum_{c=1}^{N^c} I_{c,t}^{D}}{y_t^k} \right\rceil \tag{1.5}$$

Indirect workers are employed either as managers who supervise the production process or researchers. While the demand for the former depends on the demand for direct workers (equation 1.6), the demand for the latter is determined by the firm's R&D budget and the current wage level for indirect workers (equation 1.7):[10]

$$L_{k,t}^{D,man} = \left\lfloor \rho_3 L_{k,t}^{D,dir} \right\rfloor \tag{1.6}$$

$$L_{k,t}^{D,res} = \left\lfloor \frac{\rho_2 \sum_{c=1}^{N^c} I_{c,t}^{D,\$}}{w_{k,t}^{ind,\$}} \right\rfloor \tag{1.7}$$

where the parameter ρ_3 is the fixed number of managers per direct worker, $\rho_2 \sum_{c=1}^{N^c} I_{c,t}^{D,\$}$ is the R&D budget, and $w_{k,t}^{ind,\$}$ is the indirect workers' wage level. Since managers and researchers are indirect workers, the firm's total demand for indirect workers is $L_{k,t}^{D,ind} = L_{k,t}^{D,man} + L_{k,t}^{D,res}$.[11]

1.4.1.3 Pricing

The capital goods firm follows a cost-plus pricing rule:

$$p_{k,t}^{\$} = (1 + \mu_k) \frac{(w_{k,t}^{dir,\$} + \rho_3 w_{k,t}^{ind,\$})}{y_t^k} \tag{1.8}$$

where μ_k is a fixed mark-up rate and $w_{k,t}^{j,\$}$ is the wage rate for each type $j = dir, ind$ of worker.[12]

1.4.1.4 Production

The firm's production level is given by the floor of the number of direct workers it hires in the period multiplied by their productivity, which is adjusted by a correction factor that depends on the actual ratio of managers to direct workers in comparison to the required ratio. This adjustment captures the effect of management shortcomings whenever the firm cannot

[10] These values are respectively rounded to the closest integer and rounded down. The reason for this treatment in the first case is to reach a stable average relation between $L_{k,t}^{D,dir}$ and $L_{k,t}^{D,man}$, while in the second case it is to guarantee that the cost with researchers does not exceed the R&D budget.

[11] Hired indirect workers are split between researchers and managers proportionally to their participation in $L_{k,t}^{D,ind}$.

[12] The use of mark-up rules is largely supported by the empirical literature based on surveys in different countries (Correa et al., 2018, Fabiani et al., 2006).

hire as many managers as required to supervise the direct workers and organize the production process. Formally, production is given by:

$$Q_{k,t} = min \left\{ \lfloor L_{k,t}^{dir} y_t^k [1 - h(L_{k,t}^{man,D}/L_{k,t}^{dir,D} - L_{k,t}^{man}/L_{k,t}^{dir})\mathbf{1_Q}] \rfloor, \sum_{c=1}^{N^c} I_{c,t}^D \right\} \tag{1.9}$$

where h is the sensitivity of the actual productivity level to the difference between the actual ratio of managers to direct workers and the required ratio and $\mathbf{1_Q}$ is an indicator function that takes the value of one if the actual ratio is below the required ratio and zero otherwise. As the firm never produces more than demanded by the consumption goods firms (for simplicity, there is no strategic accumulation of inventories), the second part of the equation captures the maximum production level, given by the demand for capital goods ($\sum_{c=1}^{N^c} I_{c,t}^D$).

1.4.1.5 Profits

The capital goods firm's gross and net profits are given by equations 1.10 and 1.11 respectively:

$$\Pi_{k,t}^{g,\$} = Q_{k,t} p_{k,t}^{\$} - (w_{k,t}^{dir,\$} L_{k,t}^{dir} + w_{k,t}^{ind,\$} L_{k,t}^{ind}) \tag{1.10}$$

$$\Pi_{k,t}^{n,\$} = \Pi_{k,t}^{g,\$} + iD_{k,t-1}^{\$} \tag{1.11}$$

where $L_{k,t}^{ind}$ is the number of indirect workers hired by the firm and $D_{k,t-1}^{\$}$ is the firm's deposits in the previous period.[13] In each period, the firm distributes to its owners all its current net profits, as follows:

$$\Pi_{k,t}^{dist,\$} = max(\Pi_{k,t}^{n,\$},\ 0) \tag{1.12}$$

1.4.2 Consumption goods firms

The model is composed of a set of N^c consumption goods firms that produce a homogeneous nonperishable good using labor and capital goods. The capital goods (machines) are characterized by a direct labor productivity $y_m^{c,*}$. When fully utilized, each machine produces Q_m^{fc} units of the consumption good. Demand expectations determine the desired production for the current period, while the realized production may be limited by financial constraints and labor availability. The expected production for the next period determines the desired investment level, which may also be limited by financial constraints upon firms. The firms' production of such

[13] For simplicity, we assume that, as a monopolist firm, the capital goods firms has an unlimited overdraft at the bank. Thus, if it faces difficulties to hire all demanded workers and ends up having $\Pi_{k,t}^{n,\$} < 0$, the firm may have negative deposits in that period (on which it will pay an interest rate i). In the following periods, its profits will be used to repay this amount (reducing the profits dividends accordingly).

homogeneous good is sold in the consumption goods market, where firms can nonetheless act as price makers in an imperfectly competitive manner due to imperfect and incomplete knowledge on the part of consumers.

1.4.2.1 Expectations

Firms form their expectations based on their past experience in the consumption goods market, in line with empirical evidence on adaptive expectation formation. For instance, Gennaioli et al. (2016) find that expectations tend to have an extrapolative nature, suggesting that they do not appear to be formed rationally. Similarly, Boneva et al. (2020) show that expectations on new orders are mostly correlated with past orders.[14] More precisely, expectations for current demand are a function of the weighted average of demand in the last four periods:

$$Q_{c,t}^{D,e,t} = \sum_{i=1}^{4} \omega_i Q_{c,t-i}^{D} \tag{1.13}$$

where $Q_{c,t-i}^{D}$ is the demand for the firms' products in $t-i$ and $\omega_1 > \omega_2 > \omega_3 > \omega_4 > 0$ are fixed parameters ($\sum_{i=1}^{4} \omega_i = 1$).

Similarly, expectations for demand in the following period depend on past demand levels and the expected demand for the current period (equation 1.14).[15]

$$Q_{c,t}^{D,e,t+1} = \omega_1 Q_{c,t}^{D,e,t} + \sum_{i=1}^{3} \omega_{i+1} Q_{c,t-i}^{D} \tag{1.14}$$

1.4.2.2 Desired and expected production

Based on the expected sales and considering a fixed desired share of inventories (n^{IN}), firms set their desired production level for the current period (equation 1.15), which is limited by their production level at their full capacity utilization ($Q_{c,t}^{fc}$), and the expected production level for the next period (equation 1.16), as follows:

$$Q_{c,t}^{d} = min[Q_{c,t}^{fc}\ ,\ (1+n^{IN})Q_{c,t}^{D,e,t} - Q_{c,t-1}^{IN}] \tag{1.15}$$

$$Q_{c,t}^{e,t+1} = (1+n^{IN})Q_{c,t}^{D,e,t+1} - max(Q_{c,t}^{d} + Q_{c,t-1}^{IN} - Q_{c,t}^{D,e,t},\ 0) \tag{1.16}$$

where Q_{t-1}^{IN} is the previous period inventories level.[16]

[14] Also, the experiments presented in Dosi et al. (2020) show that, in a complex and evolving system, expectations based on heuristics are more robust and accurate than those based on more sophisticated methods.

[15] As production and investment decisions occur before sales take place, firms' expectations for $t+1$ consider their expectations for t.

[16] Note that the consumption goods are nonperishable, so inventories are forever salable.

1.4.2.3 Labor demand

The consumption goods firms also hire both types of workers. The demand for direct workers is the ceiling of their desired production divided by the labor productivity, as follows:

$$L_{c,t}^{D,dir} = \left\lceil \frac{Q_{c,t}^{d}}{\bar{y}_{c,t}^{c,*}} \right\rceil \tag{1.17}$$

where $\bar{y}_{c,t}^{c,*}$ is the average direct labor productivity of the most productive machines required to produce $Q_{c,t}^{d}$ (in each period, the most productive machines are used first).

Indirect workers are hired as managers to plan the firms' activities and supervise the direct workers' activities, so they are demanded proportionally to firms' size (proxied by the demand for direct workers at full capacity output level) and to the current demand for direct workers, with the value being rounded to the closest integer, as follows:[17]

$$L_{c,t}^{D,ind} = \lfloor \rho_4 L_{c,t}^{D,dir} + \rho_5 L_{c,t}^{dir,fc} \rceil \tag{1.18}$$

where $\rho_{4,5} > 0$ are parameters and $L_{c,t}^{dir,fc}$ is the demand for direct labor at the full capacity production level.

The resources available for hiring workers may be limited by the difference between the firms' available resources (sum of deposits and new loan) minus the previous loans' principal and interest, which are paid back to the bank before the labor market opens. Therefore, the firms' production budget is:

$$\Gamma_{c,t}^{e,\$} = min[D_{c,t}^{*,\$} + \Lambda_{c,t}^{\$} - \Lambda_{c,t-1}^{\$}(1+i),\ L_{c,t}^{D,dir} w_{c,t}^{dir,\$} + L_{c,t}^{D,ind} w_{c,t}^{ind,\$}] \tag{1.19}$$

where $\Lambda_{c,t}^{\$}$ is the firms' outstanding amount of loan and $D_{c,t}^{*,\$}$ is the firms' deposits in the beginning of the period. Firms hire as many workers as possible (given the labor supply constraints they face in the labor market) until their labor demand is met or all resources available are used.[18]

1.4.2.4 Production level

Firms' production is given by equation 1.20. Also in this case, there is an adjustment factor to the productivity level if the actual ratio of managers to direct workers is below the required ratio.

$$Q_{c,t} = L_{c,t}^{dir} \bar{y}_{c,t}^{c} [1 - h(L_{c,t}^{ind,D}/L_{c,t}^{dir,D} - L_{c,t}^{ind}/L_{c,t}^{dir})\mathbf{1_Q}] \tag{1.20}$$

[17] Given the possibility of measuring the consumption goods firms' size, for this sector we incorporate the idea that managers perform office administration activities as well as directly supervise the direct workers' production activities. In this sense, managers' income have an overhead characteristic and their income tends to fluctuate less during the cycle than direct workers' income (in aggregate terms), as noted by Kalecki (1971, ch. 6).

[18] Available resources are split between direct and indirect workers following the same proportion as the relative labor demand for each type of worker.

where $\bar{y}^c_{c,t}$ is the labor productivity of the most productive capital goods required to produce $Q_{c,t}$. The total production costs are given by equation 1.21:

$$\Gamma^{\$}_{c,t} = L^{dir}_{c,t} w^{dir,\$}_{c,t} + L^{ind}_{c,t} w^{ind,\$}_{c,t} \tag{1.21}$$

1.4.2.5 Pricing

The consumption goods firms follow the normal-cost pricing procedure, which is a widely adopted pricing procedure (Lavoie, 2014, Lee, 1999b). Accordingly, instead of considering realized costs, they take a conventional measure of costs and, thus, add a variable mark-up rate over labor unit costs computed at the desired capacity utilization level. This pricing procedure adds a microfoundation to firms' pricing that is particularly important in the presence of fixed costs, such as overhead labor costs, and that has been relatively unexplored in agent-based models so far.[19]

Firms revise the mark-up rates taking into consideration the evolution of their market share and their unit costs. The former effect, which is commonly adopted in the AB literature (Dosi et al., 2010, Dweck et al., 2020, Oliveira et al., 2020), aims to capture the intuition that firms react to changes in their market share by adjusting prices (either to become more competitive when their market share falls or to benefit from increases in their market shares by increasing their prices and profits). This is in line with the evidence provided by Correa et al. (2018) that more competitive markets tend to be associated with more frequent price reviews and with the evidence provided by Fabiani et al. (2006) that variable mark-ups tend to predominate.[20] This idea is expressed by the following equation, which defines the mark-up determined by firms' competitiveness conditions (i.e., their relation *vis-à-vis* other firms):

$$\mu^*_{c,t} = \mu^*_{c,t-1} \left(1 + \nu_1 \frac{\Delta ms_{c,t-1}}{ms_{c,t-2}} \right) \tag{1.22}$$

where $ms_{c,t-1}$ is the market share in the previous period and $\nu_1 > 0$ is a parameter.

In addition to competitiveness considerations in the mark-up setting procedure, firms strategically set mark-ups considering the evolution of their unit labor costs, which summarizes their relative position *vis-à-vis* workers. Indeed, while increasing prices is a relevant adjustment strategy after a cost shock, Bertola et al. (2012) find that mark-up adjustments are also a relevant strategy for most firms. This corroborates the evidence suggesting the lack of an immediate and full pass-through of costs on to prices (Carlsson and Skans, 2012) and suggests a theoretically and empirically plausible connection between the mark-up and the dynamics of unit costs.

[19] A key implication of the normal-cost pricing procedure in the presence of fixed costs is that net profit margins become endogenous to the business cycle, as shown in the stylized facts in section 1.5.

[20] Note that in the case of our model a more competitive market is reflected in more frequent changes in firms' market shares, which leads to more frequent and larger revisions in firms' mark-ups. Also in line with the empirical literature (Fabiani et al., 2006), we assume that financial costs are not relevant to price adjustments.

Such connection is incorporated in our model through an adaptive mark-up deviation component ($m_{c,t}$), which is adjusted as follows. In case there has been an increase in unit costs, this means that nominal wages increased more than productivity, so firms tend to absorb some of the increase in unit costs in order not to hamper their competitiveness. Conversely, a decrease in unit costs results from productivity growth surpassing the wage inflation. In this case, firms take advantage of the lower unit costs to become more competitive in the market (through lower prices), but also to achieve and sustain higher mark-up rates. These relations are described by equation 1.23 as follows:

$$m_{c,t} = \nu_2 m_{c,t-1} - \nu_3 \left[\frac{\Delta \Gamma^{u,\$}_{c,t}(u^d)}{\Gamma^{u,\$}_{c,t-1}(u^d)} \right] \tag{1.23}$$

where $1 > \nu_2 > 0$ is the persistence in the mark-up deviation, $1 > \nu_3 > 0$ is the sensitivity of the mark-up deviation to changes in unit costs and $\Gamma^{u,\$}_{c,t}(u^d)$ is firms' unit costs at desired capacity utilization rate. This latter variable is given by:

$$\Gamma^{u,\$}_{c,t}(u^d) = \frac{w^{dir,\$}_{c,t} + (\rho_4 + \frac{\rho_5}{u^d}) w^{ind,\$}_{c,t}}{\bar{y}^{c,*}_{c,t}} \tag{1.24}$$

Prices are then set as follows:

$$p^{\$}_{c,t} = (1 + \mu^*_{c,t} + m_{c,t}) \Gamma^{u,\$}_{c,t}(u^d) \tag{1.25}$$

Accordingly, firms' effective mark-up is given by $\mu_{c,t} = \mu^*_{c,t} + m_{c,t}$.[21]

1.4.2.6 Sales

As mentioned, consumers have imperfect and incomplete information about the consumption goods prices, so the different price levels have a limited effect on the demand for each firm's goods. In other words, consumers will not instantaneously switch to the more competitive firms (Dosi et al., 2010). Accordingly, real aggregate demand is split between the firms according to their market share ($ms_{c,t}$).[22] As extensively assumed in the literature, firms' market shares evolve following a "quasi" replicator dynamics and depend on their competitiveness ($E_{c,t}$), which is given by the average between the normalized price level ($p^n_{c,t}$) and normalized unfilled demand level ($l^n_{c,t}$) (Dosi et al., 2010, Dweck et al., 2020, Silverberg et al., 1988). Formally, firms' competitiveness is given by equation 1.26 and their market share is given by equation 1.27, as follows:

$$E_{c,t} = \frac{(1 - p^n_{c,t}) + (1 - l^n_{c,t})}{2} \tag{1.26}$$

[21] If firms' capacity production is zero and they have positive inventories, these are sold at the previous period price level. Otherwise, inventories are sold at the current price level.

[22] Naturally, firms' real sales can be lower than that determined by their market shares in case the sum of inventories and current period production is lower than demand.

$$ms_{c,t} = ms_{c,t-1}\left(1 + \nu_4 \frac{E_{c,t} - \bar{E}_t}{\bar{E}_t}\right) \tag{1.27}$$

where $\nu_4 > 0$ is a parameter capturing the market share sensitivity to competitiveness and $\bar{E}_t$ is the average competitiveness of consumption goods firms weighted by firms' market shares in $t-1$.

1.4.2.7 Investment

The consumption goods firms invest in order to achieve the desired level of production capacity, as well as to replace machines that have become technologically obsolete or that are scrapped for being older than T^k periods, which is the machines' lifetime.[23] Investment can occur every period t, but there is a lag between investment demand and the effective change in the firms' production capacity: since the machines are delivered by the end of period t, they can only be used in period $t+1$.

Capacity adjustment investment

The capacity adjustment investment depends on demand expectations, in line with the empirical evidence showing that firms' investment is a function of their expectations on earnings growth (Gennaioli et al., 2016) or product demand (Sharpe and Suarez, 2014). Borrowing costs are not explicitly considered as there is evidence that investment plans are overall quite insensitive to potential changes in borrowing costs (Sharpe and Suarez, 2014) or that the user cost elasticity of capital formation, despite being negative, is very low, which implies a modest effect of interest rates on investment (Chirinko et al., 1999). Nevertheless, financial issues can be a constraint upon firms' investment level in case they are credit-constrained (see section 1.4.2.8).

Formally, capacity adjustment investment depends on the desired production capacity for the next period, which is set so that the desired capacity utilization (u^d) is reached if firms produce the expected production level in $t+1$, as follows:

$$Q_{c,t}^{fc,d} = \frac{Q_{c,t}^{e,t+1}}{u^d} \tag{1.28}$$

The capacity adjustment investment is the difference between the desired production capacity for $t+1$ and the productive capacity in this period if no investment is undertaken (that is, if old machines are scrapped). This difference provides the desired change in the production capacity measured in units of consumption goods, so it is divided by the units of consumption

[23] Note that the machines' lifetime parameter implies an average depreciation rate of the capital stock of $1/T^k$ per period. Thus, the parameter T^k is calibrated to reproduce empirical evidence on the depreciation rate (Nadir and Prucha, 1996).

goods produced by each machine when fully utilized (Q_m^{fc}) to obtain the desired change in the number of machines, as follows:[24]

$$I_{c,t}^{fc} = max[\lceil (Q_{c,t}^{fc,d} - Q_{c,t}^{fc,t+1})/Q_m^{fc} \rfloor,\ 0] \tag{1.29}$$

Replacement investment

Consumption goods firms also replace existing machines with new machines following a payback rule, similarly to Dweck et al. (2020) and Dosi et al. (2010). As described in equation 1.30, the payback period if a machine is replaced by a new one is given by the price of the new machine divided by the difference between the machines' production cost and the new machine's production cost (both evaluated at the desired capacity utilization level), as follows:

$$b_{m,t} = \frac{p_{k,t}^{\$}}{\Gamma^{\$}(y_{m,t}^{c}, u^{d}) - \Gamma^{\$}(y_{t}^{c,\star}, u^{d})} \tag{1.30}$$

where $y_{m,t}^{c}$ is the machines' direct labor productivity. The total replacement investment ($I_{c,t}^{r}$) is given by the sum of the machines whose payback period is positive but lower or equal to the fixed threshold b.[25]

Total investment demand

Total investment demand is given by the sum of the capacity adjustment investment and the replacement investment. The total amount of investment demanded by the firms may be limited by their available resources, which are determined by the amount of deposits available in the beginning of the period ($D_{c,t}^{*,\$}$) and the new loan obtained ($\Lambda_{c,t}^{\$}$) minus the previous loan repayment costs ($\Lambda_{c,t-1}^{\$}(1+i)$) and the expected production costs ($\Gamma_{c,t}^{e,\$}$). These financial considerations are expressed in the total investment demand equation below:

$$I_{c,t}^{D} = min\left[I_{c,t}^{fc} + I_{c,t}^{r},\ \left\lfloor \frac{D_{c,t}^{*,\$} + \Lambda_{c,t}^{\$} - \Lambda_{c,t-1}^{\$}(1+i) - \Gamma_{c,t}^{e,\$}}{p_{k,t}^{\$}} \right\rfloor\right] \tag{1.31}$$

The realized investment ($I_{c,t}$) is determined in the capital goods market, as the number of capital goods for sale in the period is determined by the capital goods firm's production and can be lower than the total investment demand by the consumption goods firms. Whenever the capital goods firm's production is lower than the number of capital goods ordered, due to the impossibility of hiring enough workers, the capital goods firm distributes its production to the

[24] We assume that entrant firms' desired investment is higher or equal to one in case they do not yet have a capital stock.

[25] In case firms wish to reduce their productive capacity ($Q_{c,t}^{fc,d} < Q_t^{fc}$), replacement investment is reduced by the number of machines proportional to the desired reduction in the productive capacity, so machines in excess will depreciate in the following periods. If that is the case but there is still a positive level of replacement investment, the firm first replaces the least productive machines.

consumption goods firms in proportion to each firm's demand with respect to total investment demand ($I_{c,t} = \lfloor (I^D_{c,t} / \sum_{c=1}^{N^c} I^D_{c,t}) Q_{k,t} \rfloor$).[26]

1.4.2.8 Loans

Whenever their internal resources are insufficient to cover their expenses in the beginning of the period (before production and sales take place), firms asks for a loan from the bank. The total amount of expected expenses in each period is given by the repayment of the outstanding debt with the bank ($\Lambda^{\$}_{c,t-1}(1+i)$), production costs ($\Gamma^{e,\$}_{c,t}$), and desired investment costs ($p_{k,t}(I^{fc}_{c,t} + I^{r}_{c,t})$). Therefore, the total amount of the new loan demanded by firms is given by:

$$\Lambda^{D,\$}_{c,t} = max[\Lambda^{\$}_{c,t-1}(1+i) + \Gamma^{e,\$}_{c,t} + p_{k,t}(I^{fc}_{c,t} + I^{r}_{c,t}) - D^{*,\$}_{c,t},\ 0] \tag{1.32}$$

We adopt a simple rule for the credit market in the model: the bank grants all the requested loan as long as the ratio of firms' interest payment to their average revenue in the previous four periods (adjusted to the current price level) is below a maximum ratio, which is determined by the exogenous parameter R. Otherwise, it grants the maximum between the amount required to reach R or the amount required to cover firms' outstanding debt.[27]

$$\Lambda^{\$}_{c,t} = \begin{cases} \Lambda^{D,\$}_{c,t} & \text{if } \Lambda^{D,\$}_{c,t} \geq 0 \text{ and } \dfrac{i\Lambda^{D,\$}_{c,t}}{\bar{Q}^{s,\$}_{c,t}} \leq R; \\ max\left[\dfrac{\bar{Q}^{s,\$}_{c,t} R}{i},\ \Lambda^{\$}_{c,t-1}(1+i) - D^{*}_{c,t}\right], & \text{if } \Lambda^{D,\$}_{c,t} \geq 0 \text{ and } \dfrac{i\Lambda^{D,\$}_{c,t}}{\bar{Q}^{s,\$}_{c,t}} > R; \\ 0 & \text{otherwise.} \end{cases} \tag{1.33}$$

where $\bar{Q}^{s,\$}_{c,t} = p^{\$}_{c,t} \sum_{i=1}^{4} Q^{s}_{c,t-i}/4$ is the firms' average revenue (considering the current price level).

1.4.2.9 Profits

Firms' gross and net profits are given by equations 1.34 and 1.35 respectively:

$$\Pi^{g,\$}_{c,t} = Q^{s}_{c,t} p^{\$}_{c,t} - (w^{dir,\$}_{c,t} L^{dir}_{c,t} + w^{ind,\$}_{c,t} L^{ind}_{c,t}) + \Delta Q^{IN}_{c,t} \Gamma^{u,\$}_{c,t} \tag{1.34}$$

[26] Note that $I_{c,t}$ is rounded down, so the remaining $Q_{k,t} - \sum_{c=1}^{N^c} I_{c,t}$ capital goods, if any, are randomly distributed to the firms with unfilled investment demand, with priority being given to entrant firms acquiring their first machines.

[27] The latter condition simply means that firms pay back the entire sum of interest and principle even if the R ratio is reached. In other words, firms always have the possibility of rolling over their previous loans and loan defaults are a possibility only when firms exit the market.

$$\Pi^{n,\$}_{c,t} = \Pi^{g,\$}_{c,t} + Q^{IN}_{c,t-1}\Delta\Gamma^{u,\$}_{c,t} + i(D^{\$}_{c,t-1} - \Lambda^{\$}_{c,t-1}) \tag{1.35}$$

where $Q^{s}_{c,t}$ is the real sales, $\Gamma^{u,\$}_{c,t}$ is the unit production cost, i is the fixed interest rate, $D^{\$}_{c,t-1}$ is the firms' deposits in the previous period, and $\Lambda^{\$}_{c,t-1}$ is the firms' total loans in the previous period.[28] At the end of each period, firms distribute net profits to their owners.[29]

1.4.2.10 Exit and entry

Consumption goods firms exit the market whenever their market share is below a threshold given by the ms^{min} parameter, their production capacity is zero or they are completely financially constrained (having no deposits at the bank and having been denied new credit from the bank). We assume that there is no secondary market for capital goods or inventories, so they are scrapped when firms exit the market. In case firms have a positive net financial wealth (deposits minus liabilities), their outstanding loans are completely repaid and the remaining deposits, if any, are transferred to their owners. Otherwise, the bank absorbs firms' unpaid loans and there is a reduction in its net worth.

There is a one-to-one replacement of exited firms by new firms. The new firms' owners are selected among those whose firm exited the market in the period. They receive the deposits that their owners received when their previous firms exited the market (if any). The new firms enter the market by the end of the current period (t), invest in $t+1$ (investment demand given by a proportion δ of the average capital stock of the established firms), and start producing in $t+2$, when their market share is equal to their full capacity production relative to the sector's total capacity production. After their first production period and for T^c periods thereafter, the firms receive all requested loan to finance their investment and production and are not subject to any exit criterion.

1.4.3 Bank

The banking sector is composed by a monopolist bank, which grants credit to firms, holds remunerated deposits and buys bonds from the government. For simplicity, the bank sets the interest rate for deposits and loans equal to the interest rate set by the central bank (i). As it is assumed that the bank is not owned by any household and that its activity involves no costs (it does not hire any workers), in case of positive (negative) profits, these are incorporated to

[28] Inventories are evaluated at the current unit cost of production, in accordance with accounting rules, and the FIFO (first in, first out) criterion is adopted. This means that the change in the value of inventories is composed of the change in its volume (evaluated at the current unit cost of production) and of the change in the unit production cost (known as inventory appreciation). As only the former is related to a production flow, profits in national accounts consider gross profits as given by equation 1.34. See Godley and Lavoie (2012, ch. 8) for more details.

[29] The amount of profit dividends may be limited by the amount of resources available at this stage (that is, bank deposits minus resources necessary for loan repayment in the beginning of the next period, which are kept as deposits at the bank from one period to the other).

(deduced from) its net worth.[30] Following the post-Keynesian approach of endogenous money and credit rationing (Lavoie, 2014, Wolfson, 1996), we assume that credit is demand-led at a given interest rate conditional to a creditworthiness condition being fulfilled, as discussed in section 1.4.2.8. In fact, the bank denies credit to clients that do not classify as creditworthy - as mentioned, this evaluation depends on firms' interest payments to average revenue ratio in comparison to the R parameter. Therefore, the amount of credit available to each firm is demand-led as long as this condition is fulfilled.

1.4.4 Households

We follow Mohun's (2016) sociological class division and split households into three heterogeneous classes: direct workers, indirect workers (researchers and managers), and capitalists. Each household is composed of a single agent and the direct and indirect workers are employed in specific tiers of the firms. Capitalist households own the capital and consumption goods firms. For simplicity, there is no social mobility across classes and no population growth.

1.4.4.1 Workers' desired and reservation wages

Workers have both a desired wage and a reservation wage, which are affected by their individual experience in the labor market and by the macroeconomic context. Workers' desired wage depends on their previous positive wage adjusted by the accumulated inflation rate since their last employment period (if positive), as expressed by the inflation-adjusted wage ($w_{h,t}^{d,*,\$}$) in equation 1.36. In case workers have been employed in the previous period and the economy experienced a positive growth rate, the adjusted wage is increased by a proportion of the previous period growth rate,[31] as shown in equation 1.37:

$$w_{h,t}^{d,*,\$} = max\left[w_{h,t-1-T_{h,t}^{w}}^{\$}\left(1+\gamma_1\frac{cpi_{t-1}-cpi_{t-2-T_{h,t}^{w}}}{cpi_{t-2-T_{h,t}^{w}}}\mathbf{1_w}\right),\ w_{h,t-1-T_{h,t}^{w}}^{\$}\right] \tag{1.36}$$

$$w_{h,t}^{d,\$} = \begin{cases} w_{h,t}^{d,*,\$}(1+\gamma_2 g_{t-1}) & \text{if } T_{h,t}^{w}=0 \text{ and } g_{t-1}>0, \\ w_{h,t}^{d,*,\$} & \text{otherwise.} \end{cases} \tag{1.37}$$

where $w_{h,t-1-T_{h,t}^{w}}^{\$}$ is the last strictly positive wage received by the worker, cpi_t is the consumer price index, $T_{h,t}^{w}$ is the number of periods the worker has been unemployed since her last employment (if employed in $t-1$, $T_{h,t}^{w}=0$), $\mathbf{1_w}$ is an indicator function that takes one if the

[30] For simplicity, we do not input a real value for the financial sector's services when computing real output. In order to guarantee consistency, we do not consider the bank's profits when calculating nominal output and the wage share. As the interest rate on bonds, loans, and deposits is the same, the bank's profits are almost negligible. This is also the reason why it is assumed that the bank has no owners.

[31] More specifically, workers consider the growth rate of private aggregate demand, since they are bargaining wages with the consumption and capital goods firms.

inflation rate is positive and zero otherwise, g_{t-1} is the previous period private aggregate demand growth rate, and $1 \geq \gamma_{1,2} \geq 0$ are parameters that capture the sensitivity to the inflation and growth rates respectively. Note that workers' desired wage will always be at least equal to the minimum wage set by the government.

Workers' reservation wage, which establishes the minimum wage they accept when looking for a job, depends on their individual experience in the labor market and decreases with the number of periods they have been unemployed, as specified in equation 1.38. The intuition is that workers become more likely to accept a lower wage if they have been unemployed for a longer interval, in line with the idea that unemployment experiences tend to lead to a lower wage (Blanchflower, 1991). There is also a minimum difference between the desired and reservation wages regardless of workers' employment status, so workers always accept a wage that is slightly below their desired wage.

$$w_{h,t}^{r,\$} = w_{h,t}^{d,\$}(1 - \gamma_3 T_{h,t}^{w} - \gamma_4) \tag{1.38}$$

where $1 \geq \gamma_{3,4} \geq 0$ are fixed parameters capturing the sensitivity of workers' reservation wage to the number of unemployment periods and the minimum difference between the desired and reservation wages respectively. Once again, the reservation wage is never lower than the minimum wage.

1.4.4.2 Households' consumption

Our approach to households' consumption follows Duesenberry's (1949) relative income theory, which stresses that consumption patterns are based on relative consumption comparisons (a "keeping up with the Joneses" effect) and on habits, so that there is some inertia in consumption *vis-à-vis* income reductions. The former idea, which provides a sociological basis for the consumption behavior in line with the sociological foundation for our social classes, is formalized in the model by class-specific propensities to consume out of disposable income, as lower income groups tend to consume a larger fraction of their income in an effort to come closer to consumption patterns of higher income groups.[32] Another way of thinking about this relation is that the rich tend to save more because the accumulation of wealth offers them some sort of utility, as an end to itself and as a source of power and status (Carroll, 2000). Empirical support to this hypothesis is offered by Dynan et al. (2004), who find that current income and saving rates are positively related. The latter idea is captured in the model by a partial downward rigidity in households' real consumption level.[33] Formally, nominal consumption demand is determined as follows:

[32] This is also related to the interplay between household debt, inequality and consumption (Cynamon and Fazzari, 2008, Kim et al., 2014, 2015). As we assume that households have no access to the credit market, this relation is beyond the scope of this chapter. For agent-based models that deal with the relation between inequality and household debt, see Cardaci and Saraceno (2018) and Carvalho and Di Guilmi (2020).

[33] Caiani et al. (2019b) adopt a similar specification for consumption, in which there are class-specific propensities to consume and downward rigidity in households consumption.

$$C_{h,t}^{D,\$} = max \left\{ c_1 \frac{C_{h,t-1}^{D,\$}}{\bar{p}_{t-1}^{C,\$}} \bar{p}_t^{C,e,\$},\ c_2^j[(w_{h,t}^{\$} + \Pi_{h,t-1}^{h,\$})(1-\tau) + d_{h,t}^{\$})] \right\} \tag{1.39}$$

where $1 > c_1 > 0$ is the real consumption persistence, $\bar{p}_t^{C,e,\$}$ is the weighted average price in t (considering firms' market shares in $t-1$),[34] $\bar{p}_{t-1}^{C,\$}$ is the weighted average price in the previous period, $1 > c_2^j > 0$ is the propensity to consume out of income for each class $j = dir, ind, cap$, $w_{h,t}^{\$}$ is the wage earned by the household, $\Pi_{h,t-1}^{h,\$}$ is the profit dividends from the previous period, $d_{h,t}^{\$}$ is the tax-exempted unemployment benefit received by unemployed workers and τ is the tax rate on income. As households do not have access to the credit market, $C_{h,t}^{D,\$}$ may be limited by their available financial resources (deposits).

1.4.5 Public sector

The public sector is composed of a government and a central bank. The government collects taxes on households' income at a tax rate τ. It pays unemployment benefits to unemployed workers at a value equal to the minimum wage ($w_t^{min,\$}$), which is adjusted by the average wage inflation rate in the previous period. This adjustment rule represents a neutral minimum wage policy that does not target a specific redistributive outcome.

The public sector also hires a fixed number of direct and indirect workers as public servants (L_g^{dir} and L_g^{ind}), who are paid the average wage paid for their class in the consumption goods sector.[35] For simplicity, it is assumed that these workers are not subject to any turnover.[36]

The government maintains a current account at the central bank and the latter holds government bonds in its balance sheet. Therefore, in each period, when the government spends, it issues new government bonds that are acquired by the central bank (unless the government's deposits at the central bank are enough to cover the total expenditure). The central bank then transfers the required amount of reserves to the bank, which credits the firms' or households' current accounts accordingly. When taxes are paid, the opposite occurs: the bank transfers reserves to the central bank and the government's account at the central bank is credited. At the end of the period, in line with the reflux principle emphasized in the post-Keynesian literature (Lavoie, 2014, ch. 4), if the government runs a deficit, the bank ends up with reserves that don't earn any interest and thus acquires government bonds from the central bank.

[34] This is an expected value because it considers firms' market share in $t-1$, while the realized average price level is based on their effective share of sales in the current period.

[35] In the national accounts, these expenditures are considered governmental services which are consumed by itself. In order to be consistent with our assumptions regarding the private sector, government expenditure in real terms is calculated assuming that the productivity of direct workers in the public sector grows in line with the average productivity in the private sector.

[36] In other words, the government never lays off its employees and the public servants never quit their job. This simplifying assumption is adopted in order to reduce the influence of the government's demand for labor in the labor market.

1.4.6 Labor market

We assume that the indirect and direct workers belong to the primary sector of the labor market, insofar as they are either managers or factory workers whose employment is long-term and full-time (Bewley, 2007).[37] Accordingly, firms follow an internal pay structure that determines the entry wage of newly hired employees.[38] There are numerous reasons for this behavior, namely concerns with fairness and negative impact on effort or on the workforce's morale, in addition to restrictions from labor market regulations and collective agreements (Bewley, 2007, Galuscak et al., 2012). In our model, this internal pay structure is modeled in a simple manner, so there are only two categories of jobs (managers or researchers and direct workers), which represent segmented labor markets, and workers within a category at a given firm receive the same wage regardless of their work experience, time on job, or skills. This also means that even if firms may know whether the worker was unemployed in previous periods, they do not discriminate against unemployed workers in a strategic way by offering them a lower wage. This wage structure is periodically revised by the firms taking in consideration some information from the labor market. In this sense, the wage level results from an interaction between firms and workers and can be affected by workers' bargaining power, even if there is no explicit negotiation with the employees or a union.

Following the evidence on downward nominal wage rigidity, we assume that firms do not cut nominal wages (Bewley, 2007, Dickens et al., 2007).[39] There are also numerous explanations for this behavior, going from employees' morale and effort concerns, fear of losing the most productive workers, to institutional restrictions (Caju et al., 2015). While some authors also find evidence of real wage rigidity in selected countries (Bewley, 2007, Dickens et al., 2007), this can result from the wage bargaining process between workers or unions and firms (Dickens et al., 2007) and thus is not explicitly considered in our model.

Finally, workers are fired if firms' demand for workers is lower than the current number of employees (i.e., there is no labor hoarding) or to meet the employees turnover target (given by the ϑ parameter).[40] Workers, on the other hand, look for new opportunities in the labor

[37] However important, our model does not intend to explore the effect of labor market reforms that have facilitated flexibility and created the so-called dual labor market, wherein primary sector workers are relatively more insulated from labor market fluctuations than secondary sector workers (Caju et al., 2015). In this sense, we aim to capture a more collective dimension of workers' bargaining power, rather than individual dimensions that nonetheless may have macro implications. For a complementary discussion on labor market flexibility in an agent-based framework, see Dosi et al. (2017, 2018).

[38] Bewley (2007) shows that new employees' pay is tied to the internal structures in the primary sector in the case of the U.S. Similarly, Galuscak et al. (2012) show that more than 70% of firms in 15 European countries declare that internal pay structures are more important to the determination of entry wages than external factors. The authors also show that more than 80% of firms that were asked whether they pay a higher (lower) wage to newly hired employees depending on shortage (abundance) of workers in the labor market denied doing so.

[39] This also means that negative inflation rates are not considered when workers adjust their desired wages or in the minimum wage adjustment.

[40] The firm may also have to fire additional workers in case it does not have the financial resources to hire them in the current period. Workers to be fired are randomly selected among current employees.

market if they have been fired or if their current employer offered them a wage lower than their reservation wage.

1.4.6.1 Wage setting

The wage setting process is organized into the following steps. Firstly, firms decide their desired wage ($w_{f,t}^{j,d,\$}$, where $j = dir,\ ind$), which, for simplicity, is equal to the wage level from the previous period ($w_{f,t-1}^{j,\$}$). Then, in line with the idea that firms can use labor market surveys of pay rates for positions that are common to many firms when adjusting their wage levels (Bewley, 2007), they consult a random set of workers in the private sector in order to assess their average desired wage level ($w_{f,t}^{j,s,\$}$). For simplicity, we assume that this survey is costless. The number of workers surveyed is a proportion $n^{s,j}$ of firms' demand for workers from class $j = dir,\ ind$.[41] The fact that each firm surveys a different sample reflects their limited and localized knowledge, so the survey can be interpreted as a metaphor for this limited knowledge in firms' assessment of the labor market conditions. Finally, the wage offered ($w_{f,t}^{j,\$}$) is a weighted average between firms' desired wage ($w_{f,t}^{j,d,\$}$) and the surveyed wage ($w_{f,t}^{j,s,\$}$). We assume that firms take into consideration the employment rate from the previous period (η_{t-1}) when setting the weight given to the wage survey, as a higher employment rate increases workers' bargaining power. These relations are described by equation 1.40 below:

$$w_{f,t}^{j,\$} = (1 - \phi\eta_{t-1})w_{f,t}^{j,d,\$} + \phi\eta_{t-1}w_{f,t}^{j,s,\$} \tag{1.40}$$

where $1 \geq \phi \geq 0$ is a fixed parameter capturing the sensitivity of workers' bargaining power to the employment rate. Thus, workers' bargaining power is given by $\phi\eta_{t-1}$, which captures how close the average nominal wage is to the average wage desired by workers.[42]

1.4.6.2 Hiring process

Once the number of open job posts for each type of worker is defined, the firms interact with workers in the labor market. This interaction is modeled as a random process in

[41] While the demand for workers by the consumption goods firms is already known at this point, it is not yet determined for the capital goods firms, whose production level depends on the investment demand. Thus, the latter uses the average production level in the four previous periods to have an approximate number of workers that will be demanded in the period. Note also that the proportion of workers surveyed is different for indirect and direct workers. The same proportion for both could lead to a very small number of indirect workers being surveyed. By randomly selecting employed and unemployed workers, firms will, on average, survey a set of workers that reflects the participation of unemployed and employed workers in the economy. Therefore, if the unemployment rate is low (high), more (less) employed workers are surveyed. The unemployment rate is also key to the wage setting process through equation 1.40.

[42] Fagiolo et al. (2004) adopt a similar equation, but in their model firms' bargaining power is exogenous. Our model captures two important determinants of workers' bargaining power dynamics: institutions that support workers' bargaining power (captured by the ϕ parameter) and changes in the employment rate. This allows for a richer and more encompassing analysis of income distribution dynamics, as the same wage share can result from different combinations of ϕ and η_t and, consequently, can be related to markedly different macroeconomic contexts, as discussed more broadly and with respect to the experience of the US economy in recent times by Setterfield (2021). The inclusion of productivity growth adds a third determinant to the story, as shown in our results in section 1.6.

order to mimic the complex and diverse nature of the job offer and search processes in reality, similarly in spirit to the process put forward by Riccetti et al. (2015). In our model, a random list of firms is formed with the capital goods firm always being in the first position. The first firm tries to match with an indirect and a direct worker by randomly selecting a worker of each type. Workers accept an offer if the offered wage is above their reservation wage; otherwise, the hiring round will have been unsuccessful. After this, the second firm starts its hiring round and so on until all firms in the list have executed one hiring round for each type of worker. The process iterates until all firms have filled all open positions or reached the maximum number of hiring rounds for each type of worker, given by a multiple n^w of the number of open positions.

1.4.7 Sequence of events

In each simulation period, the sequence of events is the following:

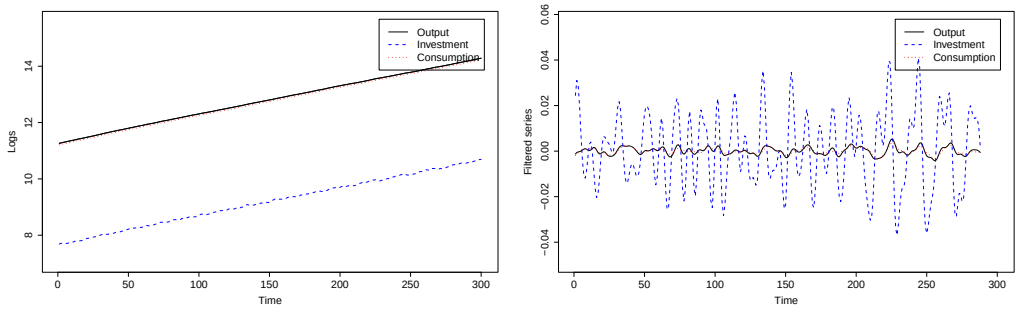
1. Interest on deposits and on government bonds are paid;
2. Consumption goods firms set desired production levels;
3. Nominal wages are set;
4. Capital goods firm sets the price and technology used and embodied in new machines;
5. Credit market opens;
6. Consumption goods firms set investment demand;
7. Labor market opens;
8. Production and R&D activities take place;
9. Unemployment benefits and wages are paid;
10. Consumption goods market opens;
11. Taxes are paid;
12. Bank acquires government bonds from the central bank;
13. New machines are delivered and old machines are scrapped;
14. National accounts and statistics are computed;
15. Exit and entry of consumption goods firms take place.

1.5 Model validation

The model is simulated for 500 periods (200 transient periods and 300 considered periods).[43] This section reports the main average results for the 100 Monte Carlo simulations for the baseline scenario, whose parameters and initial values are reported in Appendix B. We initially analyze the model's ability to reproduce important stylized facts identified in the empirical literature, with special attention being given to stylized facts related to the income distribution dynamics. Before proceeding further, it should be noted that while we did rely on parameters reported in empirical studies as much as possible, we did not estimate the model based on actual data. Accordingly, our calibration procedure is mainly intended to obtain plausible results in the baseline scenario that do not deviate from qualitative and stylized properties that are observed in the actual data. This analytical approach provides a sound basis to interpreting our experiment results as reflecting plausible theoretical relationships and causal mechanisms.

1.5.1 Micro and macro

We start the empirical validation of the qualitative properties of the model by exploring its macroeconomic characteristics. Figure 1.2 indicates that the main macroeconomic variables (output, consumption, and investment) show a sustained growth pattern with fluctuations. In addition, investment is more volatile than output and consumption is less volatile than output (Carlin and Soskice, 2014).[44]



(a) Level (logs) (b) Cycle (Bpf)

Figure 1.2: Output, consumption, and investment

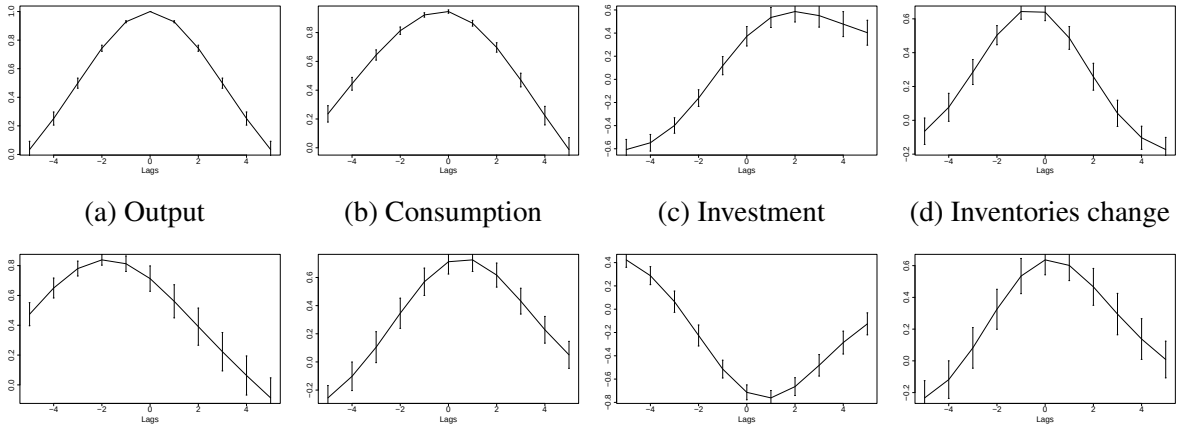
Note: Bpf: bandpass-filtered (6,32,12). Average of 100 Monte Carlo runs. All series are taken in logarithm. Source: author's own elaboration based on simulation results.

Figure 1.3 shows the cross-correlations between the cyclical components of output and selected macroeconomic series obtained through the bandpass filter. The sign of the correlation at time t indicates whether the variable is countercyclical (if negative) or procyclical

[43] Unless mentioned otherwise, all figures, tables, and statistics refer to the time span from period 201 to 500.

[44] The standard deviation of consumption relative to output is equal to 0.803, while the standard deviation of investment relative to output is equal to 8.471.

(if positive), while the position of the peak indicates whether the variable is lagged, coincident or leading output. As reported by Carlin and Soskice (2014) and Stock and Watson (1999), we observe that consumption is procyclical and coincident with output and investment is procyclical, but leading output.[45] Also in line with the empirical evidence, we observe that the change in inventories is procyclical, average labor productivity is procyclical, and capacity utilization is procyclical. We find that the unemployment rate is countercyclical, reflecting the positive effect of higher output levels on employment (despite of the increase in productivity). In addition, we find that the cyclical component of the inflation rate is procyclical.



(a) Output (b) Consumption (c) Investment (d) Inventories change

(e) Labor productivity (f) Capacity utilization (g) Unemployment rate (h) Inflation rate

Figure 1.3: Cross-correlations structure for output

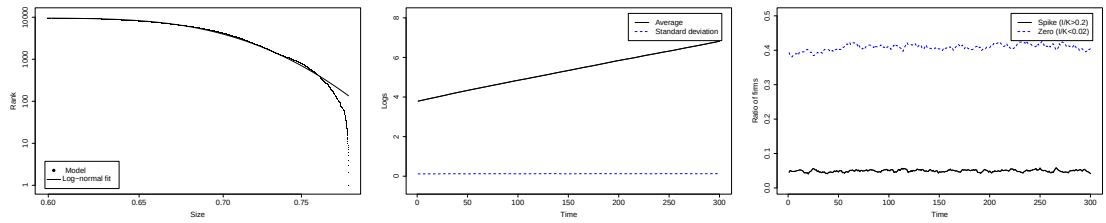
Note: Bpf: bandpass-filtered (6,32,12). Output, consumption, investment, change in inventories, and average productivity series are taken in logarithm. Bars are standard deviations of 100 Monte Carlo average cross-correlations. Source: author's own elaboration based on simulation results.

The baseline specification also reproduces the fat-tailed distribution of output growth rates (Fagiolo et al., 2008). In exponential-power (Subbotin) distributions, the smaller the shape parameter, the fatter are the tails of the density. These distributions include the Gaussian and the Laplace distributions as special cases (when the shape parameters are equal to two and one respectively). When the shape parameter is smaller than that of the Gaussian distribution, events at the extreme of the distribution (very high growth rates or very low growth rates) are more frequent than it would be expected in case of normally distribution shocks. In our baseline specification, the average shape parameter of the exponential-power distribution of aggregate output growth rates considering the 100 Monte Carlo runs is equal to 1.668 (standard deviation equal to 0.237), in line with the evidence favoring fat-tailed distribution of output growth rates.[46]

[45] Stock and Watson (1999) show that total fixed investment tends to be coincident with output, while investment in equipment lags the cycle. In our model, a leading investment probably results from the effect of replacement investment and to productivity growth being the main driver of output growth.

[46] Nevertheless, there is weaker statistical support for rejecting the hypothesis that the distribution fits a normal distribution, as the p-value of the Jarque-Bera test is equal to 0.211 (test statistics is 18.265).

The model also reproduces microeconomic characteristics, reflecting the heterogeneity of the consumption goods firms that emerges during the simulations.[47] The Zipf plot in figure 1.4a suggests that firms are very heterogeneous with respect to their sizes (measured by their real sales) and that the log-normal fits the data well except for the upper tail (Stanley et al., 1995). The deviation from log normality is confirmed by the Jarque-Bera normality test, which presents a p-value of 0 (test statistics is 2685.02). There is also evidence that the distribution of firms growth rates (measured by sales growth) presents tails fatter than a Gaussian distribution (Bottazzi and Secchi, 2003), since the fitted exponential-power distribution presents a shape parameter equal to 1.364 (standard deviation equal to 0.062).



(a) Sales distribution (pooled) (b) Productivity (logs) (c) Investment lumpiness

Figure 1.4: Stylized microeconomic facts (consumption goods sector)

Note: Average of 100 Monte Carlo runs. Period for figure 1.4a: 500. Source: author's own elaboration based on simulation results.

We find that there is a persistent productivity differential across firms (Barth et al., 2016, Dosi, 2007, Dunne et al., 2004), as reflected in the standard deviation reported in figure 1.4b. There is also evidence of strong autocorrelation in firms' productivity levels, as the average autocorrelation of productivity is 0.981 for the first lag (standard deviation equal to 0.004) and 0.97 for the second lag (standard deviation equal to 0.006). This indicates that differences in productivity tend to be persistent, as suggested by Dosi (2007). Finally, as reported in figure 1.4c, we observe that investment is lumpy (Doms and Dunne, 1998), with some firms experiencing investment spikes simultaneously to other firms presenting very low or no investment at all.

1.5.2 Wages and income distribution

In addition to reproducing key macro and micro stylized facts, the model reproduces important stylized facts concerning the income distribution dynamics captured by three key variables: the wage share, Gini coefficient, and the real wage.[48] This is particularly important for our main purpose, as it indicates that the proposed model structure offers a sound basis for

[47] Note that the same initial conditions are used for all firms in the consumption goods sector. See Appendix B for more details.

[48] The wage share refers to the share of the nominal wage bill over nominal output. The Gini coefficient reflects the comparison of the cumulative proportions of income relative to the cumulative proportions of the population. It ranges between 0 (perfect equality) and 1 (perfect inequality). The real wage is the average nominal wage over the average price of consumption goods.

the study of income distribution. The study of this broad range of stylized facts specifically related to income distribution is a further contribution of this chapter to the AB macroeconomic modelling literature, as these stylized facts have been relatively less explored so far.

As reported in table 1.1, the wage share is countercyclical and the real wage is procyclical.[49] The countercyclicality of the wage share indicates that labor productivity is more responsive to the cycle than the real wage (Giovannoni, 2010), so costs do not increase at the same rate as output in the expansion of the cycle. There are many reasons for this, such as labor hoarding and overhead labor. Indeed, Kalecki (1971, ch. 6) pointed out that the share of salaries in output varies countercyclically while the share of hourly wages is relatively stable during the cycle, thus rendering a countercyclical wage share (considering salaries and hourly wages). This is the case because in the expansion phase of the business cycle, firms do not need to hire a proportionally higher number of managers. Consequently, their share of income in output falls and productivity, measured by total output divided by total number of workers employed (including managers), increases.[50]

There is also a positive relation between unemployment and the gross income Gini coefficient,[51] as shown in Figure 1.5a. Consequently, at the peak of the business cycle, when the wage share falls, the lower unemployment rate counterbalances the inequality-inducing effect of this lower wage share (Figure 1.5b). This negative relation between the wage share and the income Gini coefficient is due to relative (more income to lower classes) and composition (more income directed to a class whose income is more equally distributed than capital income) effects of a higher wage share (Daudey and García-Peñalosa, 2007, Wolff and Zacharias, 2013).

Table 1.1: Contemporaneous correlation with output (Bpf)

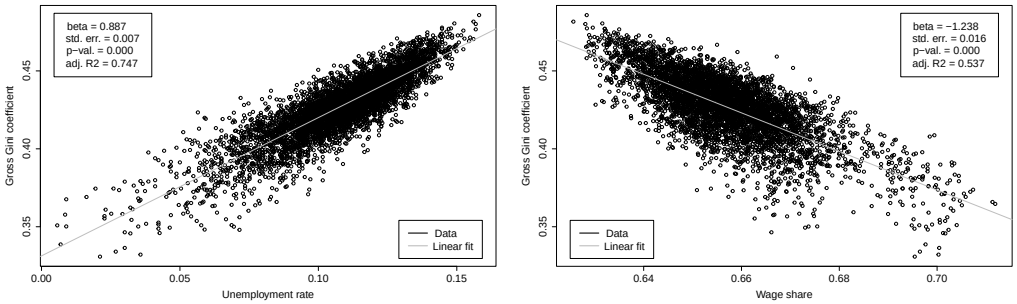
	Correlation	Standard deviation	p-value
Wage share (Bpf)	-0.478	0.108	0.000
Real wages (Bpf)	0.640	0.070	0.000

Note: Bpf: bandpass-filtered (6,32,12). Average of 100 Monte Carlo runs. Output and real wage series taken in logarithm. Source: author's own elaboration based on simulation results.

[49] For a discussion on the cyclical behavior of the real wage, see Basu and House (2016), Bils (1985), and Solon et al. (1994). For empirical evidence on the countercyclicality of the wage share, see Giovannoni (2010) and Schneider (2011).

[50] For a theoretical discussion on productivity and functional income distribution during the business cycle see Lavoie (2014, 2017). See also Cauvel (2022) and Rolim (2019) for empirical evidence.

[51] Due to the understanding that inequality before taxes and transfers reflects the income distribution determined by market forces, part of the literature adopts the term "market inequality". Nevertheless, we prefer to use the term "gross inequality", since government policies also shape such market forces (Stiglitz, 2012). An example of this is labor market institutions, such as minimum wages, or educational spending by the government (IMF, 2014). In addition, taxes and transfers may alter the gross inequality through their effects on economic activity and employment, as shown by Gerber et al. (2020) for progressive taxation, for instance.



(a) Unemployment and gross Gini coefficient (b) Wage share and gross Gini coefficient

Figure 1.5: Scatter plots

Note: Average of 100 Monte Carlo runs. Periods: 451 to 500. The number of periods has been adjusted to allow a better visualization. Source: author's own elaboration based on simulation results.

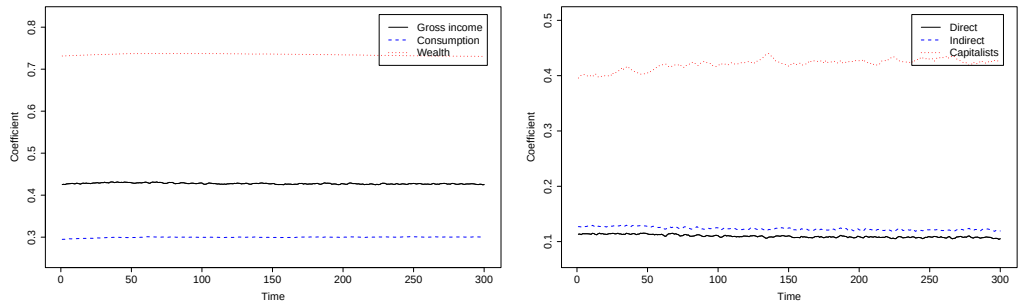
Figure 1.6a shows that the model also reproduces empirical observations concerning different inequality measures. We find that income inequality is larger than consumption inequality (Maestri and Roventini, 2012, Fisher et al., 2013, Heathcote et al., 2010) and wealth inequality is larger than income inequality (Brzozowski et al., 2010).[52] The literature suggests that consumption inequality tends to be lower than income inequality due to the smoothing role of borrowing and saving (Heathcote et al., 2010). Although households are credit-constrained in our model, they may use their savings to maintain a share of their previous real consumption when they face a reduction in their real income. An additional explanation for this empirical regularity goes beyond the idea that savings are used to smooth consumption and suggests that higher income levels are associated with higher propensities to save in the long run (Carroll, 2000, Dynan et al., 2004). This feature is also considered in our model (see equation 1.39). The higher wealth inequality is a mirror of the lower consumption inequality: if consumption inequality is smaller than income inequality, those groups earning more income are not consuming proportionally more, so they are saving more (accumulating more wealth). This highlights the strong relation between two of the main components of wealth inequality, that is, the differential in saving rates and the personal income inequality, and suggests that the factors driving income inequality may also be driving wealth inequality (Tippet et al., 2021). This latter aspect will be explored in our experiments presented below.

In addition, the pattern of within-class inequality reported in Figure 1.6b is markedly different across income groups and reproduces the main aspects identified by Wolff and Zacharias (2013), who find that the intra-class income Gini coefficient is higher for capitalists than for employees and that the intra-class income Gini coefficient for classes with a lower mean income tends to be lower than for classes with higher mean income.[53] As indirect workers' average income is equal to 2.104 of direct workers' average income and capitalists' average income is

[52] In the model, wealth inequality refers to the distribution of deposits held by the households as this is the only asset held by households whose value is measured.

[53] This applies to the comparison between the Gini coefficients for the two groups with lowest mean income (blue-collar, skilled workers and non-skilled workers) relative to the other six categories identified by Wolff and

equal to 7.517 of direct workers' average income (considering the average for the 100 Monte Carlo runs over the 300 effective periods), this last feature is also observed in our model. Indeed, capitalists' incomes are tightly linked to the consumption and capital goods markets, so the evolution of firms' market shares, costs, and prices entails changes in their owners' incomes. On the other hand, indirect and direct workers' incomes are determined by wages, unemployment benefits (which are equal to the minimum wage for both classes), and interest rates on deposits (if any). As direct workers' wages are lower than indirect workers' wages, the difference between employed and unemployed households in the former group is smaller than in the latter group, as reflected in the comparison between the Gini coefficients.



(a) Income, consumption, and wealth (b) Within-class inequality

Figure 1.6: Gini coefficients

Note: Average of 100 Monte Carlo runs. Source: author's own elaboration based on simulation results.

1.6 Class conflict: productivity, mark-up rates and wages

The literature on the recent income inequality dynamics indicates the importance of productivity growth and the lowering of workers' bargaining power. This interplay is key in our model and leads to an endogenous determination of the income distribution. Productivity growth allows firms to increase their mark-up rates as they face lower unit labor costs and thus represents an increase in their relative power *vis-à-vis* workers. Counteracting those forces, workers' bargaining power affects the evolution of nominal wages. The functional income distribution and real wages are the final result from the interaction between firms' strength (expressed primarily in prices) and workers' strength (expressed primarily in nominal wages) and, through our class structure, entail implications for the personal income distribution.

It is important to note a key implication of the class conflict framework in the model: while workers can affect the dynamics of nominal wages in the bargaining process with firms, this is only the first stage of the conflict since changes in the wage share will only occur if firms react to changes in their unit labor costs by adjusting their mark-up rates. Thus, as long as mark-ups do not fully absorb nominal wage increases, the wage share and the real wage

Zacharias (2013). The only exception identified in the article regards the comparison between the supervisors and the non-skilled workers.

determined in this second stage will disappoint workers. This reflects an intrinsic asymmetry of the class conflict: firms strength will be manifested both in the labor market when they negotiate with workers and in their pricing decisions.

In order to further explore these relations, we build three sets of experiments that provide some insights into how each of these aspects operate individually and jointly. In the first experiment, in section 1.6.1, we evaluate the effect of different levels of the sensitivity of workers' strength in the bargaining process to changes in the employment rate (ϕ), which is expected to lead to different levels of workers' bargaining power (measured by the ϕ parameter multiplied by the employment rate, as described in equation 1.40). Then, in the second experiment, described in section 1.6.2, we analyze how the economy behaves when the capital good firm's access to innovation changes (the ζ parameter in equation 1.1, which we refer to as the innovation easiness parameter), as this is expected to change the productivity growth rate and, consequently, firms' strength in the distributive conflict. Finally, in section 1.6.3 we analyze the interaction effects between productivity and workers' bargaining power by changing the ϕ and ζ parameters simultaneously.[54] In all cases, we compare the different scenarios with the baseline scenario presented in the previous section, which represents a scenario with high innovative easiness ($\zeta = 0.18$) and high sensitivity of workers' strength in the wage bargaining to the employment rate ($\phi = 0.9$).

1.6.1 Alternative workers' bargaining power scenarios

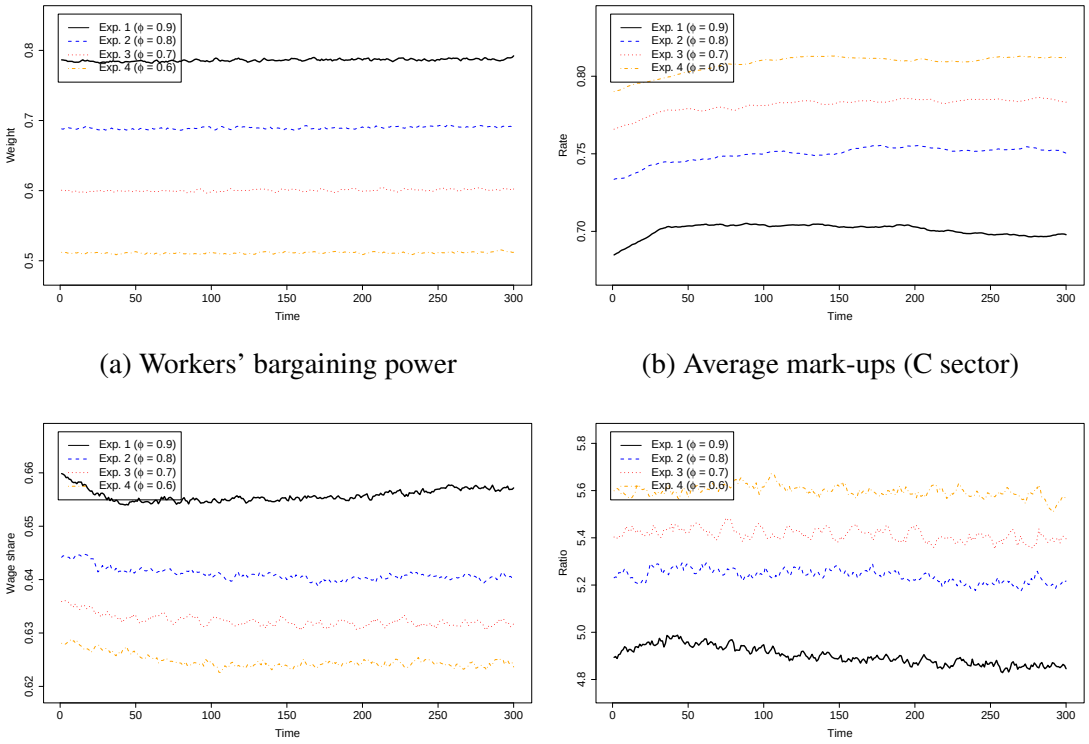
In this section, we are particularly interested in understanding how workers' bargaining power affects the income distribution and key macroeconomic variables. In the model, workers' bargaining power is related to the ϕ parameter in equation 1.40, which is assumed to capture the institutional framework supporting workers. A higher ϕ parameter means that decreases in the unemployment rate have a stronger effect on workers' strength in the bargaining process, forcing firms to consider relatively more the labor market conditions when setting the offered wage level. In order to capture the effect of the ϕ parameter, we compare four scenarios in which this parameter is progressively reduced from $\phi = 0.9$ in experiment 1 (our baseline scenario) to $\phi = 0.6$ in experiment 4. The analysis presented in this section is based on the time series generated by the simulations and on the statistical tests presented in table 1.2. In both cases, we consider the average of 100 Monte Carlo runs for each scenario.

As reported in figure 1.7, higher levels of workers' bargaining power sensitivity to the employment rate lead to higher workers' bargaining power and are effective to achieve and sustain a lower average mark-up rate in the consumption goods sector, which is associated with a higher wage share.[55] This results mainly from the interplay between productivity, mark-ups and wages being more favorable to firms when workers' bargaining power is low, meaning that they take advantage of productivity growth to increase their income shares. The opposite occurs

[54] The interaction effects are further explored in the sensitivity analysis in section 1.7.

[55] Recall that the mark-up rate in the capital goods sector is fixed.

when workers' bargaining power is high, as the interplay between productivity, mark-ups and wages becomes more favorable to workers and firms adopt a more protective attitude, using productivity increases to prevent nominal wage increases from passing on to prices entirely, as this can be harmful for their competitiveness. Nevertheless, nominal wage increases still force mark-ups downward and this results in a higher wage share, which translates into a lower ratio between average profit dividends and average wages. As explored below, it is interesting to note that the effect of the ϕ parameter on the wage share is non-linear (the effect of increasing ϕ by a fixed value increases with ϕ).



(a) Workers' bargaining power

(b) Average mark-ups (C sector)

(c) Wage share

(d) Profit dividends to average wages

Figure 1.7: Comparison of experiments: wage bargaining and functional income distribution (alternative values of ϕ)

Note: Higher values of ϕ represent a higher sensitivity of workers' bargaining power to changes in the employment rate. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

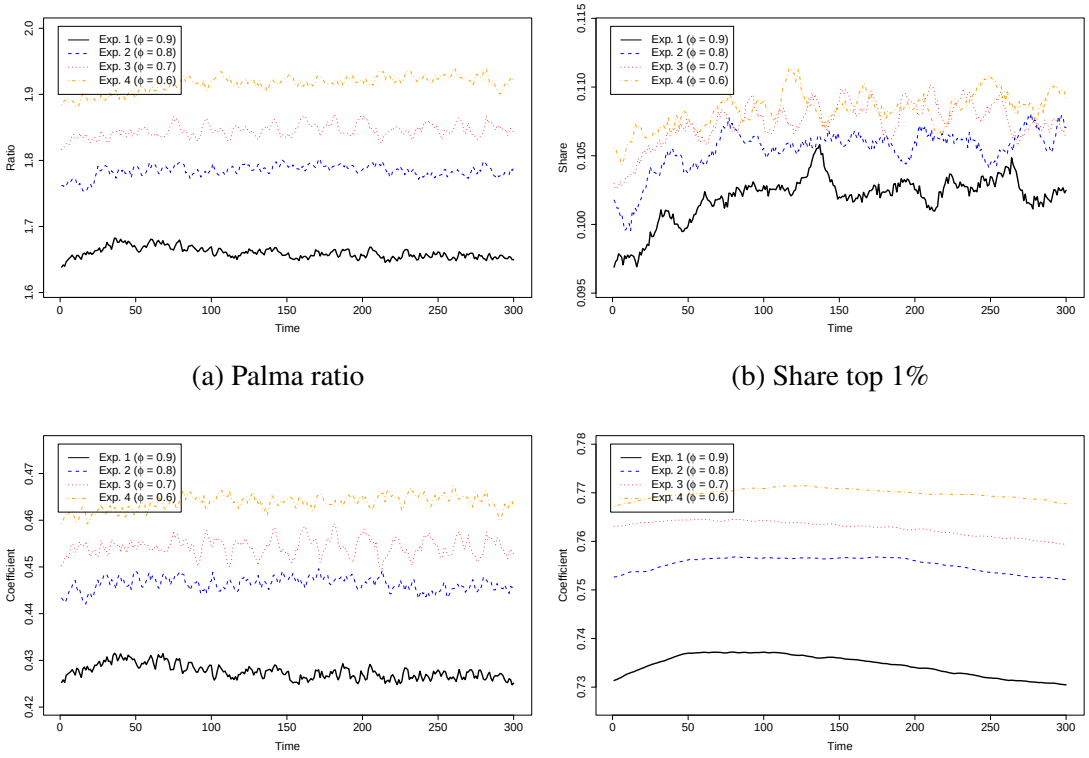
The different scenarios also lead to different levels of personal income inequality measured by the income Gini coefficient, Palma ratio,[56] and income share of the top percentile in the income distribution, as well as different levels of inequality in the personal wealth distribution (measured by the Gini coefficient), as reported in figure 1.8. There is a clear relation between higher levels of workers' bargaining power and lower income inequality. Interestingly the differences in income inequality are better captured by the income Gini coefficient and Palma

[56]The Palma ratio divides the share of income of the top 10% of the income distribution by that of the bottom 40%.

ratio, with the share of income received by the top percentile changing less across experiments.[57] This is because not all capitalists are part of the top percentile and the scenarios with higher levels of workers' bargaining power sensitivity to the employment rate are associated with a more concentrated income in the capitalist class (see table 1.2). Therefore, even if the capitalist class as a whole is earning a smaller share of total income, the increase in income inequality between capitalists leads to a smaller change in the share of the top percentile. This means that the higher workers' bargaining power also affects the intra-capitalist class conflict and benefits the richest capitalists (at least in comparison with their competitors).[58] Finally, the higher levels of workers' bargaining power are related with lower levels of wealth inequality, in line with the evidence by Tippet et al. (2021). The main mechanism driving this result is the dynamics of savings in a context of lower propensities to consume for high-income households: if their share of income reduces, they save less in each period (reducing the increase in deposits through current income) and they also face a reduction in interest payments from previously accumulated deposits.

[57] This exemplifies the importance of using a multitude of measures to evaluate changes in the income distribution.

[58] There is also a small difference in the Gini coefficient for wages across the experiments (table 1.2), which tends to decrease when workers' bargaining power decreases (lower ϕ). This is because in the scenarios with high workers' bargaining power, the increase in output stimulates investment demand, which has a positive effect on the number of researchers hired by the capital goods firms. Since these researchers are indirect workers, there are more indirect workers employed and demanding real wage increases than in the scenarios with a lower ϕ parameter, which leads to a higher ratio between indirect workers' and direct workers' wages. Nevertheless, the difference between the wage Gini coefficients is very small and insufficient to compensate the reduction in income inequality due to the increase in the wage share.



(a) Palma ratio

(b) Share top 1%

(c) Gross income Gini coefficient

(d) Wealth Gini coefficient

Figure 1.8: Comparison of experiments: personal income and wealth inequality (alternative values of ϕ)

Note: Higher values of ϕ represent a higher sensitivity of workers' bargaining power to changes in the employment rate. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

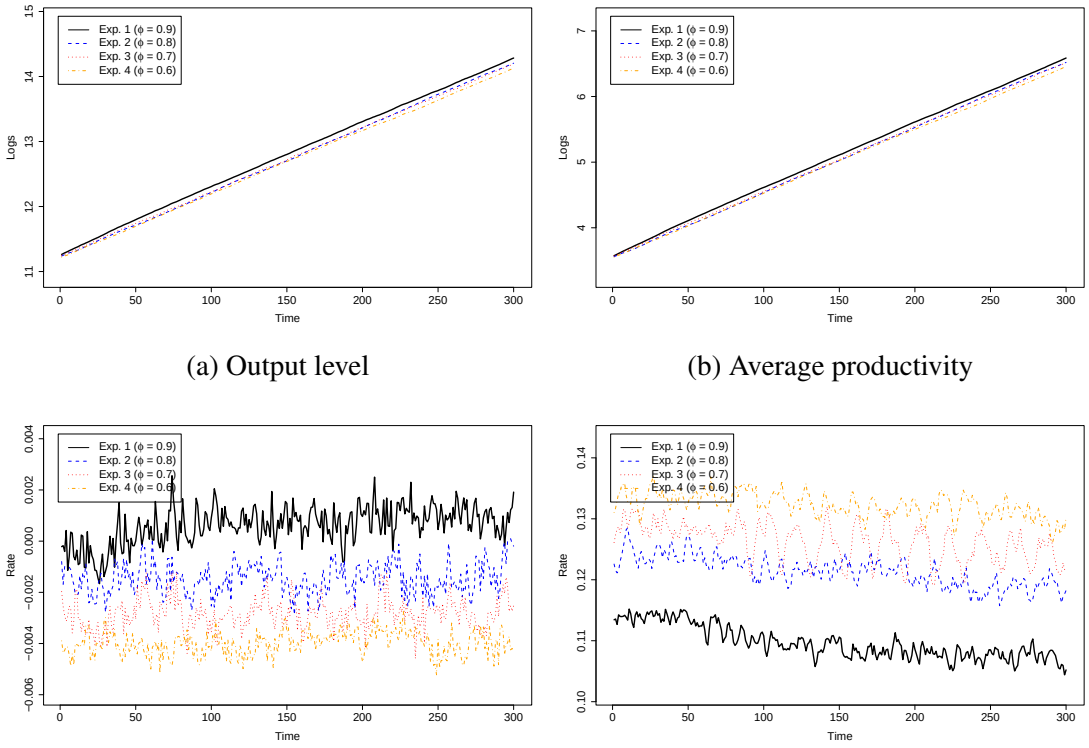
The macroeconomic implications of the different levels of workers' bargaining power are reported in figure 1.9. In general, a higher ϕ parameter is associated with a higher output level, with the difference being clearer for the comparison between experiment 1 and the other experiments.[59] A similar situation occurs with respect to the average productivity level, whose dynamics is key for that of output. Overall, this indicates that the more egalitarian income distribution associated with a higher workers' bargaining power does not compromise the output and productivity dynamics and, in some situations, can actually stimulate it. With respect to the inflation dynamics, the results indicate that higher workers' strength is associated with higher inflation rates, resulting from firms' effort to protect their income shares by passing on nominal cost increases to prices.[60] Finally, there is a lower unemployment rate when the ϕ parameter increases.[61] As the unemployment rate results from the interaction between productivity and output levels, this pattern indicates the predominant effect of output growth on employment. Note

[59] Table 1.2 shows that the output growth rate in experiment 1 is higher than in the other experiments and that this difference is statistically significant at the 10% significance level.

[60] Nevertheless, inflation rates are very modest and some scenarios experience negative average inflation rates due to part of the productivity gains being passed on to prices.

[61] Note that the unemployment rate is given by the number of employed workers divided by the number of workers ($L^{dir} + L^{ind}$), so it is assumed that capitalists are not part of the labor force.

that the lower average unemployment rate following a higher ϕ parameter explains the non-linear effect of ϕ highlighted before, characterizing a self-reinforcing mechanism and cumulative causation triggered by the model: by affecting the employment rate, the ϕ parameter reinforces its direct effect on workers' bargaining power, in addition to increasing the share of workers who increase their desired real wage due to being employed (equation 1.37). Also, the negative relation between unemployment rates and inflation rates observed in figure 1.9 reproduces a dynamics consistent with the conflicting-claims inflation approach to which our model is closely related to. In this approach, inflation is understood as a cost-push phenomenon that conciliates (in an *ex-post* manner) the conflicting income claims from different groups and, consequently, is mediated by institutions that affect workers' and firms' relative strengths (Rowthorn, 1977, Summa and Braga, 2019).[62]



(a) Output level

(b) Average productivity

(c) Inflation rate

(d) Unemployment rate

Figure 1.9: Comparison of experiments: macroeconomic series (alternative values of ϕ)

Note: Higher values of ϕ represent a higher sensitivity of workers' bargaining power to changes in the employment rate. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

[62] See Santoro (2020, ch. 2) for an agent-based model also inspired by the conflicting-claims inflation model.

Table 1.2: Average values: alternative workers' bargaining power regimes (ϕ)

	Exp. 1	Exp. 2	p-val	Exp. 3	p-val	Exp. 4	p-val
Weight of surveyed wage in bargaining	0.7860	0.6895	0.0000	0.6003	0.0000	0.5112	0.0000
Average mark-up (C sector)	0.7009	0.7498	0.0000	0.7816	0.0000	0.8082	0.0000
Wage share	0.6558	0.6410	0.0000	0.6323	0.0000	0.6247	0.0000
Profit dividends to average wages	4.9003	5.2392	0.0000	5.4140	0.0000	5.5970	0.0000
Palma index	1.6601	1.7842	0.0000	1.8449	0.0000	1.9157	0.0000
Income share top percentile	0.1020	0.1054	0.0000	0.1075	0.0000	0.1084	0.0000
Gross Gini coefficient	0.4276	0.4464	0.0000	0.4543	0.0000	0.4638	0.0000
Net Gini coefficient	0.3836	0.3980	0.0000	0.4042	0.0000	0.4115	0.0000
Wealth Gini coefficient	0.7345	0.7553	0.0000	0.7628	0.0000	0.7698	0.0000
Gini income capitalists coefficient	0.4210	0.4066	0.0000	0.4007	0.0000	0.3892	0.0000
Gini wages coefficient	0.1731	0.1717	0.0006	0.1682	0.0000	0.1660	0.0000
Gini consumption coefficient	0.2997	0.3099	0.0000	0.3138	0.0000	0.3183	0.0000
Output growth rate	0.0100	0.0097	0.0729	0.0097	0.1061	0.0096	0.0106
Output per capita (final period)	600.1547	554.3781	0.1987	548.6623	0.1286	513.7002	0.0043
Productivity growth rate	0.0099	0.0097	0.0833	0.0097	0.1217	0.0096	0.0167
Inflation rate	0.0006	-0.0015	0.0000	-0.0028	0.0000	-0.0040	0.0000
Unemployment rate	0.1097	0.1214	0.0000	0.1262	0.0000	0.1323	0.0000

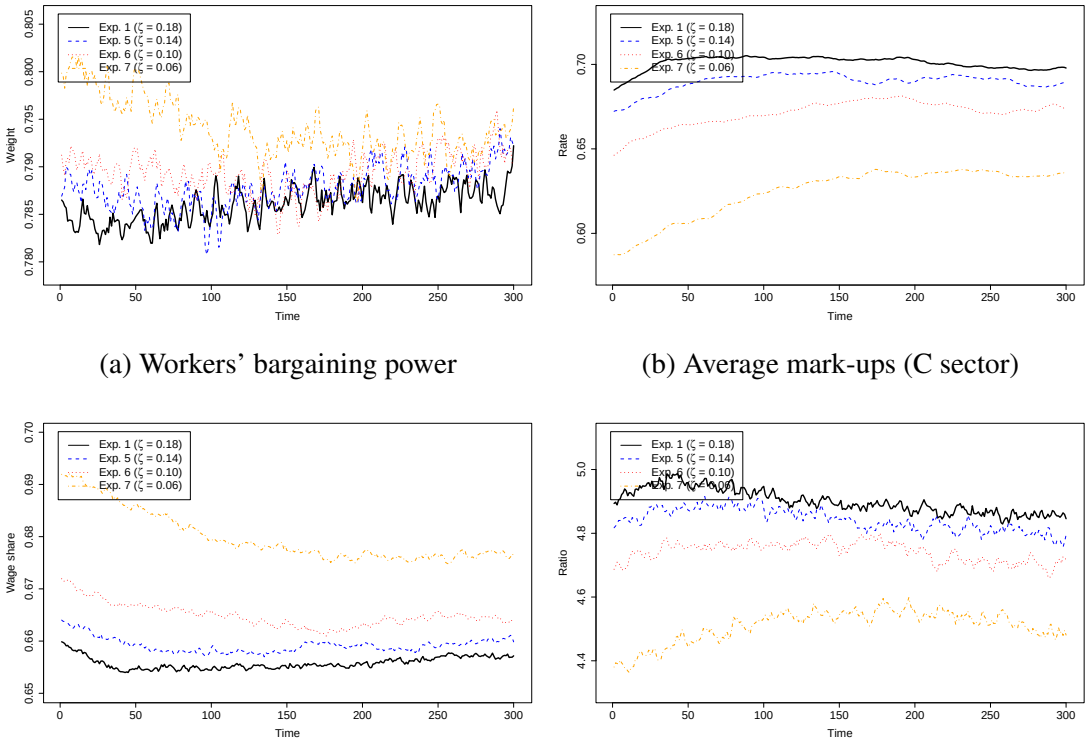
Note: Average of 100 Monte Carlo runs. P-values refer to comparison with baseline scenario. Source: author's own elaboration based on simulation results.

1.6.2 Alternative innovation dynamic scenarios

In this section, we investigate how the model behaves if the sensitivity of workers' bargaining power to the employment rate is constant, but the capital goods firm's innovation capabilities changes (ζ parameter in equation 1.1, referred to as innovation easiness). In the model, higher productivity growth in the capital goods sector is passed on to the consumption goods sector through more productive machines. The consumption goods firms can take advantage of those productivity gains by increasing their mark-up rates (equation 1.23) and, consequently, affecting the wage share and personal income distribution. As previously discussed, this is another dimension of the conflict over income distribution, as real wages may fail to accompany the productivity growth. We explore the effect of the ζ parameter by progressively reducing it from $\zeta = 0.18$ in the baseline scenario (experiment 1) to $\zeta = 0.06$ in experiment 7. As in the previous section, our analysis is based on the time series generated by the simulations and on the statistical tests presented in table 1.3 (considering the average of 100 Monte Carlo runs for each scenario).

Figure 1.10 reports the main series for the wage bargaining process and the functional income distribution for the scenarios characterized by different values for the ζ parameter. Despite of a constant value for the sensitivity of workers' bargaining power to the employment rate (ϕ parameter), the different values of the innovation easiness parameter are associated with different values of workers' power (expressed by the ϕ parameter multiplied by the employment rate). This indicates that more innovative economies can experience higher levels of unemployment (as

reported below), which triggers the previously mentioned endogenous mechanism in a different manner: productivity growth directly reduces unit labor costs if nominal wages are constant, but by increasing unemployment rates it also reduces workers' bargaining power in the wage setting process and increases the number of workers that do not increase their desired real wage for being unemployed, thus affecting the average nominal wage dynamics. The combination of these factors leads to a higher mark-up rate in the consumption goods sector, which translates into a lower wage share and higher profit dividends to average wages ratio when ζ is higher.



(a) Workers' bargaining power

(b) Average mark-ups (C sector)

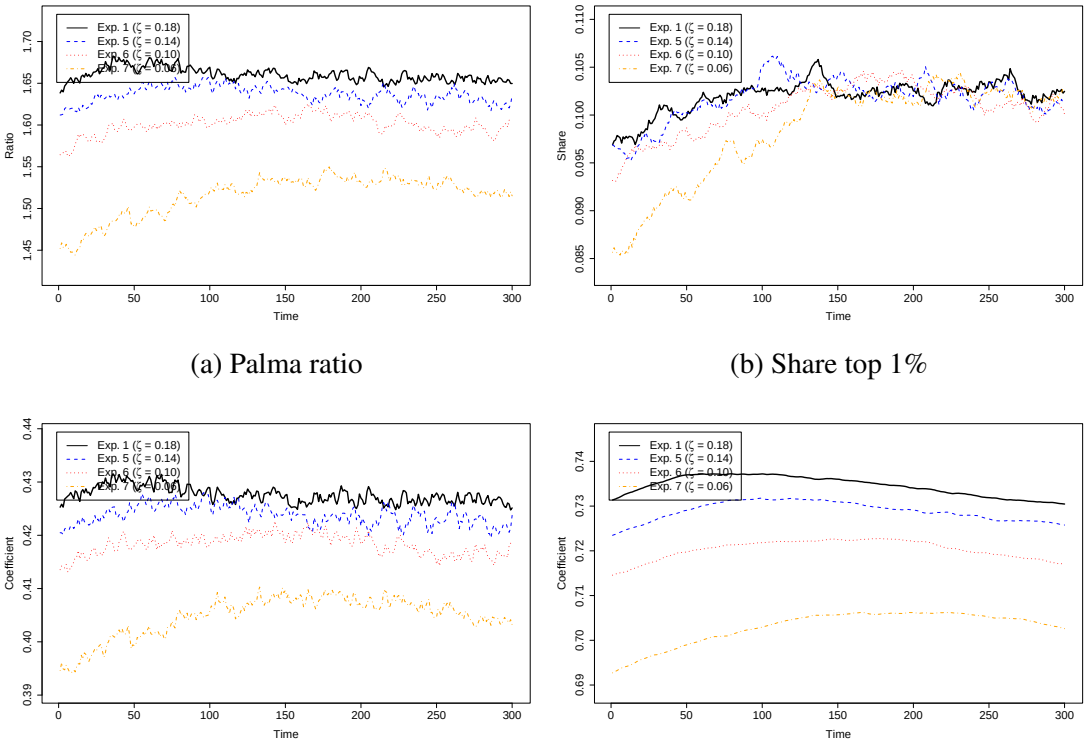
(c) Wage share

(d) Profit dividends to average wages

Figure 1.10: Comparison of experiments: wage bargaining and functional income distribution (alternative values of ζ)

Note: Higher values of ζ represent more innovation easiness. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

Following the same dynamics as in the previous set of experiments, the lower wage share associated with a higher ζ parameter has clear implications for the personal income distribution, leading to a higher Palma ratio and income and wealth Gini coefficients (figure 1.11). In this case, the scenarios barely differ with respect to the income share of the top percentile, especially by the end of the simulation period.



(a) Palma ratio

(b) Share top 1%

(c) Gross income Gini coefficient

(d) Wealth Gini coefficient

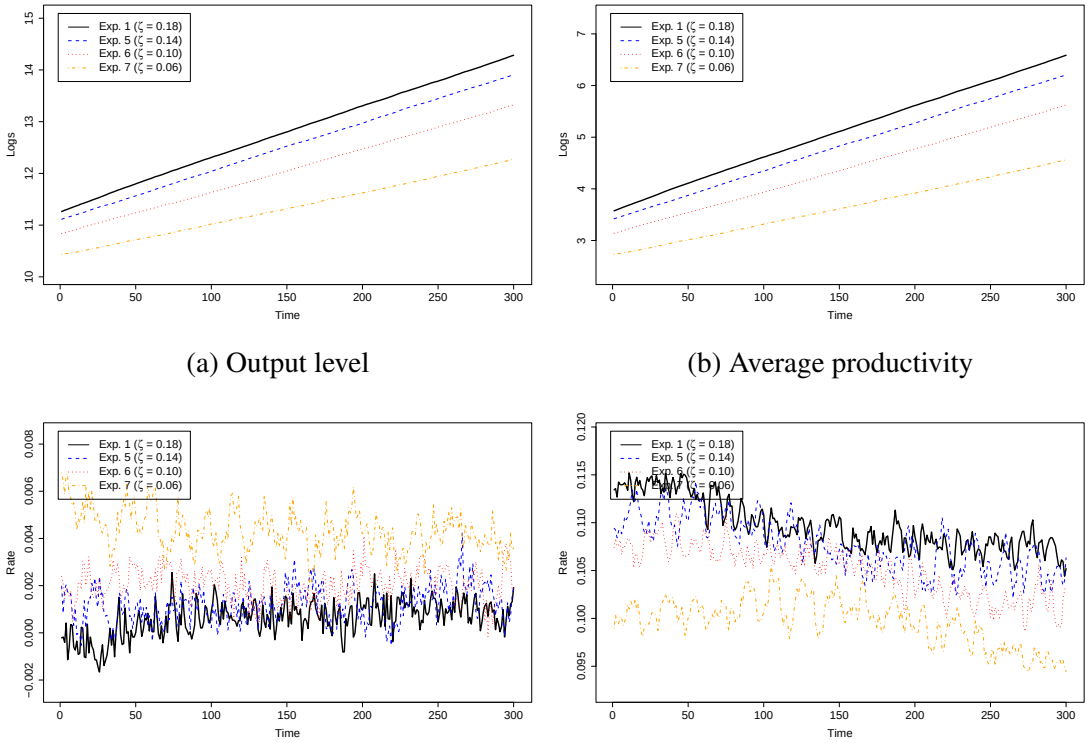
Figure 1.11: Comparison of experiments: personal income and wealth inequality (alternative values of ζ)

Note: Higher values of ζ represent more innovation easiness. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

The implications of higher values of ζ parameter on macroeconomic variables are explored in figure 1.12. As the key growth driver in the model is productivity growth, it is no surprise that the patterns of growth and productivity differ clearly in this case, with higher output and productivity levels being observed when the ζ parameter is higher.[63] As already mentioned, these divergent paths of productivity also imply differences in the unemployment rate, which tends to be higher when productivity is higher. This reveals the possibility of technological unemployment, which was not observed in the previous experiment, when higher productivity was associated with higher levels of workers' bargaining power. Indeed, in the current experiment the negative effect on employment from the higher productivity dominates the positive effect associated with the higher output level, except in the comparison between two of our scenarios: the higher output level in experiment 1 than in experiment 5 seems to be sufficient to counteract the negative effect of its higher productivity on the employment rate and the unemployment rates are not significantly different (table 1.3). Finally, the inflation dynamics is also different across the experiments, reflecting the interaction between the different unemployment and productivity growth rates. As the former tends to reduce nominal wage growth and the latter has a negative

[63] As shown in the sensitivity analysis in section 1.7, the parameters related to the innovation dynamics are among the most important parameters for the output growth dynamics.

effect on prices (as long as firms do not fully incorporate productivity gains in their mark-up rates), higher values of the ζ parameter are associated with a lower inflation rate. This result suggests that productivity growth contributes to alleviating the inflationary pressures generated by the social conflict over the income distribution.



(a) Output level

(b) Average productivity

(c) Inflation rate

(d) Unemployment rate

Figure 1.12: Comparison of experiments: macroeconomic series (alternative values of ζ)

Note: Higher values of ζ represent more innovation easiness. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

In sum, the alternative innovation dynamics scenarios suggest that productivity growth can indeed benefit firms as it offers them the possibility of taking advantage of the lower unit labor costs by increasing their mark-up rates. This is an endogenous and bottom-up mechanism that has macro implications for inequality. As productivity growth is strongly associated with output growth, we observe that a higher wage share and lower inequality in the personal income distribution are associated with a lower output level and growth rate. This results from the treatment of the wage share and workers' bargaining power as endogenous variables in our model, which also respond to the dynamics of productivity growth rates.

Table 1.3: Average values: alternative innovation regimes (ζ)

	Exp. 1	Exp. 5	p-val	Exp. 6	p-val	Exp. 7	p-val
Weight of surveyed wage in bargaining	0.7860	0.7878	0.1851	0.7894	0.0135	0.7941	0.0000
Average mark-up (C sector)	0.7009	0.6897	0.0025	0.6710	0.0000	0.6245	0.0000
Wage share	0.6558	0.6592	0.0048	0.6649	0.0000	0.6799	0.0000
Profit dividends to average wages	4.9003	4.8417	0.0592	4.7423	0.0000	4.5098	0.0000
Palma index	1.6601	1.6366	0.0414	1.6009	0.0000	1.5152	0.0000
Income share top percentile	0.1020	0.1017	0.6471	0.1007	0.0112	0.0985	0.0000
Gross Gini coefficient	0.4276	0.4238	0.0577	0.4183	0.0000	0.4048	0.0000
Net Gini coefficient	0.3836	0.3806	0.0387	0.3760	0.0000	0.3645	0.0000
Wealth Gini coefficient	0.7345	0.7289	0.0615	0.7203	0.0000	0.7030	0.0000
Gini income capitalists coefficient	0.4210	0.4230	0.3702	0.4254	0.0484	0.4289	0.0028
Gini wages coefficient	0.1731	0.1721	0.0338	0.1715	0.0007	0.1693	0.0000
Gini consumption coefficient	0.2997	0.2970	0.0112	0.2932	0.0000	0.2833	0.0000
Output growth rate	0.0100	0.0092	0.0000	0.0081	0.0000	0.0059	0.0000
Output per capita (final period)	600.1547	411.4328	0.0000	229.4678	0.0000	80.3815	0.0000
Productivity growth rate	0.0099	0.0092	0.0000	0.0081	0.0000	0.0059	0.0000
Inflation rate	0.0006	0.0012	0.0007	0.0021	0.0000	0.0043	0.0000
Unemployment rate	0.1097	0.1078	0.1705	0.1051	0.0013	0.0997	0.0000

Note: Average of 100 Monte Carlo runs. P-values refer to comparison with baseline scenario. Source: author's own elaboration based on simulation results.

1.6.3 Interaction effects

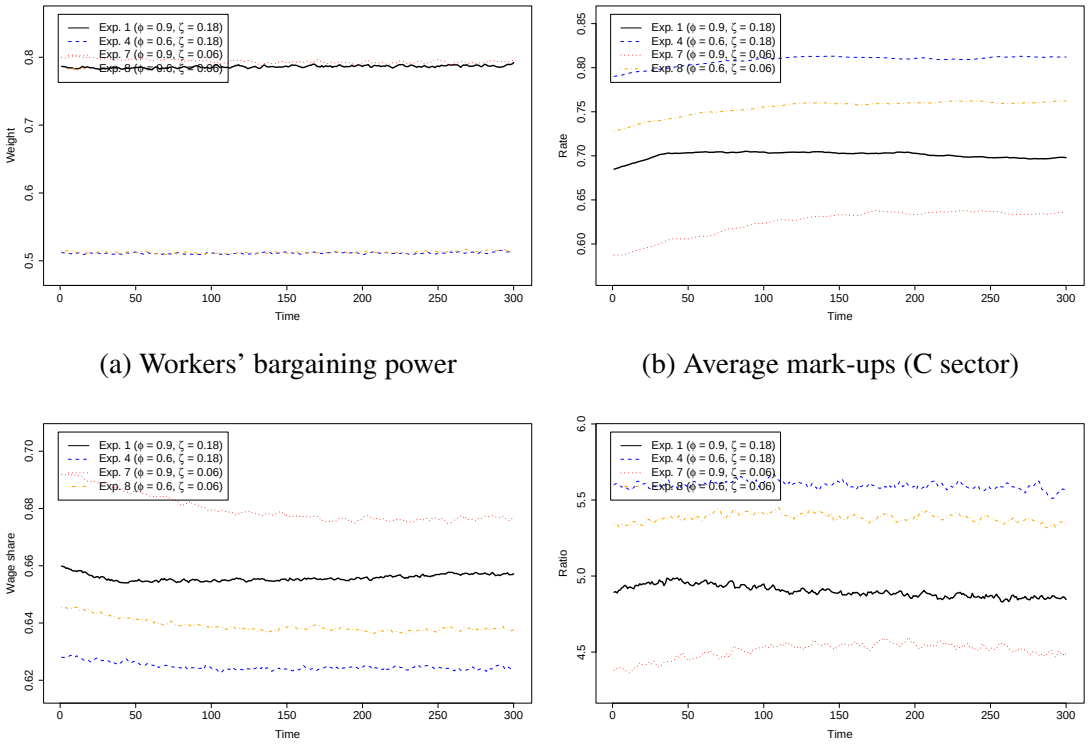
The previous sections showed the effect of changing the ϕ parameter or the ζ parameter individually. However, the interaction between productivity growth and workers' bargaining power is key to understanding the dynamics of income distribution in many economies and provides further insights into the relation between income distribution and economic activity. Thus, in this section we further explore the model properties by combining different values of ϕ (0.9 and 0.6) with different values of ζ (0.18 and 0.06). The experiments settings define two intermediate cases which affect firms and workers in different directions (experiment 1, where $\phi = 0.9$ and $\zeta = 0.18$, and experiment 8, where $\phi = 0.6$ and $\zeta = 0.06$), an economic structure favorable to firms (experiment 4, where $\phi = 0.6$ and $\zeta = 0.18$), and favorable to workers (experiment 7, where $\phi = 0.9$ and $\zeta = 0.06$).[64] Also in this case our analysis is based on the time series generated by the simulations and on the statistical tests presented in table 1.4 (considering the average of 100 Monte Carlo runs for each scenario).

We observe that workers' bargaining power varies with the values of the ϕ and ζ parameters, thus altering the functional income distribution (figure 1.13). The scenarios that present the lowest mark-up rates and, consequently, highest wage shares and lowest profit dividends to average wage ratios are the ones with the largest ϕ parameter, regardless of the value of the ζ parameter. This indicates that, at least for the parameter values adopted here, the effect

[64] Most of these experiments were presented in the previous sections when only one parameter was allowed to change. Their inclusion here allows us to better understand the interaction effects in the model.

of workers' bargaining power on the income distribution has a stronger effect on the income distribution than the productivity dynamics. Nevertheless, productivity dynamics is also key for the results: despite of a small difference in workers' bargaining power associated with the different values of ζ when ϕ is kept constant, there is a significant difference between the wage share in each scenario. This reveals the dual effect exerted by productivity growth in the model: it reduces the employment rate and thus reduces workers' bargaining power and the proportion of workers demanding real wage adjustments, but it also allows firms to directly increase their mark-up rates. In terms of our mark-up deviation equation (equation 1.23), this means that unit labor costs grow less because nominal wages are growing less and because productivity is growing more, with both factors benefiting firms.

The most favorable scenario to firms (experiment 4) is the scenario with the highest mark-up rate and lowest wage share. Indeed, in this case firms benefit from lower cost pressures, as nominal wage adjustments are lower, and can take advantage of the high productivity growth to increase their mark-ups. The opposite occurs in the scenario that is the most favorable to workers (experiment 7), as nominal wage adjustments will follow more closely the desired values by workers and productivity growth will be lower, reducing firms' opportunities to increase their mark-ups. As expected, the intermediate cases present intermediate values for the wage share and mark-ups. In the scenario with low workers' bargaining power and low innovation easiness (experiment 8), nominal wage adjustments exert a weaker downward pressure on mark-ups, but firms also have lower leeway to increase their mark-ups due to the lower productivity growth. Conversely, in the scenario with high workers' bargaining power and high innovation easiness (our baseline specification, experiment 1), nominal wage adjustments present a stronger downward pressure on mark-ups, but the higher productivity growth strengthens firms and they can (at least partially) sustain their mark-up rates.



(a) Workers' bargaining power

(b) Average mark-ups (C sector)

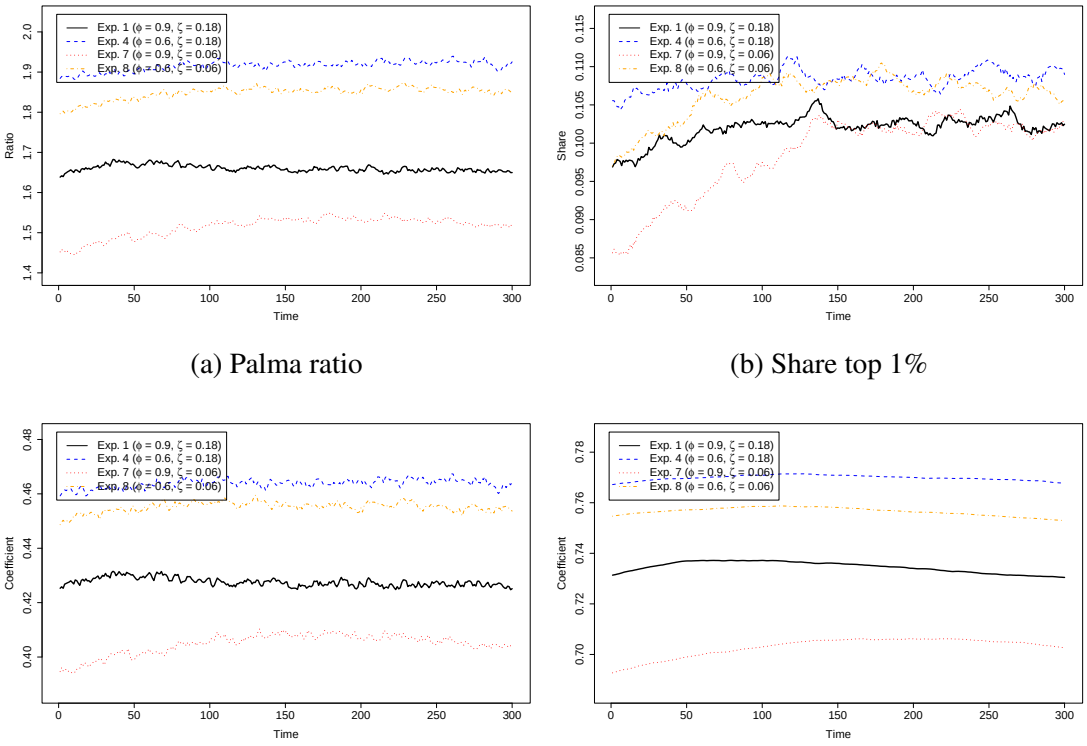
(c) Wage share

(d) Profit dividends to average wages

Figure 1.13: Comparison of experiments: wage bargaining and functional income distribution (alternative values of ϕ and ζ)

Note: Higher values of ϕ represent a higher sensitivity of workers' bargaining power to changes in the employment rate and higher values of ζ represent more innovation easiness. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

As reported in figure 1.14, the different patterns in the functional income distribution lead to important differences in the personal income and wealth distribution, as observed in the previous cases. Indeed, we find that a higher wage share is always associated with a more equal distribution of income and wealth, so the most favorable scenario to workers (experiment 7) presents the lowest inequality indicators and the most favorable scenario to firms (experiment 2) leads to the highest inequality indicators among the different scenarios.



(a) Palma ratio

(b) Share top 1%

(c) Gross income Gini coefficient

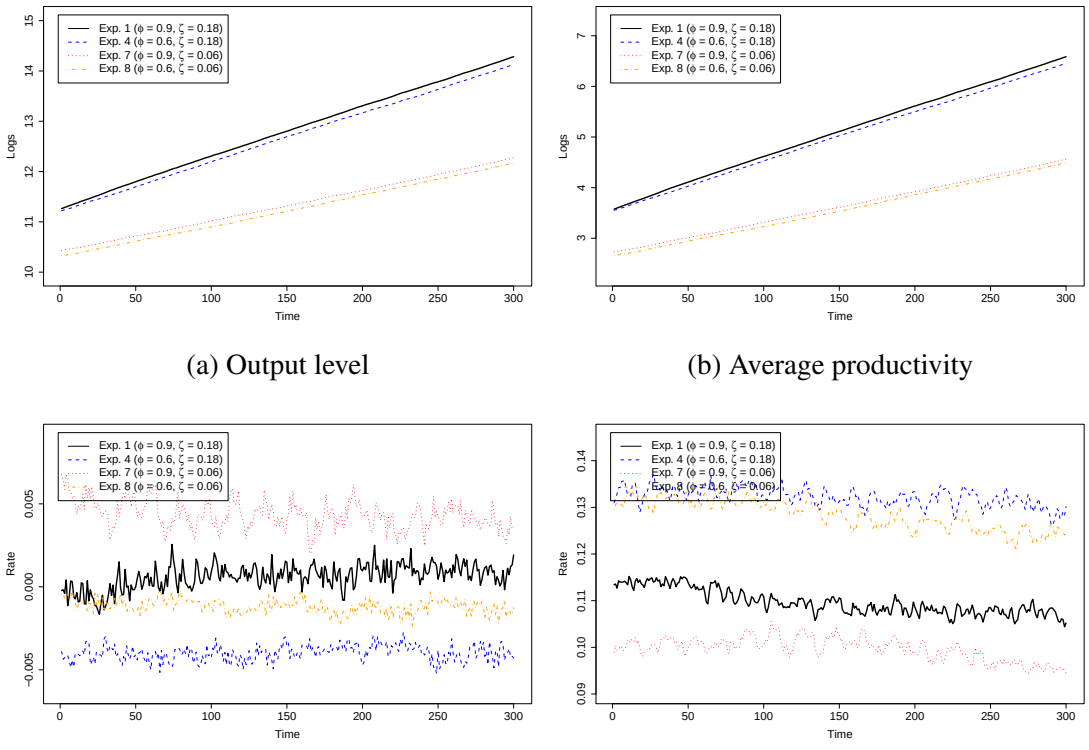
(d) Wealth Gini coefficient

Figure 1.14: Comparison of experiments: personal income and wealth inequality (alternative values of ϕ and ζ)

Note: Higher values of ϕ represent a higher sensitivity of workers' bargaining power to changes in the employment rate and higher values of ζ represent more innovation easiness. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

The macroeconomic implications of the different combinations of the ϕ and ζ parameters offer new insights into the relation between income inequality and macroeconomic variables (figure 1.15). As expected, the comparison between the different scenarios confirms the main properties identified in the previous sections: when the ϕ parameter is kept constant and the ζ parameter increases (and income distribution worsens), higher output and productivity levels are observed. Conversely, when the ζ parameter is kept constant and the ϕ parameter decreases (and income distribution worsens), there is a reduction in the output and productivity levels. This indicates that a higher wage share and lower personal income inequality can present different relations with output and productivity depending on the type of economic stimulus (changes in ϕ or ζ). More importantly, our results also suggest that regardless of the level of the ζ parameter, economic activity can be further stimulated and more equality can be achieved if workers' bargaining power is strengthened (higher ϕ parameter). Interestingly, the relation between the different combinations of the ϕ and ζ parameters with the unemployment rate is not the same as that observed with the output level, as it is mediated by the dynamics of the productivity rate. Indeed, when we compare the unemployment rate for each level of the ϕ parameter, we observe a lower unemployment rate when ζ decreases, despite of the lower

output level, due to the technological unemployment effect mentioned in section 1.6.2. Yet, when ζ is kept fixed, a higher ϕ parameter is always associated with lower unemployment rate and higher output and productivity rates. Therefore, also the unemployment rate will present different relations with the output level depending on the type of economic stimulus, suggesting that whether a higher output level translates into lower unemployment or not crucially depends on productivity gains being shared with workers.[65] This also means that the most favorable scenario to workers (experiment 7) is not only characterized by lower inequality, but also lower unemployment rates, which is an important variable for assessing workers' situation. Finally, we also observe that higher unemployment rates are associated with lower inflation rates. While this suggests that there is an "inflationary cost" in order to keep the unemployment rate at low levels, an alternative interpretation is also possible: in order to keep inflation at low levels (either through lower workers' bargaining power or productivity growth), there is an "unemployment and inequality cost" (which is not necessarily associated with an "output cost").



(a) Output level

(b) Average productivity

(c) Inflation rate

(d) Unemployment rate

Figure 1.15: Comparison of experiments: macroeconomic series (alternative values of ϕ and ζ)
Note: Higher values of ϕ represent a higher sensitivity of workers' bargaining power to changes in the employment rate and higher values of ζ represent more innovation easiness. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

[65] Note that even when workers' bargaining power is high ($\phi = 0.9$), productivity gains are not entirely shared with workers, since this depends on the parameters associated with the mark-up deviation (equation 1.23). If productivity growth is higher, firms will still be able to maintain relatively high mark-up rates, even if partially limited by the higher workers' bargaining power. This explains why for each level of ϕ the unemployment rate is higher in the scenarios with higher ζ (which are associated with more productivity growth).

Table 1.4: Average values: alternative workers' bargaining power regimes (ϕ) and innovation regimes (ζ)

	Exp. 1	Exp. 4	p-val	Exp. 7	p-val	Exp. 8	p-val
Weight of surveyed wage in bargaining	0.7860	0.5112	0.0000	0.7941	0.0000	0.5128	0.0000
Average mark-up (C sector)	0.7009	0.8082	0.0000	0.6245	0.0000	0.7547	0.0000
Wage share	0.6558	0.6247	0.0000	0.6799	0.0000	0.6391	0.0000
Profit dividends to average wages	4.9003	5.5970	0.0000	4.5098	0.0000	5.3833	0.0000
Palma index	1.6601	1.9157	0.0000	1.5152	0.0000	1.8481	0.0000
Income share top percentile	0.1020	0.1084	0.0000	0.0985	0.0000	0.1062	0.0000
Gross Gini coefficient	0.4276	0.4638	0.0000	0.4048	0.0000	0.4552	0.0000
Net Gini coefficient	0.3836	0.4115	0.0000	0.3645	0.0000	0.4041	0.0000
Wealth Gini coefficient	0.7345	0.7698	0.0000	0.7030	0.0000	0.7566	0.0000
Gini income capitalists coefficient	0.4210	0.3892	0.0000	0.4289	0.0028	0.3862	0.0000
Gini wages coefficient	0.1731	0.1660	0.0000	0.1693	0.0000	0.1651	0.0000
Gini consumption coefficient	0.2997	0.3183	0.0000	0.2833	0.0000	0.3101	0.0000
Output growth rate	0.0100	0.0096	0.0106	0.0059	0.0000	0.0058	0.0000
Output per capita (final period)	600.1547	513.7002	0.0043	80.3815	0.0000	72.2852	0.0000
Productivity growth rate	0.0099	0.0096	0.0167	0.0059	0.0000	0.0058	0.0000
Inflation rate	0.0006	-0.0040	0.0000	0.0043	0.0000	-0.0012	0.0000
Unemployment rate	0.1097	0.1323	0.0000	0.0997	0.0000	0.1284	0.0000

Note: Average of 100 Monte Carlo runs. P-values refer to comparison with baseline scenario. Source: author's own elaboration based on simulation results.

1.6.4 Summary of the main findings

The experiments presented in this section compared different scenarios characterized by different degrees of the sensitivity of workers' bargaining power to the employment rate and values of innovation easiness in the capital goods sector. The results confirm the importance of these aspects to how the class conflict over the income distribution unfolds, as the former aspect tends to increase workers' bargaining power and the latter aspect tends to increase firms' bargaining power. Additionally, our analysis provides important insights into the relation between income distribution and economic activity, as we observe that the effect of a higher wage share (and lower personal income inequality) can have a positive or negative relation with output depending on the factors altering the income distribution. Indeed, if productivity growth drives the output dynamics (a supply-side factor), it will be associated with a lower wage share since productivity growth increases firms' bargaining power. Yet, if it is the higher wage share obtained through more institutional support to workers that drives the output dynamics (a demand-side factor due to the different class-specific propensities to consume), there will be a positive relation between the wage share and the output level. Thus, an important insight for empirical studies investigating the relation between income distribution and economic activity is offered by our experiments, as these studies may capture a negative correlation between the wage share and output that is mostly due to the productivity dynamics and, consequently, has limitations as a counterfactual (how the economy would behave in case workers' bargaining

power was enhanced by institutional changes) or as an explanation to the performance of an economy during a specific period (e.g., what was the contribution of specific policies aiming to increase the nominal wage).[66]

Interestingly, the relation between inequality and unemployment rates is always in the same direction, with a higher wage share (and lower personal income inequality) being associated with lower unemployment rates. While this reflects a bidirectional relation,[67] it also bespeaks an important feature of the scenarios characterized by more innovation easiness (higher ζ parameter). In these cases a higher output level can be achieved, but this economic improvement may be concentrated in the wealthier households, since the working class will collectively face a reduction in the wage share and an increase in the number of workers unemployed. Therefore, productivity growth may be insufficient to promote better living conditions for the society as a whole.

While this raises the possibility of a policy dilemma between promoting productivity growth and improving equality in the income distribution, a more optimistic interpretation of our results is also possible. Indeed, when we analyze the interaction effects in the third set of experiments we observe that the highest output level for each level of innovation easiness (ζ parameter) is always associated with more institutional support for workers (higher ϕ parameter). Thus, despite the highest wage share being achieved when innovation dynamics is weaker and workers' bargaining power is at its highest level (the best scenario for workers in section 1.6.3), for each level of innovation easiness a higher output level, lower unemployment rate, and higher wage share will be achieved if workers' bargaining power increases. Therefore, strengthening workers reinforces the positive stimulus of higher productivity levels on economic output and attenuates its negative effect on the wage share and employment by forcing firms to share productivity gains with workers.

1.7 Sensitivity analysis

In order to further explore our model's behavior, we perform a global sensitivity analysis exploring joint variations of key parameters. This type of analysis provides further insights into the relation between the inputs (parameters) and outputs (variables) of the model, indicating the influence of each input on the results and which inputs do not have a relevant effect. It also provides further information concerning the interaction of the parameters and possible non-linearities that are not captured when varying a specific parameter individually. With the aim of further exploring the dynamics generated by the model with respect to the social conflict

[66] Given this endogeneity of the wage share, an alternative strategy for empirical studies would be to use the components of the wage share. This is the case of Cauvel (2022), who replaces the wage share with the real wage rate and labor productivity.

[67] Lower inequality can stimulate demand and reduce unemployment (as seen in section 1.6.1), but lower unemployment reduces the share of workers receiving unemployment benefits and reduces inequality (as mentioned in section 1.5).

over the income distribution and its macroeconomic implications, the 11 parameters selected for the sensitivity analysis are among the most important parameters for the dynamics of output and productivity growth and workers' bargaining power. In line with this aim, we explore how the selected parameters affect the wage share, gross income Gini coefficient, and output growth rate.

The methodology for the sensitivity analysis follows the work by Salle and Yıldızoğlu (2014).[68] We employ the Nearly Orthogonal Latin Hypercube (NOLH) sampling (Cioppa and Lucas, 2007) as a design of experiment (DoE) method. This method selects in a parsimonious way a sample of the possible parameters combinations in the entire parameters domain. The data collected from the 33 design of experiment samples and 10 external samples is used to construct the Sobol decomposition and estimate a Kriging meta-model, which relate the parameters and the variables of interest.

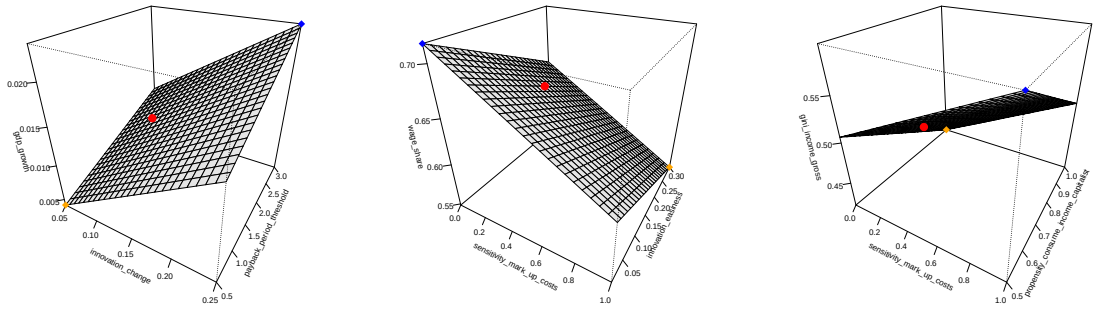
We firstly analyze the Sobol decomposition for all the parameters analyzed in the sensitivity analysis (table 1.5). This analysis decomposes the variance of the selected computational output (simulation result) in contributions from each input parameter (Sobol, 2001). As expected due to the key role of productivity growth on output growth, we find that the main parameters affecting the output growth rate dynamics are those related to innovation dynamics (x) and firms' replacement investment (b), while the sensitivity of workers' bargaining power to the employment rate also appears among the three most important parameters (ϕ). In line with our experiments, we also find that parameters related to the firms' mark-up setting rule (ν_3) and the innovation dynamics (ζ and x) exert an important effect on the wage share. While there is a small direct effect of the sensitivity of workers' bargaining power (ϕ), the interaction effect is considerably larger than those of the other parameters. As for the personal income distribution, the gross income Gini coefficient is also significantly affected by the innovation dynamics (x), the parameter related to the firms' mark-up setting rule (ν_3), and the propensity to consume out of income for capitalists (c_2^{cap}). Overall, these relations are in line with our conjecture that the coevolutionary interaction between workers' bargaining power and productivity growth determines the personal and functional income distribution.

[68] See also Saltelli et al. (2008). For examples of agent-based models using a similar methodology, see Dosi et al. (2018), Pedrosa and Lang (2021), and Possas et al. (2020).

Table 1.5: Sobol decomposition: direct effects and interactions

			Output growth		Wage share		Gross Gini coef.	
		Param. Range	Dir.	Inter.	Dir.	Inter.	Dir.	Inter.
x	Beta distribution support parameter (innovation) (Sec. 1.4.1.1)	[0.05, 0.25]	0.417*	0.001	0.158*	0.003	0.179*	0.002
ζ	search capability (K firm) (Eq. 1.1)	[0.01, 0.3]	0.117	0.001	0.160*	0.002	0.125	0.002
b	payback rule threshold (Eq. 1.4)	[0.5, 3]	0.158*	0.001	0.029	0.002	0.007	0.001
h	sensitivity of productivity to unfilled labor demand for managers (Eq. 1.9)	[0, 1]	0.024	0.001	0.004	0.003	0.003	0.002
ν_3	sensitivity of mark-up rate to unit costs (C firms) (Eq. 1.23)	[0, 1]	0.004	0.001	0.345*	0.003	0.305*	0.002
ϕ	sensitivity of surveyed wage weight in bargaining to employment rate (Eq. 1.40)	[0.1, 0.9]	0.132*	0.002	0.001	0.020	0.024	0.002
γ_1	sensitivity of desired wage by workers to inflation (Eq. 1.36)	[0, 1]	0.011	0.001	0.002	0.002	0.000	0.002
γ_2	sensitivity of desired wage by workers to growth rate (Eq. 1.37)	[0, 1]	0.066	0.001	0.100	0.002	0.019	0.001
c_2^{dir}	propensity to consume out of income (direct workers) (Eq. 1.39)	[0.5, 1]	0.031	0.001	0.032	0.002	0.010	0.001
c_2^{ind}	propensity to consume out of income (indirect workers) (Eq. 1.39)	[0.5, 1]	0.033	0.001	0.051	0.002	0.028	0.002
c_2^{cap}	propensity to consume out of income (capitalists) (Eq. 1.39)	[0.5, 1]	0.001	0.001	0.087	0.003	0.292*	0.002

Note: $\star$ denotes the three most important inputs for each output. Results consider 100 Monte Carlo runs for each scenario in DoE. Equation or section numbers in parentheses indicate where the parameters first appear in the text. Source: author's own elaboration based on simulation results.



(a) Output growth rate (b) Wage share (c) Income Gini coefficient

Figure 1.16: Global sensitivity analysis: response surfaces

Note: Average values for 100 Monte Carlo runs for each scenario in DoE. Dot identifies baseline specification and squares identify the maximum and minimum values. Input parameters: innovation_change = x, payback_period_threshold = b, sensitivity_mark_up_costs = ν_3, innovation_easiness = ζ, propensity_consume_income_capitalist = c_2^{cap}. Source: author's own elaboration based on simulation results.

Figure 1.16 shows the response surfaces modeled by the Kriging meta-model for the two most important parameters identified by the Sobol decomposition for each model output (which is always in the vertical axis). Figure 1.16a indicates that when higher productivity gains from innovation are possible (x) or when firms are more likely to replace old machines by more modern ones (b), output growth rates are higher. These parameters allow for more productivity

growth, which is a key driver of output growth in the model. Figure 1.16b indicates a negative effect of the ζ parameter on the wage share, which indicates that productivity growth can benefit firms by allowing them to increase their mark-up rates. Indeed, firms face a lower growth rate of unit labor costs due to the direct effect of productivity on costs and its indirect effect on the nominal wage dynamics through the labor market. Also, an increase in the sensitivity of firms to changes in unit labor cost (ν_3) has a negative effect on the wage share. We expected that this effect was approximately neutral, since this sensitivity can either benefit firms or workers. Its negative effect probably reflects a tendency of productivity growth being more relevant than nominal wage growth, which benefits firms relatively more. Finally, reflecting the relation between the functional and the personal income distribution, figure 1.16c shows that the income Gini coefficient tends to increase with the sensitivity of firms to changes in unit labor cost (ν_3). Conversely, the income Gini coefficient tends to decrease when the propensity to consume out of capitalists income increases. This is likely to be the case because higher consumption increases output and reduces the unemployment rate, which leads to a reduction in the personal income inequality (as explored in section 1.5).

1.8 Conclusions

This chapter proposed a novel agent-based macroeconomic model inspired by the post-Keynesian literature, in particular the neo-Kaleckian approach to income distribution. Its aim was to study the effect of two important aspects related to the recent trends of increasing income inequality, namely the changes in institutions that support workers' bargaining power and productivity growth. These factors have been associated with the decreasing wage share and increasing wage-productivity gap, thus revealing that the dynamics of firms' mark-ups over costs was also a relevant factor in the process (De Loecker et al., 2020). Indeed, productivity growth can be an opportunity for firms to increase their profit margins and thus represents a potential increase in firms' strength. Nevertheless, its effect is mediated by workers' bargaining power, which is a counteracting force to that of employers. Therefore, the income distribution dynamics results from the social conflict over the income distribution, which is characterized by the coevolutionary interplay between productivity, mark-up rates and nominal wages.

The model structure reproduces a number of stylized facts concerning the macro and micro dynamics. It also reproduces important stylized facts concerning the functional and personal income distribution and the wealth distribution that have been relatively less explored in the agent-based modeling literature so far. In this sense, it offers a sound basis for the study of the income distribution dynamics. The model was employed to assess the effects of technological innovation and workers' bargaining power. We observe that when workers' strength in the bargaining process increases, there is a reduction in inequality and an increase in the output level. With respect to the innovation dynamics, we observe that scenarios with higher capital good firm's search capabilities are associated with an increase in inequality, higher output levels and

higher unemployment rates. Thus, the coevolutionary interaction between productivity growth and workers bargaining power indicates that the relation between the wage share or income inequality and output will depend on the relative strength of the key parameters determining the dynamics of these variables. If the source of economic stimulus is mainly associated with the technological innovation dynamics, there may be negative consequences in terms of the income distribution, as productivity growth is an opportunity for firms to increase their profit margins. Yet, if there is an increase in workers' bargaining power, firms will be forced to share productivity gains with workers and the higher output level will be associated with the higher wage share and lower personal income inequality. The results also show that the coupled dynamics of unemployment rates and output levels crucially depends on firms sharing productivity gains with consumers, so we always find a negative relation between the wage share and unemployment rates.

In conclusion, by highlighting the possible negative effects of productivity growth on the income distribution, our results suggest the possibility of a policy dilemma between promoting productivity growth and improving income equality. This sheds revealing light on the mechanisms explaining the recent trends in income inequality observed in many economies, since changes in labor market institutions that reduced workers' strength (e.g., changes in union density, collective bargaining coverage, or minimum wage adjustments) in a context of productivity growth allowed firms to increase their mark-up rates. Yet, we also find that this trade-off is weakened if workers' bargaining power is increased simultaneously to the higher innovation dynamics. In this case, there will be a higher wage share, lower income inequality, lower unemployment rate and even a higher output level than when only innovation is stimulated. Thus, while this combination does not fully offset the consequences of productivity growth on inequality, it does indicate a path for (at least partially) (re)conciliating different policy objectives by combining policies and institutions that sustain workers' strength with policies that stimulate innovation and productivity growth.

Chapter 2

Income distribution, economic activity, and inflation in an open economy agent-based model

2.1 Introduction

Small open economies are frequently affected by external shocks of different types, which influence greatly their economic dynamics. Trade shocks affecting exports and imports are one category of such factors, and they are expected to have consequences not only for output growth, but also for income distribution. Indeed, trade shocks affect domestic production decisions and firms' international competitiveness, while also having implications for the labor market and thus altering the bargaining position of workers. The combination and interaction between these (and other) changes means that international trade comes with sharp distributional consequences (Rodrik, 2021). Moreover, foreign shocks such as increases in foreign price levels (e.g. higher import and oil prices) may trigger an inflationary process in the domestic economy. Thus, there is a relevant connection between domestic and foreign inflation rates (Bobeica and Jarocinski, 2019, Borio and Filardo, 2007), which is likely to exert additional distributive implications.

Empirically, the relation between trade and distribution is far from homogeneous across countries. The empirical literature investigating the relation between international trade (trade openness) or globalization often draws upon the predictions of the Stolper-Samuelson theorem (Stolper and Samuelson, 1941), according to which high- and low-income countries are expected to be affected differently by globalization since their initial factor endowments are different. This empirical literature tends to find a positive relation between globalization and inequality, but results differ depending on the how each variable is measured and the group of countries included in the sample.[1] While in case of developing countries the Stolper-Samuelson theorem predicts that inequality would decrease, there is scarce evidence in favor of such prediction (Cornia, 2014, Goldberg and Pavcnik, 2007). Nevertheless, these results also seem to be very time specific. In the case of Latin American countries, for instance, the

[1] See, for instance, Dorn et al. (2017) and Milanovic (2005).

commodities boom in the 2000s was associated with more equality in the income distribution (Sánchez-Ancochea, 2021), while the rest of the world was facing the opposite process. Such contrast is interesting because it also concerns the comparison between Latin American countries and other developing economies that benefited from the high commodity prices and high world growth rates during the period (Cornia, 2014).

Arguably, the observed trends in income distribution always result from numerous influences, with trade and globalization being additional factors affecting a complex process involving (private and public) domestic agents. Nevertheless, at least at a theoretical level, disentangling several of those factors and analyzing the effect of specific conditions contributes to the understanding of how small open economies can be affected by external shocks, and why there is a diversity of responses across countries. In this sense, this chapter analyzes the dynamics of a small open economy subject to temporary external shocks of different types, signs, magnitudes, and lengths in order to investigate the dynamics of output, income distribution, and inflation during and after the shocks. Two types of shocks, which have not been explored so far in the AB models literature, are investigated: a shock on the foreign output growth rate (a demand shock) and a shock on the foreign inflation rate (a price shock). Although these shocks commonly take place at the same time, analyzing them simultaneously makes it difficult to identify which are the transmission mechanisms in place (FitzGerald, 1996). Thus, by analyzing them separately we contribute to the understanding of the complex relation between foreign shocks and the domestic economic dynamics and also provide insights into the dynamics of specific periods in which one of these factors prevailed, such as in the recent spike in inflation rates in numerous countries following the COVID-19 pandemic and the Ukraine-Russian war (Storm, 2022). An additional dimension that we intend to capture, and which has been less emphasized in the literature so far, is the feedback effect from income distribution to the output dynamics in the domestic economy, since this can be one of the many mechanisms through which foreign shocks affect the domestic output.

The analysis is undertaken in an open economy AB model, which revises and extends the closed economy AB model presented in chapter 1. A key feature of that model is that income distribution is determined by the bargaining process between domestic agents. In this reformulated version, a foreign sector is included and it is assumed that it trades consumption goods with domestic agents. Trade and international competition have direct and indirect implications for the bargaining position of domestic agents, making the foreign sector another actor in the social conflict over the income distribution (Blecker, 1989, Krugman and Taylor, 1978, Ribeiro et al., 2017). Thus, our model emphasizes a dimension that has been much less emphasized by the more traditional literature, which tends to prioritize models in which wages are set in spot markets (Rodrik, 1997, 2021). Moreover, our approach has the advantage of capturing and emphasizing the connection between the functional and personal income distribution, thus also capturing the distributive implications of changes in the price levels and in the inflation rate. Finally, the model captures the role of the real exchange rate in driving the income distribution

dynamics (Ribeiro et al., 2020, Rossi and Galbraith, 2016). Overall, we contribute to the AB literature by investigating shocks that have important distributive consequences and have not been explored so far.

We observe that the type of shock, sign, magnitude, and length are of primary importance for understanding how income distribution is affected by foreign shocks that operate through international trade. These characteristics are also key for understanding how the dynamics of income distribution is related to that of output since shocks that stimulate export growth have very different effects on output and distribution depending on these characteristics. Our results also show that income distribution is an important mechanism through which foreign shocks influence the domestic economy dynamics.

The remaining of this chapter is organized as follows. In section 2.2 the related literature is discussed. In section 2.3 the model structure and the extension to the open economy model are presented. In section 2.4 we summarize the key stylized facts reproduced by the model, while 2.5 presents and discusses the simulation results for the experiments with foreign shocks. In section 2.6 we further explore the effects of foreign shocks by analyzing different transmission mechanisms. Concluding remarks follow in section 2.7.

2.2 Related literature

Arguably, most AB macroeconomic models represent closed economies, but there are important exceptions which pursue different modelling strategies according to the research questions proposed. In a way, there is a parallel between the different categories of open economy AB models and those of more traditional open economy macroeconomic models, which model multiple economies, two economies or regions (e.g. North-South models), or a single economy in relation with the rest of the world.

A first group of models aims to analyze the relation between multiple (more than two) countries. While this is a detailed approach, part of this literature focuses on the relation between countries that are part of the same monetary union, and therefore does not consider the role of the (level or changes in the) exchange rate. Examples of this approach are the studies by Caiani et al. (2018, 2019a), in which a monetary union is modeled. In particular, the experiments on alternative wage regimes (Caiani et al., 2019a) are interesting for our purposes since they explore how increases in nominal wages affect demand and labor productivity (which affects the economy's external competitiveness). Also, the model by Petrović et al. (2017) is a multi-country version of the EURACE model (Deissenberg et al., 2008) that incorporates a monetary union of two countries and two independent countries. The model by Dosi et al. (2019) is one of the few multiple-countries models that incorporates the exchange rate as an important variable affecting the relation between the different economies and the global income dispersion.

A second group of open economy AB models consists on two-country or two-region models. While this is a simplification relative to models from the first group, it has the advantage

of facilitating the comparison between the countries and the understanding of how shocks on one economy are transmitted to the other. As in the previous groups, many of the two-country models focus on a monetary union or in the comparison between two regions. An example is the EURACE model concerning the convergence between two regions in the European Union, in which policies that can be implemented in the less developed region are analyzed (Dawid et al., 2014). Also, Cardaci and Saraceno (2019) explore the role of inequality in driving the current account deficit through its effect on the demand for credit in a country where emulation effects are stronger. This dynamics leads to a debt-led growth model that stimulates an export-led growth model (with current account surpluses) in the other country, thus leading to current account imbalances in a currency union. While in their model inequality is determined in an exogenous manner, their results provide interesting insights with respect to how inequality affects macroeconomic variables in an open economy.

A third group of models adopts an important simplification relative to the previous groups by treating the foreign sector as an aggregate sector and analyzing a small open economy. In this case, instead of modeling feedback effects between two (or more) economies, priority is given to the dynamics of the domestic economy and how it is affected by specific transmission mechanisms that link it to the foreign sector treated simply as the rest of the world (for instance, trade and financial relations). Given this emphasis, these models also consider the exchange rate, which is either kept fixed or explicitly modeled as time-varying (usually in an endogenous fashion). A representative of this group is the family of models known as "Micro-Macro Multisectoral" (MMM) model (Busato and Possas, 2016, Dweck, 2006, Dweck et al., 2020, Possas and Dweck, 2004).

Albeit also somehow drawing from models of the other groups in specific aspects, our open economy AB model is closer in spirit to the last group of open economy AB models, since we are primarily concerned with the effects of foreign shocks that affect a single artificial small open economy. This is an adequate approach for studying economies that are not part of a monetary union and that cannot be considered large open economies, wherein feedback effects would be more relevant, and thus provides important general insights into the dynamics of a large set of economies, in particular several developing ones. In addition, our model incorporates numerous features of the conflicting-claims inflation model in the post-Keynesian literature (Rowthorn, 1977), which emerge endogenously through the interaction between heterogeneous firms and workers. In an open economy framework, this leads to a connection between the foreign and domestic inflation rates and, consequently, a more realistic approach to the determinants of inflation (Bobeica and Jarocinski, 2019, Borio and Filardo, 2007). In sum, this chapter contributes to the existing literature by analyzing the effect of foreign shocks on important domestic variables (output, inflation, and income distribution) and capturing their interactions and feedback effects.

2.3 Model structure

The model is a reformulated version of the model set forth in chapter 1. The main difference is its extension to an open economy framework, which involves the addition of a foreign sector (identified by the subscript x) and its interactions with the domestic economy.[2] The structure and the interactions between the agents are represented in figure 2.1. The model is composed by six types of agents:

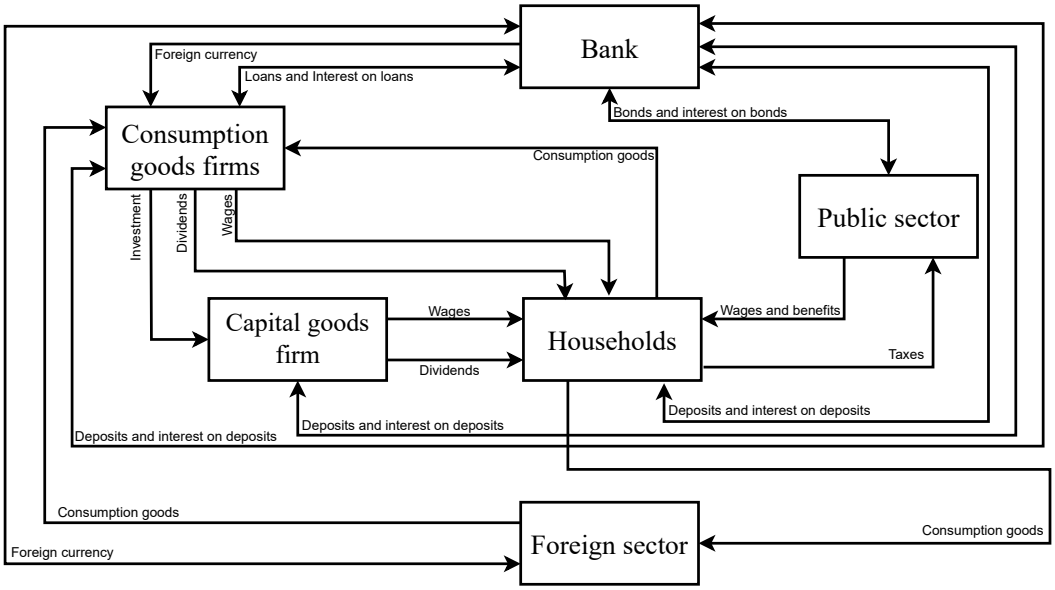


Figure 2.1: Open economy model structure
Note: arrows point from paying sector to receiver sector. Source: author's own elaboration.

- A monopolist **capital goods firm**, which produces machines and undertakes research and development (R&D) activities. It distributes to its owners all its net profits.
- A set of N^c **consumption goods firms**, which produce a homogeneous good using labor and machines. They invest in capital goods and may ask for a loan to finance production or investment. These firms sell consumption goods to households and, if they are exporters, to the foreign sector.
- A monopolist **bank**, which grants loans to consumption goods firms, buys bonds from the government and holds firms' and households' deposits. The bank is the agent that trades foreign currency with foreign and domestic agents and it is the sole agent that can accumulate foreign reserves as assets or get indebted with the foreign sector.
- A set of N^h **households** divided in N^{cap} capitalists, N^{dir} direct workers, and N^{ind} indirect workers. Workers sell their labor to firms and receive wages in return, while capitalists own the firms and receive profit dividends (each firm is owned by ρ_1 capitalist households).

[2] Unless explicitly mentioned otherwise, all variables and agents are the domestic ones.

Unemployed workers receive a tax-exempt unemployment benefit from the government. Households buy consumption goods from domestic firms and from the foreign sector through an intermediary (imports) and keep their savings as domestic deposits at the bank. They also pay taxes on profit dividends and wages.

- A **public sector** composed by a central bank and a government. The government employs a fixed number of direct and indirect workers, pays unemployment benefits to unemployed workers, collects taxes, and issues bonds to cover its deficits. The central bank holds the government's reserves account in domestic currency and acquires government bonds.

- A **foreign sector** represented as an aggregate sector. Its variables are affected in such a negligible way by the domestic sector that they can be taken as exogenous to the dynamics of the domestic variables.[3] It is characterized by a price level $p^x_{x,t}$,[4] which captures the average price level prevailing in world markets for the homogeneous consumption good that is traded between the foreign and domestic economies. This world price level grows over time, and its growth rate is given by $\hat{p}_x$. The foreign sector is also characterized by a real output level $Y_{x,t}$, whose growth rate is given by g_x. For simplicity, there is no cyclical fluctuation in g_x. There is also a nominal interest rate in the foreign sector given by i_x.

As this chapter focuses on effects of international trade on a small open economy, the behavior of the consumption goods firms, which can be in direct competition with the foreign sector, is of particular importance. In line with the literature on firms' performance in international markets (Bernard et al., 1995, 2012), the model structure is such that only a fraction of the firms will be exporters. These firms price discriminate across markets (Krugman, 1986), so one of the components of export prices is the price level prevailing in the world economy. Households buy imported consumption goods from the foreign sector through an intermediary at a price level in domestic currency set according to the foreign price level and the nominal exchange rate. The nominal exchange rate, which represents the price of the foreign currency expressed in domestic currency, evolves following the previous period trade balance and the nominal interest rate differential between the domestic and foreign sectors. For simplicity, we assume that there is no international labor or physical capital mobility and that only domestic currency can be used as means of payment in the domestic sector.[5]

The social conflict over the domestic income distribution is now affected by a larger multitude of factors, extending considerably the dimensions included in chapter 1. While the dynamics of nominal labor unit costs, which reflects the interplay between productivity growth

[3] As mentioned, this is grounded on our understanding that such methodological strategy is adequate for understanding the effect of external shocks in several developing economies. For multi-country AB models, see the works listed in section 2.2.

[4] We use the superscript x when the value is denominated in foreign currency. As in chapter 1, the superscript \$ denotes nominal values in domestic currency.

[5] In other words, there is no foreign direct investment from or to the domestic sector. Note also that the domestic consumption goods firms only acquire capital goods from the domestic capital goods firm, which does not export these goods. As future research, an extension of the model could also include international trade of capital goods.

and nominal wages, is once again a key determinant of the relative strength of each class, it is itself affected by the foreign sector. If foreign demand stimulates economic activity and employment, an increase in workers' bargaining power is likely to take place, while at the same time it may trigger endogenous growth in labor productivity through the innovation process. Also, firms react to the international competition in the domestic and foreign markets by adjusting their mark-up rates. Finally, the nominal exchange rate and the foreign price level are key factors determining the functional and personal income distribution through their direct effect on exporters' income in domestic currency (Rossi and Galbraith, 2016).

The next subsections summarize the main equations of the entire model (domestic and foreign agents). Equations and relations that have been already extensively detailed in chapter 1 are also briefly mentioned so that the reader has a complete summary of the model.[6]

2.3.1 Capital goods firm

The monopolist capital goods firm produces machines employing a technique characterized by direct labor productivity y_t^k. The new machines' productivity is equal to $y_t^{c,\star}$. These machines are sold to the consumption goods firms and they produce a maximum Q_m^{fc} units of consumption goods for a maximum of T^k periods, after which they are scrapped.

The innovation process undertaken by the capital goods firm is based on two successive random draws (Dosi et al., 2010, Nelson and Winter, 1982). The probability of success in innovating is given by:

$$\theta_t = 1 - e^{-\zeta L_{k,t}^{res}} \tag{2.1}$$

where $1 > \zeta > 0$ is a parameter and $L_{k,t}^{res}$ is the number of researchers employed by the firm (determined by an R&D investment equivalent to $\rho_2 < 1$ of the current nominal demand). In case of success, the new technology is characterized by the pair $y_t^{c,in}$ and $y_t^{k,in}$:

$$y_t^{c,in} = y_t^{c,\star}(1 + x_t^c) \tag{2.2}$$

$$y_t^{k,in} = y_t^k(1 + x_t^k) \tag{2.3}$$

where x_t^c and x_t^k are random draws from a $Beta(\alpha, \beta)$ distribution over the $[-x, x]$ support. The firms decides whether it adopts the new pair $(y_t^{c,in}, y_t^{k,in})$ or stays with the previous one by selecting the technology that minimizes the sum of the price of the machine and the total production cost at the consumption goods firms' desired capacity utilization rate (u^d) times a payback factor:

$$min(p_k(y_{t-1}^k) + b\Gamma^{\$}(y_{t-1}^{c,\star}, u^d),\ p_k(y_{t-1}^{k,in}) + b\Gamma^{\$}(y_{t-1}^{c,in}, u^d)) \tag{2.4}$$

[6]The main differences with respect to the model in chapter 1 are presented from section 2.3.2 to section 2.3.8.

where p_k is the capital goods price function, b is the exogenous payback factor, and $\Gamma^{\$}$ is the consumption goods firms' total cost function.

The firm hires both direct and indirect workers (managers and researchers). The labor demand for direct and indirect workers are given by equations 2.5 and 2.6 respectively:

$$L_{k,t}^{D,dir} = \left\lceil \frac{\sum_{c=1}^{N^c} I_{c,t}^{D}}{y_t^k} \right\rceil \tag{2.5}$$

$$L_{k,t}^{D,ind} = \left\lfloor \frac{\rho_2 \sum_{c=1}^{N^c} I_{c,t}^{D,\$}}{w_{k,t}^{ind,\$}} \right\rfloor + \left\lfloor \rho_3 L_{k,t}^{D,dir} \right\rfloor \tag{2.6}$$

where $\rho_2 \sum_{c=1}^{N^c} I_{c,t}^{D,\$}$ is the R&D budget, $w_{k,t}^{ind,\$}$ is the indirect workers' wage level, and ρ_3 is the fixed number of managers per direct worker.

The firm's production level is given by the floor of the number of direct workers it hires in the period multiplied by their productivity, which is adjusted by a correction factor that depends on the actual ratio of managers to direct workers in comparison to the required ratio. This adjustment captures the effect of management shortcomings whenever the firm cannot hire as many managers as required to supervise the direct workers and organize the production process. Formally, production is given by:

$$Q_{k,t} = min \left\{ \lfloor L_{k,t}^{dir} y_t^k [1 - h(L_{k,t}^{man,D}/L_{k,t}^{dir,D} - L_{k,t}^{man}/L_{k,t}^{dir}) \mathbf{1_Q}] \rfloor, \sum_{c=1}^{N^c} I_{c,t}^{D} \right\} \tag{2.7}$$

where h is the sensitivity of the actual productivity level to the difference between the actual ratio of managers to direct workers and the required ratio and $\mathbf{1_Q}$ is an indicator function that takes the value of one if the actual ratio is below the required ratio and zero otherwise. As the firm never produces more than demanded by the consumption goods firms (for simplicity, there is no strategic accumulation of inventories), the second part of the equation captures the maximum production level, given by the demand for capital goods ($\sum_{c=1}^{N^c} I_{c,t}^{D}$).

The price of the new machines depends on a fixed mark-up rate applied to the unit labor costs, as follows:

$$p_{k,t}^{\$} = (1 + \mu_k) \frac{(w_{k,t}^{dir,\$} + \rho_3 w_{k,t}^{ind,\$})}{y_t^k} \tag{2.8}$$

where μ_k is a fixed mark-up rate and $w_{k,t}^{j,\$}$ is the wage rate for each type $j = dir, ind$ of worker.

2.3.2 Consumption goods firms

The model is composed of a set of N^c consumption goods firms that produce a homogeneous nonperishable good using labor and capital goods. All firms sell in the domestic

market, while a subset of exporting firms also have access to the international market. In both cases, the consumption goods market is characterized by imperfect competition and firms' sales depend on their market shares.

Firms form their expectations based on the past level of (domestic and foreign) demand ($Q^e_{c,t} = Q^D_{c,t-1}$). Given this expected demand, they set the desired production level ($Q^d_{c,t}$) by considering also a fixed desired share of inventories (n^{IN}) relative to the expected demand and the inventory level from the previous period.

The labor demand for direct and indirect workers is given by equations 2.9 and 2.10 respectively:

$$L^{D,dir}_{c,t} = \left\lceil \frac{Q^d_{c,t}}{\bar{y}^{c,*}_{c,t}} \right\rceil \tag{2.9}$$

$$L^{D,ind}_{c,t} = \lfloor \rho_4 L^{D,dir}_{c,t} + \rho_5 L^{dir,fc}_{c,t} \rceil \tag{2.10}$$

where $\bar{y}^{c,*}_{c,t}$ is the average direct labor productivity of the most productive machines required to produce $Q^d_{c,t}$, $\rho_{4,5} > 0$ are parameters, and $L^{dir,fc}_{c,t}$ is the demand for direct labor at the full capacity production level.

Firms' production is given by equation 2.11. Also in this case, there is an adjustment factor to the productivity level if the actual ratio of managers to direct workers is below the required ratio.

$$Q_{c,t} = L^{dir}_{c,t} \bar{y}^c_{c,t} [1 - h(L^{ind,D}_{c,t}/L^{dir,D}_{c,t} - L^{ind}_{c,t}/L^{dir}_{c,t})\mathbf{1_Q}] \tag{2.11}$$

Firms set prices by adding a variable mark-up rate over unit labor costs computed at the desired capacity utilization level. Since firms are exposed to international competition, their mark-up rates also reflect their perceived international competitiveness in each specific market. Therefore, in addition to the mark-up components considered in chapter 1, the price of exported goods also includes a component capturing the international competition, as described below.

Firms invest to adjust their capital stock to the desired level and to replace machines that have become technologically obsolete and hence will be scrapped. In the first case, firms calculate their desired capital stock in $t+1$, which depends on the desired capacity utilization rate ($Q^{fc,d}_{c,t} = Q^{e,t+1}_{c,t}/u^d$). The capacity adjustment investment is the difference between the desired production capacity for $t+1$ and what will be the productive capacity in this period if no investment is undertaken. While firms always replace all machines older than T^k (as long as they do not wish to reduce their capital stock), they are more cautious with respect to the expansion of their productive capacity. Thus, the expansion investment is given by the difference between the current full capacity and the desired production capacity in $t+1$ multiplied by the investment adjustment speed ($1 > v > 0$). The replacement investment demand is determined by a payback

rule (Dosi et al., 2010, Dweck et al., 2020). A machine is replaced by a new one if its payback period (equation 2.12) is positive and lower or equal to the fixed threshold b.

$$b_{m,t} = \frac{p^{\$}_{k,t}}{\Gamma^{\$}(y^{c}_{m,t}, u^{d}) - \Gamma^{\$}(y^{c,\star}_{t}, u^{d})} \tag{2.12}$$

Whenever their internal resources are insufficient to cover their expenses in the beginning of the period (before production and sales take place), firms asks for a loan from the bank. The bank grants all the requested loan as long as the ratio of firms' interest payment to their average revenue in the previous four periods (adjusted to the current price level) is below a maximum ratio R. Otherwise, it grants the maximum between the amount required to reach R or the amount required to cover firms' outstanding debt.

Consumption goods firms exit the market whenever their market share of the domestic market relative to the domestic firms ($ms_{c,t}/\sum_{c=1}^{N^c} ms_{c,t}$) is below a threshold given by the ms^{min} parameter, their production capacity is zero, or when they have no deposits available and cannot ask for loans to cover their production or investment projects. New firms enter the market with a desired production capacity equal to a fraction δ of the average capital stock of the established firms. They receive all loans requested and are not subject to any exit criterion for $T^c > 1$ periods after their first production period.

2.3.2.1 Sales to the domestic market

Prices for the domestic market are set following the same procedure as that in chapter 1. The first component reflects their position *vis-à-vis* other firms (including the foreign sector), as reflected in the evolution of their market shares (equation 2.13). In an open economy context, this means that, whenever the market share of the foreign sector increases, the domestic firms face a reduction in their market share (at least on average), which makes their prices sensitive to international competition in the domestic market. The second component reflects their position *vis-à-vis* workers, which is given by the evolution of nominal unit labor costs (equation 2.14).

$$\mu^{*}_{c,t} = \mu^{*}_{c,t-1}\left[1 + \nu_1\left(\frac{ms_{c,t-1}}{ms_{c,t-2}} - 1\right)\right] \tag{2.13}$$

$$m_{c,t} = \nu_2 m_{c,t-1} - \nu_3\left(\frac{\Delta\Gamma^{u,\$}_{c,t}(u^{d})}{\Gamma^{u,\$}_{c,t-1}(u^{d})}\right) \tag{2.14}$$

where $1 > \nu_1 > 0$ is the sensitivity of the mark-up to the domestic market share, $1 > \nu_2 > 0$ is the persistence in the mark-up deviation, $1 > \nu_3 > 0$ is the sensitivity of the mark-up deviation to changes in unit costs, and $\Gamma^{u,\$}_{c,t}(u^{d})$ is firms' unit costs at desired capacity utilization rate. The final mark-up rate for domestic prices is applied on unit costs computed at the desired capacity utilization rate and is given by $\mu^{*}_{c,t} + m_{c,t}$.[7]

[7]This value is limited by the minimum mark-up rate accepted by firms, which is given by μ^{min}.

Aggregate domestic demand for domestic goods is split between firms according to their market share. Firms' market shares of the domestic market evolve following a "quasi" replicator dynamics and depend on their competitiveness ($E_{c,t}$), which is given by the average between the normalized price level ($p^n_{c,t}$) and normalized unfilled demand level ($l^n_{c,t}$) (Dosi et al., 2010, Dweck et al., 2020, Silverberg et al., 1988). Formally, firms' competitiveness is given by equation 2.15 and their market share is given by equation 2.16, as follows:

$$E_{c,t} = \frac{(1 - p^n_{c,t}) + (1 - l^n_{c,t})}{2} \tag{2.15}$$

$$ms_{c,t} = ms_{c,t-1}\left(1 + \nu_4 \frac{E_{c,t} - \bar{E}_t}{\bar{E}_t}\right) \tag{2.16}$$

where $\nu_4 > 0$ is a parameter capturing the market share sensitivity to competitiveness and $\bar{E}_t$ is the average competitiveness of consumption goods firms weighted by firms' market shares in $t-1$. Firms' sales to the domestic market are then given by their market share multiplied by total domestic demand for consumption goods.

2.3.2.2 Sales to the foreign market

A subset of firms will sell to the foreign market in addition to selling to the domestic market, thus gaining access to an additional demand. In line with the literature on firms performance in international markets and reflecting the inherent difficulties in accessing new markets (Bernard et al., 1995, 2012), only firms that have already acquired a considerable size of the domestic market will adventure themselves in the new market represented by the foreign sector, with a certain probability of succeeding in this effort. Additionally, large firms that have already gained access to the foreign market remain as exporters. Formally, this means that, in case a firm was an exporter in the previous period and its market share of the domestic market is greater than or equal to ms^{exp}, it will be an exporter in the current period. Firms that were not exporting in the previous period and whose market share of the domestic market is lower than ms^{exp} remain as non-exporters. The exporter status of firms in intermediate cases (exporters whose market share of the domestic market is lower than ms^{exp} and non-exporters whose market share is greater than or equal to ms^{exp}) is defined by a Bernouilli draw with probability of success (become an exporter) given by $\iota_1 ms_{c,t-1} / \sum_{i=1}^{N^c} ms_{c,t-1}$, where $\iota_1 > 0$ is a parameter capturing the sensitivity of the probability to export to firms' market share and $\sum_{i=1}^{N^c} ms_{c,t-1}$ is the domestic firms' aggregate market share of the domestic market (excluding exports).[8]

We assume that the domestic and international consumption goods markets are segregated enough so that firms can follow the so-called pricing to market strategy (Krugman,

[8] In the first period of the simulation, the exporter status of all firms is determined through the Bernouilli draw.

1986).[9] This means that our consumption goods firms price discriminate across these two markets: they apply a specific mark-up rate for setting the reference price in foreign currency and consider also the foreign price level when setting their export prices. The former factor means that firms take advantage of a favorable international scenario to increase their mark-up rates in the foreign market, while the latter factor leads to a limited pass-through from the nominal exchange rate and domestic costs to prices as firms seek to keep their market shares in foreign markets (Warmedinger, 2004).[10]

Formally, firms will consider an adjustment factor in their mark-up rates depending on their performance in the international market, which is captured by the growth rate of their real exports demand. This adjustment factor is given by equation 2.17:

$$m_{c,t}^{'} = \nu_2 m_{c,t-1}^{'} - \nu_5 \left(\frac{\Delta X_{c,t-1}^{D}}{X_{c,t-2}^{D}} \right) \tag{2.17}$$

where ν_5 is the sensitivity of the mark-up rate to exports growth and $X_{c,t}^{D}$ is real export demand. The final mark-up rate for the reference export price is applied on unit costs computed at the desired capacity utilization rate and is given by $\mu_{c,t}^{*} + m_{c,t} + m_{c,t}^{'}$.

Since exporters also consider the price level prevailing in the international market ($p_{x,t}^{x}$), export prices denominated in foreign currency are given by:

$$p_{c,t}^{x} = k p_{x,t}^{x} + (1-k) \frac{(1 + \mu_{c,t}^{*} + m_{c,t} + m_{c,t}^{'}) \Gamma_{c,t}^{u,\$}(u^{d})}{\epsilon_t} \tag{2.18}$$

where $1 \geq k \geq 0$ is a parameter capturing the degree of pricing to market and ϵ_t is the nominal exchange rate.[11] This equation creates a link between the real exchange rate and firms' mark-up rates, which are now partially endogenous, for which empirical support is provided by Berman et al. (2012).

The quantity exported by firms depends on their market share of the foreign market, as formally expressed in equation 2.19:

$$ms_{c,t}^{\prime} = \iota_2 (1 - e^{(-p_{x,t}^{x}/p_{c,t}^{x})^{(\iota_3)}}) \tag{2.19}$$

[9] Pricing to market is one of the reasons why the law of one price is not observed, in addition to transportation costs and tariffs (Rogoff, 1996). As shown by Aucremanne and Druant (2005) and Fabiani et al. (2006), pricing to market is widely adopted by firms and its most relevant determinant is the competitors' prices.

[10] The degree of pricing to market indicates firms' power in that market, which is lower if firms react more to the international price level.

[11] Note that this equation also includes two extreme options. If $k = 1$ firms are price-takers in the international market, while if $k = 0$ they do not discriminate prices between the domestic and foreign markets (if also $\nu_5 = 0$). In the former scenario, a domestic currency depreciation will have a direct effect on the exporters' revenue in domestic currency, leading to a higher (*ex-post*) mark-up rate. This has direct implications to the income distribution, as emphasized by Rossi and Galbraith (2016). In the latter scenario, a domestic currency depreciation may also increase exporters' revenue, but this will occur through their increased international competitiveness (since export prices denominated in foreign currency will be lower). In intermediate scenarios (when $1 > k > 0$), a combination of both effects will be observed. Also in this case the price level has a minimum floor set by the minimum mark-up rate accepted by firms (μ^{min}).

where $\iota_{2,3} > 0$ are parameters capturing, respectively, the maximum market share limit reflecting legal barriers, tariffs, local tastes, and preferences that limit domestic firms' market share of the foreign sector and the price sensitivity of the domestic firms' market share. As the total real demand for consumption goods from the foreign sector is equal to $c_x Y_{x,t}$, with c_x being the foreign sector's propensity to consume, the export demand for exporting firms in real terms is equal to:

$$X^D_{c,t} = ms'_{c,t} c_x Y_{x,t} \tag{2.20}$$

Firms' realized exports depends on whether their supply capacity (previous inventories level plus current period production) is enough to fulfill the total (domestic and foreign) demand for their production. If supply is greater than or equal to demand ($Q_{c,t} + Q^{IN}_{c,t-1} \geq Q^D_{c,t}$), firms' realized exports are equal to the demand for exports ($X^D_{c,t}$) and their total sales are equal to total demand ($Q^s_{c,t} = Q^D_{c,t}$) . Yet, if that is not the case ($Q_{c,t} + Q^{IN}_{c,t-1} < Q^D_{c,t}$), firms sales are limited by their supply capacity ($Q^s_{c,t} = Q_{c,t} + Q^{IN}_{c,t-1}$) and they have to choose how to allocate it to their foreign and domestic customers. We assume that firms follow a simple rule of thumb according to which the same share of each type of demand is fulfilled, as reported in equation 2.21 for exports.[12]

$$X_{c,t} = \frac{Q^s_{c,t}}{Q^D_{c,t}} X^D_{c,t} \tag{2.21}$$

2.3.3 Bank

The banking sector is composed by a monopolist bank, which grants credit to creditworthy firms, holds remunerated deposits and buys bonds from the government. For simplicity, the bank sets the interest rate for deposits and loans equal to the interest rate set by the central bank (i_t). The bank is also the only agent that acts in the exchange market, trading domestic and foreign currencies for domestic and foreign clients. As explained in section 2.3.8, it is assumed that the exchange rate is affected by commercial and financial factors, but the latter are not explicitly modeled given our focus on commercial flows. Thus, the bank either accumulates foreign currency or gets indebted with the foreign sector in order to guarantee that the foreign reserves demanded by private agents are available.[13]

[12] For instance, if $Q^s_{c,t}/Q^D_{c,t} = 0.5$, 50% of the foreign demand and 50% of the domestic demand is fulfilled. Note that this implies that firms do not fulfill relatively more of the type of demand whose price is higher in domestic currency (due to price discrimination, export prices converted to domestic currency can be different from prices in the domestic consumption goods market). Nevertheless, the more important adjustment is simply an increase in the desired production level in the following period.

[13] For simplicity, this credit is infinitely elastic at the current international interest rate. Thus, in this framework, the domestic monopolistic bank is not internationally credit-constrained. As mentioned, this derives from our focus on trade flows. A relevant extension of our model would be to explicitly model these and other financial constraints in order to better incorporate financial relations between the domestic and foreign sectors.

2.3.4 Households

As in the original model reported in chapter 1, households are split into three heterogeneous social groups: direct workers, indirect workers, and capitalists (Mohun, 2016). These social groups are characterized by specific relations with the production process, which also reflect different income levels.

Workers' desired wage depends on the macroeconomic environment, their individual employment experience, and their previous wage level. The desired wage is based on the previous strictly positive wage received by the workers (i.e. the wage received in the workers' last job) adjusted by the inflation rate (if positive). Then, workers who were employed in the previous period increase this wage by a parameter γ_2 times the growth rate of the economy in the previous period (if positive), while workers who were unemployed in the previous period adjust the wage downward proportionally to the number of periods since her last employment multiplied by the parameter γ_5, as shown in equation 2.22:

$$w_{h,t}^{d,\$} = \begin{cases} w_{h,t}^{d,*,\$}(1 + \gamma_2 g_{t-1}\mathbf{1_g}) & \text{if } T_{h,t}^{w} = 0, \\ w_{h,t}^{d,*,\$}(1 - \gamma_5 T_{h,t}^{w}) & \text{otherwise.} \end{cases} \tag{2.22}$$

where $w_{h,t}^{d,*,\$}$ is the most recent strictly positive nominal wage adjusted by the inflation rate, $T_{h,t}^{w}$ is the number of periods the worker has been unemployed since her last employment (if employed in $t-1$, $T_{h,t}^{w} = 0$), g_{t-1} is the previous period private aggregate demand growth rate, $\mathbf{1_g}$ is and indicator function that takes the value of one if $g_{t-1} > 0$ and zero otherwise, and $\gamma_{2,5} > 0$ are parameters that capture the sensitivity of the desired wage to the output growth rate and to the individual unemployment status respectively.[14]

Whenever the wage offered by the current employer is below their individual desired wage and below the average wage in the market, workers consider looking for a new job. This decision is based on a random draw from a Bernoulli distribution with the probability of success given by a parameter s multiplied by the percentage difference between the wage offered by the current employer and the average wage in the market. When employed workers search for new job positions while still being employed, they accept a job offer if the wage offered is above the wage offered by their current employer. On the other hand, unemployed workers are always looking for new job positions and accept any offer made by firms.

Households' consumption depends on their previous real consumption, on their current nominal income, which is consumed according to class-specific propensities to consume, and their wealth (deposits):

[14]There is a maximum real growth rate for the desired wage which is given by $\hat{w}^{max}$. Also, the desired wage by workers has a lower limit represented by the minimum wage.

$$C_{h,t}^{D,\$} = max\left(c_1 \frac{C_{h,t-1}^{D,\$}}{\bar{p}_{t-1}^{C,\$}} \bar{p}_t^{C,e,\$},\ c_2^j((w_{h,t}^{\$} + \Pi_{h,t-1}^{h,\$})(1-\tau) + d_{h,t}^{\$})) + c_3 D_{h,t}^{\$,*}\right) \tag{2.23}$$

where $1 > c_1 > 0$ is the real consumption persistence, $\bar{p}_t^{C,e,\$}$ is the weighted average price in t,[15] $\bar{p}_{t-1}^{C,\$}$ is the weighted average price in the previous period, $1 > c_2^j > 0$ is the propensity to consume out of income for each class $j = dir, ind, cap$, $w_{h,t}^{\$}$ is the wage earned by the household, $\Pi_{h,t-1}^{h,\$}$ is the profit dividends from the previous period, $d_{h,t}^{\$}$ is the tax-exempt unemployment benefit received by unemployed workers, τ is the tax rate on income, c_3 is the propensity to consume out of wealth, and $D_{h,t}^{\$,*}$ is the households' deposits in the beginning of the period (minus the past profits).

2.3.5 Public sector

The public sector is composed of a government and a central bank. The government collects taxes on households' income at a tax rate τ and on interest payments on deposits at a tax rate τ^i. It pays unemployment benefits to unemployed workers at a value equal to the minimum wage ($w_t^{min,\$}$), which is adjusted by the average wage inflation rate in the previous period.[16] When a worker becomes unemployed, the unemployment benefit is paid for a maximum of T^u periods or until she finds a new job. The public sector also hires a fixed number of direct and indirect workers as public servants (L_g^{dir} and L_g^{ind}), who are paid the average wage paid for their class in the consumption goods sector. These workers are not subject to any turnover.

The central bank follows the inflation targeting regime and adjusts the nominal interest rate depending on the inflation gap (realized inflation rate minus inflation target).[17] We assume that there is a partial adjustment process of the interest rate, so that the actual nominal interest rate depends on the desired nominal interest rate (i.e., the nominal interest rate level that reflects the current inflation gap) and the past nominal interest rate, as follows in equation 2.24. This inertial behavior of the nominal interest rate is adopted to avoid a high frequency of large fluctuations in the rate.

$$i_t = (1-\lambda_1)[\bar{\hat{p}}_{t-1} + \lambda_2(\bar{\hat{p}}_{t-1} - \hat{p}^T)] + \lambda_1 i_{1-1} \tag{2.24}$$

[15] This is an expected value because it considers firms' market share in $t-1$, while the realized average price level is based on their effective share of sales in the current period. The foreign sector is considered in both cases.

[16] As in the case of workers' desired wage, there is a maximum growth rate for the minimum wage in real terms, which is given by $\hat{w}^{max}$.

[17] For simplicity, we assume that the monetary authority does not consider the output gap.

where λ_1 is the smoothing parameter of the nominal interest rate, $\bar{\hat{p}}_{t-1}$ is the average inflation rate in the previous T^p periods, λ_2 is the sensitivity to the inflation gap, and $\hat{p}^T$ is the inflation target.[18]

2.3.6 Labor market

The labor market structure is the same as that reported in chapter 1. Thus, firms follow an internal pay structure, according to which workers from the same class at the same firm earn the same wage. There is downward rigidity in nominal wages (Bewley, 2007, Dickens et al., 2007). At each period, firms have a desired wage, which is based on the previous nominal wage and the change in the unemployment rate, as follows:[19]

$$w_{f,t}^{j,d,\$} = w_{f,t-1}^{j,\$}(1 + \gamma_6(\eta_{t-1} - \eta_{t-2})) \tag{2.25}$$

where $w_{f,t-1}^{j,\$}$ is the previous wage level, γ_6 is the sensitivity of firms' desired wage to the unemployment rate, and η_t is the employment rate.

The wage level is a weighted average between the desired wage by firms and the wage desired by workers (assessed through a random survey with a proportion $n^{s,j}$ of the demand for workers), with the weight given to the latter depending on workers' bargaining power, which depends on a parameter ϕ (capturing institutional factors) and the employment rate (capturing cyclical factors), as follows in equation 2.26:

$$w_{f,t}^{j,\$} = (1 - \phi\eta_{t-1})w_{f,t}^{j,d,\$} + \phi\eta_{t-1}w_{f,t}^{j,s,\$} \tag{2.26}$$

where $1 > \phi > 0$ is a fixed parameter capturing the sensitivity of workers' bargaining power to the employment rate. Firms that could not hire all workers in the previous period interpret the wage adjustment rule described in equation 2.26 as having been insufficient and thus they increase this value proportionally to a parameter γ_7 times the percentage of unfilled job positions relative to the total demand for workers in the previous period.

Given the nominal wage level and firms' labor demand, a random list of firms is formed with the capital goods firm always being in the first position. The first firm tries to match with an indirect and a direct worker by randomly selecting a worker of each type. Workers accept an offer if the offered wage is above their reservation wage; otherwise, the hiring round will have been unsuccessful. After this, the second firm starts its hiring round and so on until all firms in the list have executed one hiring round for each type of worker. The process iterates until all firms have filled all open positions or reached the maximum number of hiring rounds for each type of worker, given by a multiple n^w of the number of open positions.

[18] There is also a minimum nominal interest rate $i^{min} > 0$ in order to assure that it is always strictly positive. This reflects the effective lower bound adopted by the central bank.

[19] There is also a limit for the real wage growth desired by firms, which is given by $\hat{w}^{max}$.

2.3.7 Foreign sector

We assume that the foreign sector sells imported goods to households through an intermediary that is part of the domestic consumption goods market. The price of imported goods in domestic currency is given by the foreign price level multiplied by the nominal exchange rate, as follows:[20]

$$p^{\$}_{x,t} = p^{x}_{x,t}\epsilon_t \tag{2.27}$$

In each period, the foreign sector's market share of the domestic demand for consumption goods ($ms_{x,t}$) is determined by its price competitiveness *vis-à-vis* domestic producers, as follows:

$$ms_{x,t} = \iota_4(1 - e^{(-\bar{p}^{C,*,\$}_t/p^{\$}_{x,t})^{(\iota_5)}}) \tag{2.28}$$

where $1 > \iota_{4,5} > 0$ are parameters capturing the maximum market share for the foreign sector, which reflects legal barriers, tariffs, local tastes, and preferences that limit the foreign sector's share of the domestic market, and the sensitivity of the foreign sector's market share to price competitiveness, respectively, and $\bar{p}^{C,*,\$}_t$ is the average price level of domestic producers.[21]

Consequently, the real imports demand is given by the market share of the foreign sector multiplied by the real demand of the domestic consumers.[22] In domestic currency, the aggregate import demand is given by equation 2.29. Since, for simplicity, we assume that the foreign sector (through an importer firm) can always fulfill the domestic sector's demand for imported goods,[23] this value is also equal to the realized nominal imports in domestic currency.

$$IM^{D,\$}_t = IM^{\$}_t = ms_{x,t}p^{\$}_{x,t}\sum_{h=1}^{N^h} C^D_{h,t} \tag{2.29}$$

where $\sum_{h=1}^{N^h} C^D_{h,t}$ is the households' real consumption demand.

2.3.8 Exchange rate dynamics

Given the simplified structure of our open economy model, we follow an exchange rate determination process similar to that in Dosi et al. (2019). Formally, we assume that the exchange rate dynamics depends on the previous period nominal trade balance and on the change

[20] For simplicity and focus on the main issues of interest in this chapter, we abstract from transportation costs.

[21] After $ms_{x,t}$ is set, domestic firms' market shares (equation 2.16) are rescaled so that the sum of their market shares is equal to $1 - ms_{x,t}$.

[22] As in the closed economy model version, this demand is simply the households' nominal demand divided by the average price level in the market weighted by the sellers' market shares.

[23] In other words, the supply of the imported goods is infinitely elastic at their current price.

in the nominal interest rate differential relative to the international nominal interest rate, as follows:[24]

$$\epsilon_t = \epsilon_{t-1}\left(1 - \lambda_3 \frac{X^{\$}_{t-1} - IM^{\$}_{t-1}}{Y^{\$}_{t-1}} + \lambda_4 \sum_{i=1}^{T^e} \Delta i^{dif}_{t+1-i}\right) \tag{2.30}$$

where $\lambda_{3,4} \geq 0$ are fixed parameters capturing the sensitivity of the nominal exchange rate to the trade balance and to the interest rate differential respectively, $i^{dif}_t = i_x - i_t$ is the interest rate differential between the foreign and domestic sectors, and T^e is the number of periods that the exchange rate takes to adjust to a change in the interest rate differential.

The real exchange rate is defined as:

$$\epsilon^r_t = \frac{\epsilon_t p^x_{x,t}}{\bar{p}^{C,*,\$}_t} \tag{2.31}$$

2.3.9 Sequence of events

In each simulation period, the sequence of events is the following:

1. The central bank sets the nominal interest rate;
2. The nominal exchange rate is determined;
3. Consumption goods firms set desired production levels and prices;
4. Exporter firms are selected;
5. Nominal wages are set;
6. Capital goods firm sets the price and the technologies used and embodied in new machines;
7. Credit market opens;
8. Consumption goods firms set investment demand and all firms set labor demand;
9. Labor market opens;
10. Production and R&D activities take place;
11. Unemployment benefits and wages are paid;
12. Households set their nominal consumption demand and the foreign sector sets its demand for domestic goods;

[24] Arguably, this is a simplification of the dynamics of the nominal exchange rate. Nevertheless, such a simplification allows us to focus on some specific factors affecting the nominal exchange rate which are more aligned with our purpose in this chapter, while assuming that the other factors remain constant.

13. Market shares in the domestic and foreign consumption goods markets are determined and consumption takes place;

14. Taxes are paid;

15. New machines are delivered and old machines are scrapped;

16. National accounts and statistics are computed;

17. Exit and entry of consumption goods firms take place.

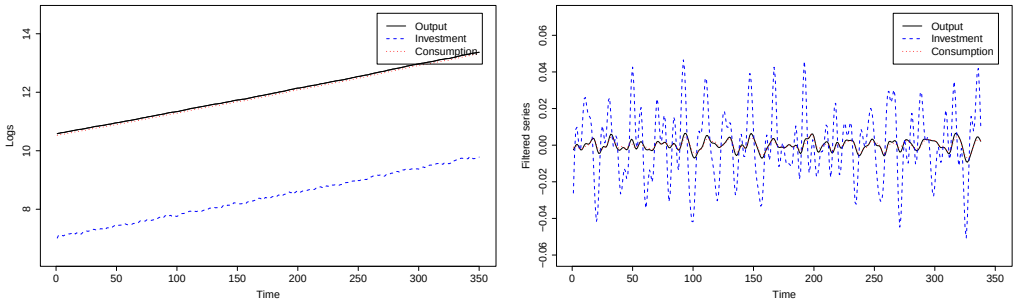
2.4 Model validation

This section analyzes the ability of the model to reproduce key stylized facts reported in the empirical literature. We extend our analysis beyond the stylized facts reported in chapter 1 by incorporating stylized facts related to open economy variables and also referring to studies that focus more specifically on developing economies.[25] The model is simulated for 600 periods (250 transient periods and 350 considered periods). This section reports the main average results for the 100 Monte Carlo simulations for the baseline scenario, whose parameters are reported in Appendix C.

We find that domestic output presents a sustained growth pattern with fluctuations (figure 2.2). With respect to the domestic components of aggregate demand, we find that consumption is less volatile than output and that investment is more volatile than output (Carlin and Soskice, 2014).[26] In developing economies, nonetheless, consumption may be more volatile than output, but it is always less volatile than investment (Jacobo and Marengo, 2020), as reproduced in our model.

[25] In this section we also report a few of the stylized facts that were reproduced by chapter 1. Yet, it should be mentioned that the model structure is robust and the stylized facts analyzed in chapter 1 are also reproduced in the open economy model outlined in this chapter.

[26] The standard deviation relative to that of output is equal to 0.783 and 7.919 for consumption and investment, respectively.

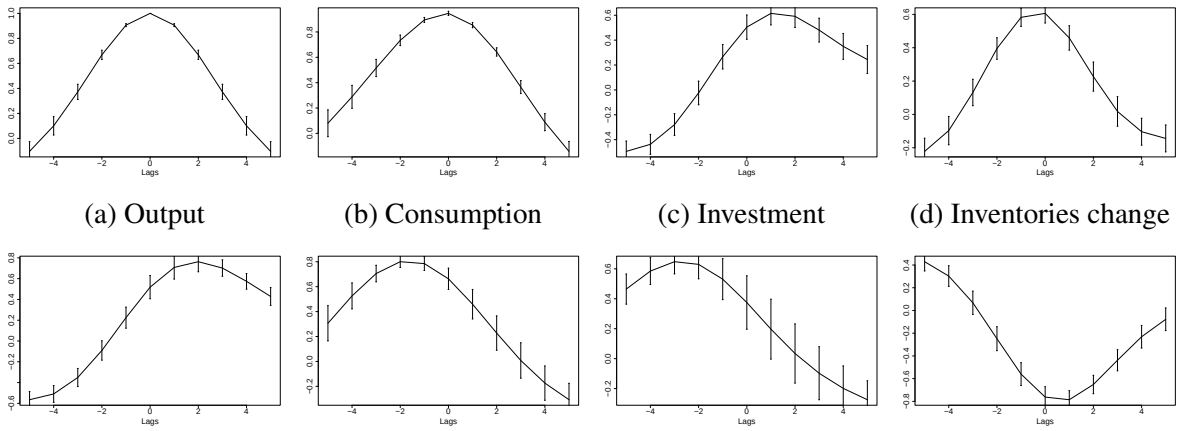


(a) Level (logs) (b) Cycle (Bpf)

Figure 2.2: Output, consumption, and investment

Note: Bpf: bandpass-filtered (6,32,12). Series represent average of 100 Monte Carlo runs. All series are taken in logarithm. Source: author's own elaboration based on simulation results.

Figure 2.3 reveals additional information concerning the cyclical components of selected macroeconomic series obtained through the bandpass filter. As reported in chapter 1, we find that consumption, investment, change in inventories, and labor productivity are procyclical, while the unemployment rate is countercyclical (Agenor et al., 2000, Toledo, 2008, Stock and Watson, 1999). In addition, we find that real aggregate exports and real aggregate imports are procyclical.[27]



(a) Output (b) Consumption (c) Investment (d) Inventories change

(e) Exports (f) Imports (g) Labor productivity (h) Unemployment rate

Figure 2.3: Cross-correlations structure for output

Note: Bpf: bandpass-filtered (6,32,12). Output, consumption, investment, change in inventories, average productivity, exports and imports series are all taken in logarithm. Bars are standard deviations of 100 Monte Carlo average cross-correlations. Source: author's own elaboration based on simulation results.

In line with empirical evidence, we find that the real and nominal exchange rates are positively correlated (Agenor et al., 2000), presenting a correlation coefficient of 0.949 (standard deviation equal to 0.03).

[27] It should be noted that these stylized facts are not necessarily observed in all developing economies, since not all of these economies present procyclical real aggregate exports (Jacobo and Marengo, 2020).

At the micro level, the model also reproduces empirical regularities concerning firms' penetration in international markets (table 2.1). In line with the evidence reported by Bernard et al. (1995, 2003, 2012), we find that only a fraction of the firms are exporters. In addition, these exporter firms are larger and more productive than non-exporting firms. Thus, firms are also heterogeneous with respect to their trade relations with the foreign sector and the model endogenously reproduces a key empirical finding indicating that exporters tend to be more productive than other firms.

Table 2.1: Exporters

Variable	Average	Standard deviation
Ratio of exporters (of total consumption goods firms)	0.335	0.022
Size (exporters relative to non-exporters)	4.252	0.503
Productivity (exporters relative to non-exporters)	1.086	0.033

Note: Averages across 100 Monte Carlo runs. Source: author's own elaboration based on simulation results.

2.5 Foreign shocks, output, income distribution, and inflation

The aim of this chapter is to investigate how external shocks affect the economic activity, inflation, and the income distribution of a small, open economy. Income distribution in this artificial economy is determined by a social conflict that presents a multitude of determinants, most of which are likely to be directly or indirectly influenced by external shocks. Indeed, the effect on income distribution largely depends on how external shocks affect the relative strength of the different groups through different channels, which depends on the underlying economic structure. While distributional changes affect the economic activity, the external shocks are also expected to affect output directly through changes in imports and exports. Similarly, changes in output can be a further factor influencing income distribution following an external shock. The changes in the conflict over income distribution also have implications to the inflation dynamics, which is further impacted by changes in the nominal exchange rate and foreign price levels. Thus, the experiments reported below capture this coevolutionary dynamics between income distribution, economic activity, and inflation rates that is already present in the model and is now disturbed by external shocks.

We investigate and compare the effect of two types of external shocks with different magnitudes, signs, and durations to analyze how these shocks and their characteristics affect the system. The first experiment consists on applying a temporary shock on the foreign output growth rate, which represents an external demand shock for the domestic economy. The second experiment consists on applying a temporary shock on the foreign price inflation rate, which has

implications for the domestic economy's terms of trade.[28] Given the different natures of each type of shock, their impacts on the domestic economy operate through different mechanisms and, thus, lead to different economic and distributional outcomes. All scenarios are compared with the baseline scenario reported in the previous section, in which there are no shocks.

2.5.1 Foreign output growth rate shocks

In our first experiment, we investigate the effect of temporary shocks on the foreign output growth rate on the dynamics of the domestic economy. This experiment intends to capture key mechanisms that operate in an economy when there is a context of higher (or lower) world output growth rates, which can have a direct effect on domestic output through exports. The different scenarios configurations with shocks of different magnitudes, signs, and durations on the foreign output growth rate (g_x) are reported in table 2.2 below.[29]

Table 2.2: Design of experiments (shocks on g_x)

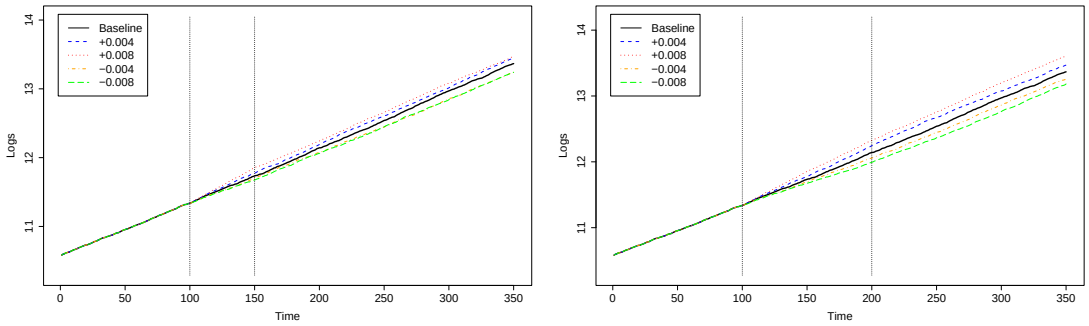
Experiment	Period	Δg_x			
1	50 to 100	+ 0.004	+ 0.008	- 0.004	- 0.008
2	50 to 150	+ 0.004	+ 0.008	- 0.004	- 0.008

Note: Source: author's own elaboration.

As expected, a positive foreign demand shock is associated with an increase in the domestic output level (figure 2.4), which is not reverted when the foreign output growth rate returns to the baseline value. Despite the different magnitudes, output levels do not clearly differ between both positive shocks on g_x when they are applied from period 50 to 100. This is related to the behavior of the growth rates during and after the shocks, as discussed in the end of this section (see table 2.3). Yet, despite not presenting a clear difference between the two shocks, both of them lead to a higher output growth rate if compared to the baseline scenario, indicating at least a persistent level effect. The negative foreign demand shocks are associated with lower domestic output levels. In this case, the difference between both magnitudes are much clearer when the shock is applied from 50 to 150, with the output level being even lower and more persistently affected when the magnitude of the negative shock is larger.

[28] Albeit directly affecting one component of the terms of trade (the foreign price level), such shock also indirectly affects its other components (nominal exchange rate and domestic price inflation) as discussed in the analysis of the experiments.

[29] The periods of the shocks refer to the time span after the transient phase (that is, during the considered simulation periods).

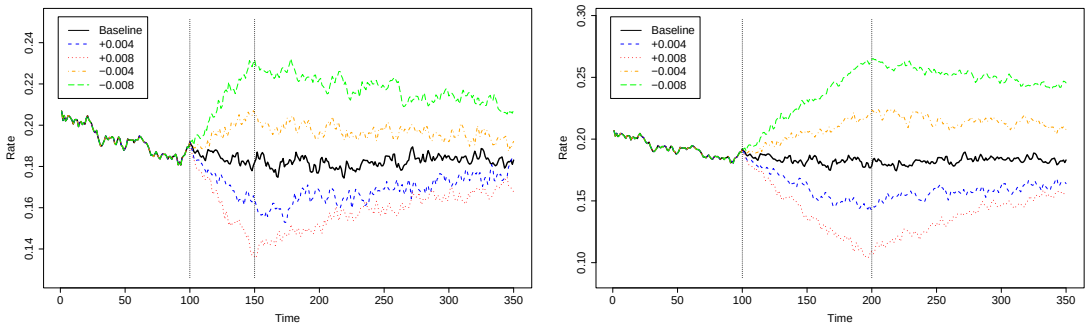


(a) Exp. 1 (b) Exp. 2

Figure 2.4: Comparison of experiments: output level in logs (shocks on g_x)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

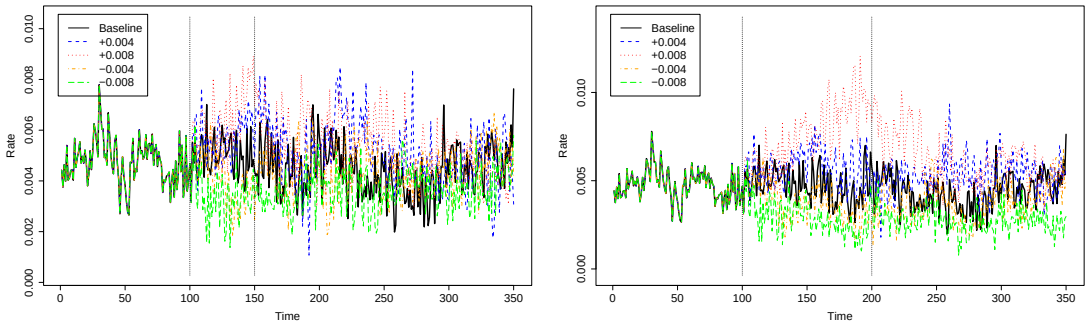
The foreign demand stimulus also leads to lower unemployment rates (figure 2.5), which stabilize at different levels after the shock is reverted. Such a decrease in the unemployment rate increases workers' power in the nominal wage bargaining process and increases the number of employed workers, who desired an increase in their real wage. These processes lead to higher nominal wages, which are partially passed-on to prices. Therefore, the inflation rate also tends to be higher when there is an increase in g_x (figure 2.6). Such increase in the inflation rate triggers a response of the central bank, and higher levels of the nominal interest rate are observed as well (figure 2.7). In the case of the negative shocks on g_x the response is quite symmetric, with higher unemployment rates and lower inflation and interest rates being observed.



(a) Exp. 1 (b) Exp. 2

Figure 2.5: Comparison of experiments: unemployment rate (shocks on g_x)

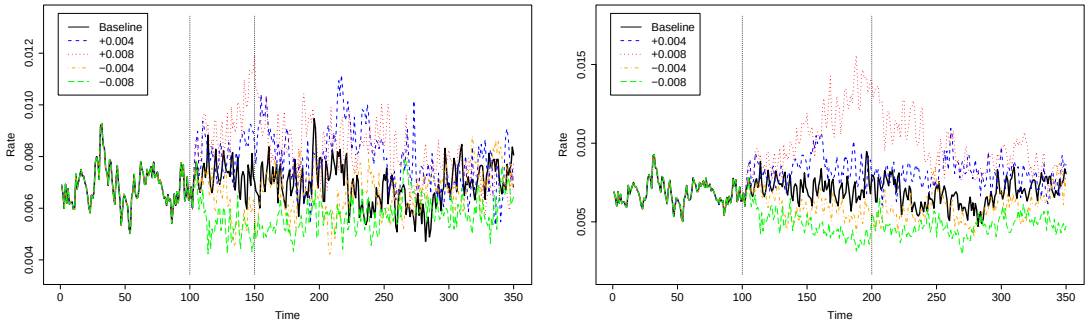
Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.



(a) Exp. 1 (b) Exp. 2

Figure 2.6: Comparison of experiments: inflation rate (shocks on g_x)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

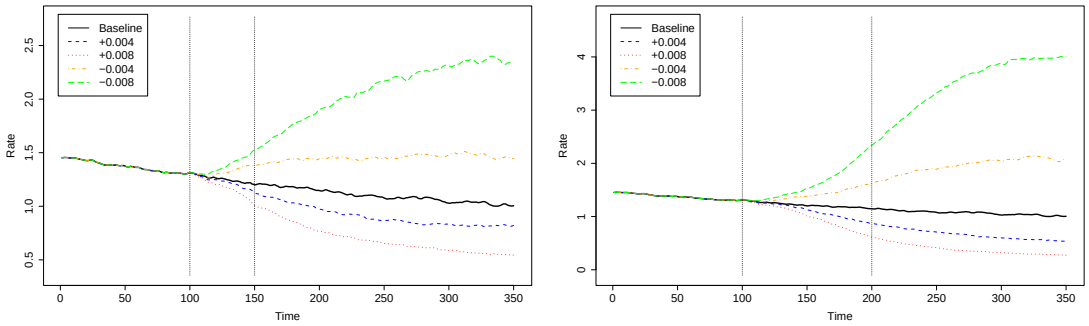


(a) Exp. 1 (b) Exp. 2

Figure 2.7: Comparison of experiments: nominal interest rate (shocks on g_x)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

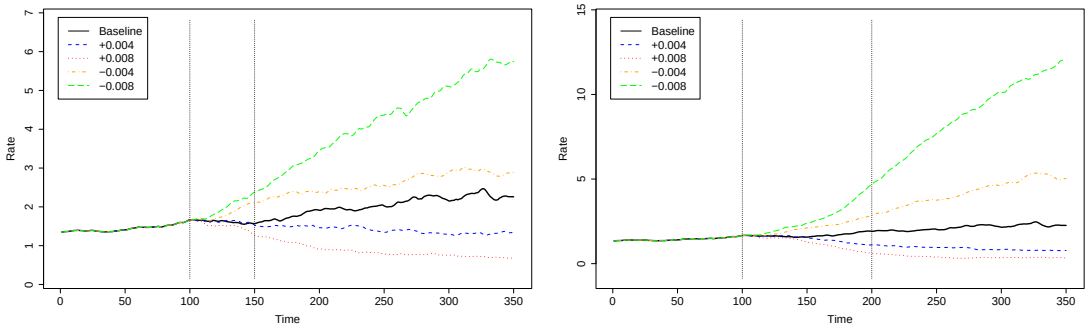
The combination of the foreign demand shock and the resulting higher inflation and interest rates has important implications for how the nominal and the real exchange rates behave (figures 2.8 and 2.9 respectively). Since the scenarios with higher values of g_x are those experiencing nominal trade balance surpluses (due to the higher external demand) and higher nominal interest rates, these scenarios present a tendency of nominal exchange rate appreciation. The real exchange rate, which is described by equation 2.31, tends to decrease due to this nominal exchange rate appreciation, but also due to the higher domestic inflation rate resulting from the positive shock on g_x (in this scenario, the foreign inflation rate is kept constant). Consequently, these scenarios present a lower real exchange rate, which is not reverted after the shock is over. It is interesting to note that the domestic currency appreciation during the period of the shock operates to reduce the increase in export growth, as firms' competitiveness reduces, but this is insufficient to fully compensate the positive shock on exports due to the increase in the foreign demand. Also in this case, the effect of negative shocks is almost symmetric, with negative shocks on g_x leading to higher nominal and real exchange rates.



(a) Exp. 1 (b) Exp. 2

Figure 2.8: Comparison of experiments: nominal exchange rate (shocks on g_x)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.



(a) Exp. 1 (b) Exp. 2

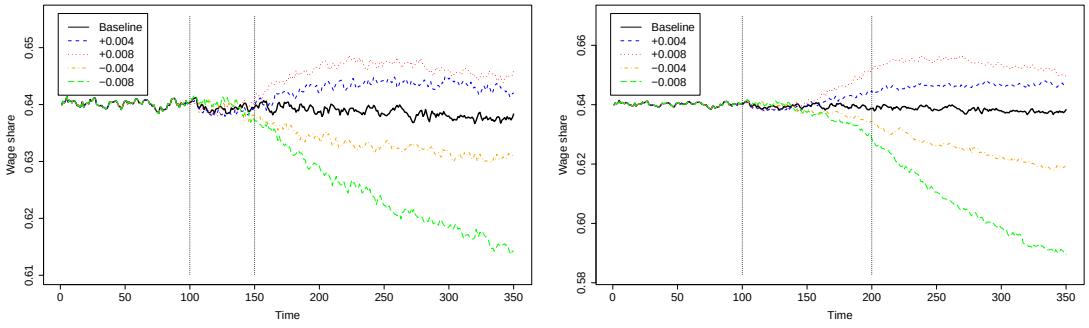
Figure 2.9: Comparison of experiments: real exchange rates (shocks on g_x)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

Income distribution is significantly affected by positive shocks on g_x (figures 2.10 and 2.11). Indeed, positive shocks on g_x are associated with a higher wage share and lower Gini index, especially after the shock is reverted. As previously discussed, there are several factors that affect the relative strengths of capitalists and workers in the model and explain the observed dynamics of the income distribution. Considering first the dynamics of the functional income distribution, a key factor is how workers' bargaining power evolve. Indeed, by stimulating economic activity and leading to a lower unemployment rate, positive shocks on g_x increase workers' bargaining power, which translates into stronger nominal wage adjustments. These adjustments pressure downwards firms' mark-up due to an increase in unit labor costs. Yet, there are other channels through which the foreign sector affects prices and mark-up rates in this economy. While the profit share is positively affected by the export growth stimulated by the higher foreign output growth rates, which leads to a positive adjustment in the mark-up used to calculate export prices, there are other factors that exert a negative effect on it and thus lead to a lower mark-up rate. Indeed, despite the increase in the mark-up set on export prices, such

prices are negatively affected by the currency appreciation, which reduces the value in domestic currency of one of its components (the foreign price level) in an *ex-post* manner. In net terms, this effect may compensate the first effect. With respect to prices of domestic goods, since the domestic currency real appreciation leads to an increase in the foreign sector's market share of the domestic market, firms react by decreasing the mark-up rate set on domestic prices. Thus, the functional income distribution results from the complex interaction between all of these determinants, and overall there is a positive association between positive shocks on g_x and the wage share. The dynamics of the functional income distribution has direct implications for the personal income distribution, since a higher wage share represents a higher average income to classes that tend to earn a lower income and whose income is more equally distributed (Daudey and García-Peñalosa, 2007, Wolff and Zacharias, 2013).

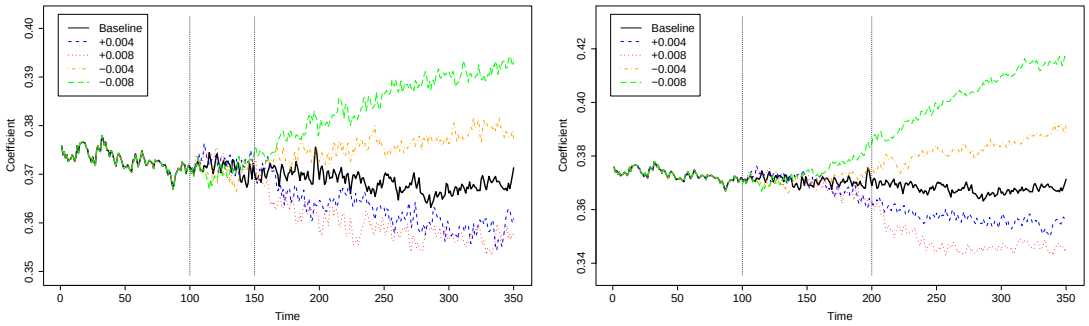
The negative shocks on g_x lead to an increase in income inequality. Such effect on income inequality is also the combination of two factors associated to the social conflict over income distribution: while the lower g_x leads to an increase in unemployment, which leads to higher mark-up rates through the behavior of production costs, it is also associated with lower inflation rates, which increase firms' international competitiveness and leads to further increases in the mark-up rate. Thus, in an open economy firms take advantage of low workers' bargaining power also through the improvement in their international competitiveness: not only wage increases are lower, which allows firms to adjust upward their mark-up rates, but also the lower growth rate of prices (given that costs are growing less) improve firms' position in the foreign market and allow them to further increase their mark-up rates.



(a) Exp. 1 (b) Exp. 2

Figure 2.10: Comparison of experiments: wage share (shocks on g_x)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.



(a) Exp. 1 (b) Exp. 2

Figure 2.11: Comparison of experiments: income Gini coefficient (shocks on g_x)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

Overall, the magnitude, sign and duration of the shocks are important for the dynamics of our variables and their long-run behavior (when g_x has returned to the baseline value).[30] In order to better understand each scenario, table 2.3 reports the average values of key variables for the periods during and after the shocks on g_x and compares them with the average values observed for the baseline scenario. With respect to the positive shocks on g_x, it is possible to observe that the domestic output growth rate increases during the period of the shock, and that such increase relative to the baseline is the larger, the larger the shock on g_x is. Yet, in the period after the shock the growth rates are not always statistically different from the baseline, indicating only a persistent level effect in two cases. On the other hand, distributional changes tend to be statistically significant and persist in the long run in all cases: positive shocks on g_x are associated with higher wage shares and lower income Gini coefficients, and the differences relative to the baseline scenario increase with the magnitude and duration of the shock. Given the loss in price competitiveness associated with the real exchange rate appreciation, the market share of domestic firms of the foreign market (market share exports) tends to be lower than in the baseline scenario, while the market share of the foreign sector of the domestic market (market share imports) is higher. This means that, when the shock is over, the export dynamics is negatively affected by the loss in price competitiveness, since the demand effect is no longer present. As a result, there is a reduction in the share of exports in output when the shock is over. Thus, while the effect on output growth rates is clear during the shock, its persistence in the long run depends on the interaction between domestic consumption and international competitiveness. Indeed, a more equal income distribution tends to be associated with more domestic consumption (given that lower classes tend to consume more out of their income) and more loss in price competitiveness (as higher workers' bargaining power is associated with higher inflation rates). If the former effect compensates the latter effect on exports and imports, a higher output growth

[30] In the following analysis and in the remaining of this chapter, we adopt a significance level of 10%.

rate can be obtained. Yet, when the former effect is not enough to compensate the latter effect, the average output growth rate can be lower.

The dynamics generated by the negative shocks on g_x tends to go on the opposite direction. In this case, the output growth rates are statistically smaller than the baseline scenario only during the shocks, while the worsening in income distribution is statistically significant even after the shock. Since the worsening in income distribution results from a reduction in workers' bargaining power due to the increase in unemployment rates following the negative shocks on g_x, there is also a lower inflation rate, which leads to an increase in firms' international competitiveness. Yet, such improvement in firms' international competitiveness is insufficient to compensate the negative effect of the worsening in income distribution and stimulate higher output growth rates.

In sum, the analysis of the positive and negative shocks on g_x highlights the importance of the interaction between domestic and foreign demands for the output dynamics and, consequently, the interaction between income distribution and international price competitiveness. In the short run, shocks on g_x tend to be positively related with the output growth rate, since they alter the exports dynamics, which can stimulate (or hamper) output growth. In the long run, when the shock is over, there is a statistically significant difference in income distribution (shocks on g_x are negatively related to inequality) and in the domestic firms' price competitiveness, since output growth tends to be followed by nominal wage negotiations that lead to higher inflation rates. Thus, the long-run dynamics of the economy depends on the interaction between income distribution and price competitiveness effects. Indeed, a lower price competitiveness is not a factor that necessarily inhibits economic growth in the long run, as it may be associated with more domestic consumption due to the improvement in income distribution. Nonetheless, this is not guaranteed for all cases, since price competitiveness may exert a dominant role in specific scenarios, as discussed above.

Table 2.3: Summary statistics for shocks on g_x

Exp. 1 (Shock period: 50 to 100)																	
Period	Total	During								After							
Experiment	Baseline	+0.004		+0.008		-0.004		-0.008		+0.004		+0.008		-0.004		-0.008	
Variable	Average	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val
Output growth rate	0.0077	1.0622	0.1282	1.2616	0.0000	0.8936	0.0146	0.8430	0.0001	1.0454	0.1016	1.0142	0.6036	0.9764	0.3716	0.9957	0.8637
Unemployment rate	0.1856	0.9349	0.0220	0.8762	0.0000	1.0595	0.0463	1.1333	0.0000	0.9069	0.0003	0.8535	0.0000	1.0603	0.0250	1.1729	0.0000
Inflation rate	0.0046	1.2189	0.0060	1.3837	0.0000	0.8915	0.1397	0.7431	0.0002	1.1078	0.0486	1.1481	0.0045	0.9565	0.4194	0.7957	0.0001
Interest rate	0.0069	1.1618	0.0062	1.3022	0.0000	0.9177	0.0931	0.8014	0.0000	1.1416	0.0003	1.1646	0.0000	0.9669	0.3584	0.8358	0.0000
Wage share	0.6392	0.9995	0.9229	1.0003	0.9535	1.0009	0.8549	1.0012	0.8050	1.0060	0.2158	1.0105	0.0133	0.9903	0.0953	0.9760	0.0004
Income Gini	0.3701	1.0065	0.4879	1.0066	0.4897	1.0004	0.9644	1.0020	0.8315	0.9798	0.0416	0.9717	0.0018	1.0157	0.1569	1.0402	0.0013
Market share exports	0.0023	1.0029	0.9725	0.9833	0.8406	1.0545	0.5176	1.0947	0.2672	0.8181	0.0407	0.7183	0.0011	1.0427	0.6400	1.2052	0.0298
Market share imports	0.2234	0.9942	0.9124	1.0041	0.9388	0.9761	0.6574	0.9593	0.4537	1.0723	0.1687	1.1233	0.0139	0.9574	0.4551	0.8572	0.0192
Domestic consumption share of output	0.8017	0.9832	0.0374	0.9750	0.0025	1.0004	0.9603	1.0085	0.2628	1.0231	0.0101	1.0247	0.0066	1.0157	0.0687	1.0170	0.0399
Exports share of output	0.1435	1.0960	0.0268	1.1395	0.0016	0.9978	0.9576	0.9503	0.2200	0.8759	0.0102	0.8707	0.0082	0.9108	0.0546	0.8973	0.0209
Imports share of output	0.2522	0.9769	0.7201	0.9826	0.7862	0.9715	0.6635	0.9590	0.5327	1.1161	0.0768	1.1761	0.0056	0.9807	0.7807	0.8753	0.0863
Exp. 2 (Shock period: 50 to 150)																	
Period	Total	During								After							
Experiment	Baseline	+0.004		+0.008		-0.004		-0.008		+0.004		+0.008		-0.004		-0.008	
Variable	Average	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val
Output growth rate	0.0077	1.1125	0.0017	1.2103	0.0000	0.9197	0.0155	0.8268	0.0000	1.0259	0.3818	1.0682	0.0349	1.0113	0.6827	1.0107	0.7021
Unemployment rate	0.1856	0.8728	0.0000	0.7658	0.0000	1.0988	0.0009	1.2309	0.0000	0.8494	0.0000	0.7409	0.0000	1.1581	0.0000	1.3568	0.0000
Inflation rate	0.0046	1.2380	0.0003	1.6437	0.0000	0.8194	0.0024	0.6399	0.0000	1.1531	0.0087	1.3585	0.0000	0.8120	0.0008	0.6003	0.0000
Interest rate	0.0069	1.2072	0.0000	1.5375	0.0000	0.8728	0.0012	0.7069	0.0000	1.1563	0.0002	1.3820	0.0000	0.8589	0.0001	0.6901	0.0000
Wage share	0.6392	1.0020	0.6829	1.0053	0.2640	0.9984	0.7518	0.9968	0.5399	1.0112	0.0108	1.0228	0.0000	0.9777	0.0023	0.9474	0.0000
Income Gini	0.3701	0.9996	0.9669	0.9989	0.9110	1.0032	0.7435	1.0106	0.2904	0.9646	0.0002	0.9403	0.0000	1.0338	0.0131	1.0888	0.0000
Market share exports	0.0023	0.9423	0.4909	0.8759	0.1335	1.0836	0.3367	1.1582	0.0718	0.6978	0.0004	0.4605	0.0000	1.1632	0.0812	1.4457	0.0000
Market share imports	0.2234	1.0233	0.6561	1.0543	0.2879	0.9648	0.5222	0.9214	0.1606	1.1389	0.0048	1.2508	0.0000	0.8897	0.0665	0.7129	0.0000
Domestic consumption share of output	0.8017	0.9849	0.0723	0.9758	0.0053	1.0093	0.2309	1.0229	0.0023	1.0291	0.0015	1.0485	0.0000	1.0229	0.0074	1.0304	0.0001
Exports share of output	0.1435	1.0875	0.0521	1.1398	0.0027	0.9454	0.1907	0.8647	0.0008	0.8471	0.0020	0.7448	0.0000	0.8656	0.0034	0.8133	0.0000
Imports share of output	0.2522	1.0147	0.8185	1.0419	0.5042	0.9710	0.6640	0.9315	0.3119	1.1959	0.0018	1.3434	0.0000	0.9139	0.2327	0.7273	0.0003

Note: Averages across 100 Monte Carlo runs for each scenario. Ratios with respect to baseline scenario. Source: author's own elaboration based on simulation results.

2.5.2 Foreign inflation rate shocks

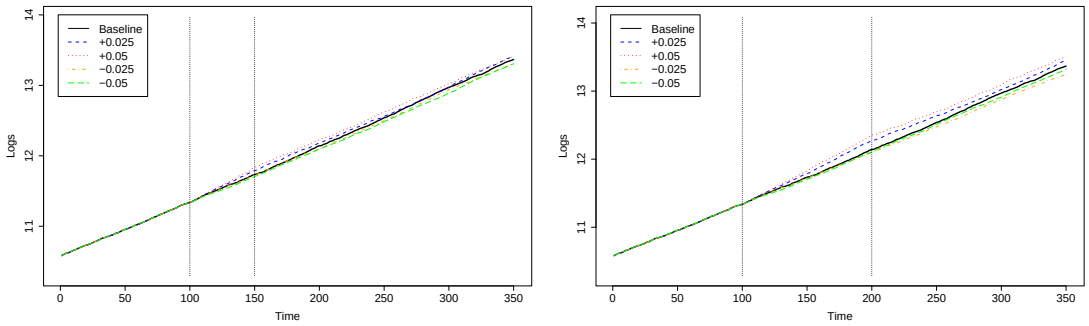
The second experiment concerns a shock on the foreign price inflation rate, which is expected to affect the domestic economy's terms of trade. The experiment is constructed by applying temporary shocks to the foreign inflation rate. The different scenarios are reported in table 2.4 below.

Table 2.4: Design of experiments (shocks on $\hat{p}_x$)

Experiment	Period	$\Delta\hat{p}_x$			
3	50 to 100	+ 0.025	+ 0.05	- 0.025	- 0.05
4	50 to 150	+ 0.025	+ 0.05	- 0.025	- 0.05

Note: Source: author's own elaboration.

As expected, when there is an increase in the foreign price inflation rate, this leads to higher output rates in the domestic economy. This is due to the gain in price competitiveness by domestic firms when the foreign price level grows at a higher rate, thus leading to higher aggregate exports. In the case of the negative shocks, however, we do not necessarily observe a lower output level (as explored in the end of this section).



(a) Exp. 3 (b) Exp. 4

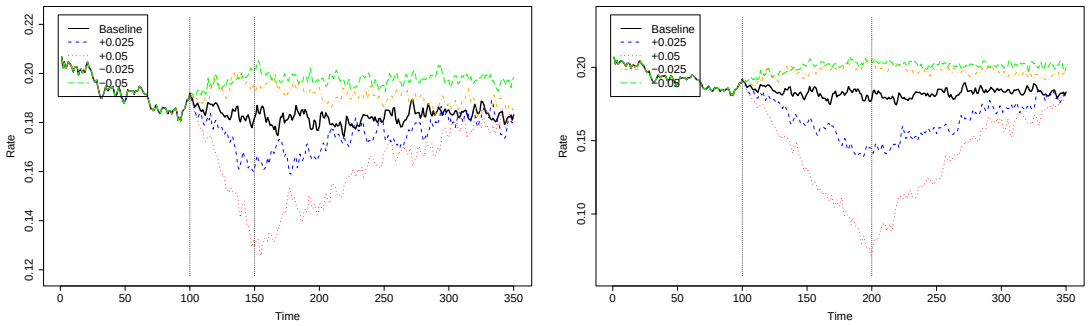
Figure 2.12: Comparison of experiments: output level in logs (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

The positive stimulus on domestic demand leads to a temporary decrease in unemployment rates (figure 2.13), which nonetheless return to the previous value when the foreign inflation rate returns to the baseline value. Similarly to the previous case, there is an increase in domestic inflation rates following the external shock (figure 2.14), but there are two mechanisms operating in the same direction in this case. On the one hand, the increase in the foreign inflation rate leads to some "imported" inflation, since there is a pass-through from the foreign inflation to the domestic inflation through the imported goods. On the other hand, the lower unemployment rate means that workers have more bargaining power, achieving larger nominal wage adjustments in their negotiations with firms and inducing higher inflation rates of domestic goods as well.

Actually, even the desired wage by workers is affected by the higher foreign inflation rate, since they are concerned with their total consumption goods basket, which includes imported goods. Thus, the imported inflationary pressures have an effect on nominal wage negotiations and domestic inflation rate also through the desired wage by workers. Indeed, foreign inflation rates exert a direct (or exogenous) impact on the domestic inflation through imported goods and an indirect (or endogenous) impact that is mediated by the perceived inflation rate by the domestic agents and by the changes in the dynamics of the social conflict.

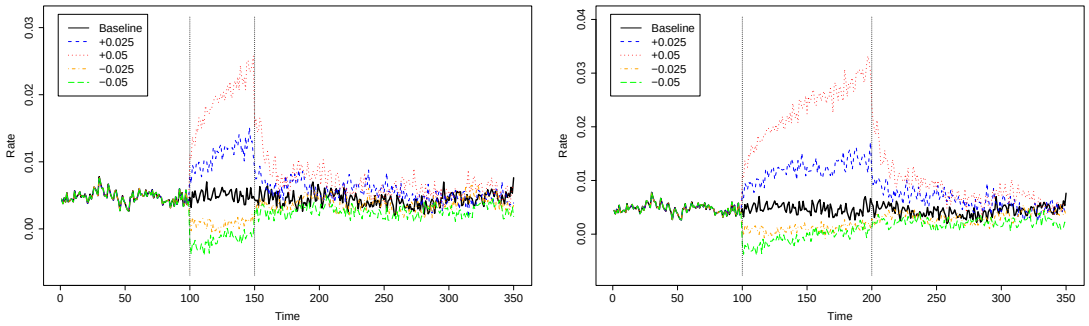
The higher inflation rates once again trigger a response by the central bank, so the scenarios with a higher $\hat{p}_x$ are associated with higher nominal interest rates (figure 2.15). In the case of the negative shocks on $\hat{p}_x$, the effect of $\hat{p}_x$ on the desired wage is not as expressive as in the case of positive shocks on $\hat{p}_x$ due to the existence of downward nominal wage rigidity. This rigidity may also explain this why output does not fall in a symmetrical way, since it helps to keep wages at the same level, and thus sustain aggregate demand. Thus, the predominant factor driving down the inflation rate in this case is the foreign price level through imported goods. Due to the weaker strength of the other mechanisms, the effect of shocks of the same magnitude and different signs on $\hat{p}_x$ is asymmetric, which explains why inflation rates decrease less in case of negative shocks than they increase when there is a positive shock. Another implication of this is that when there is a negative shock the decrease in the nominal interest rate is of a smaller magnitude.



(a) Exp. 3 (b) Exp. 4

Figure 2.13: Comparison of experiments: unemployment rate (shocks on $\hat{p}_x$)

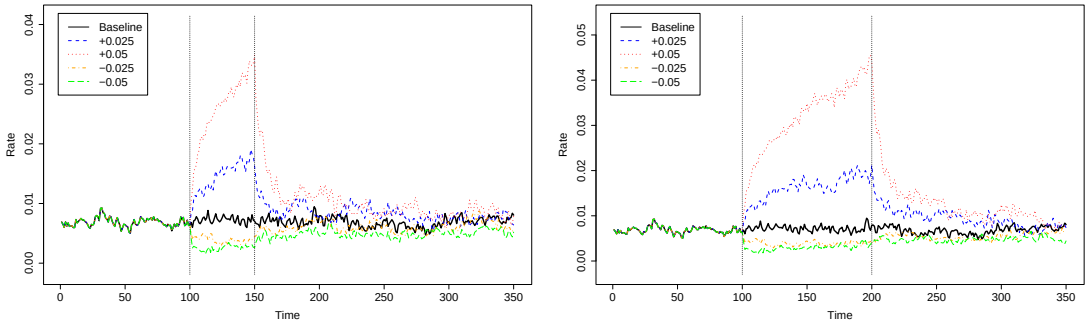
Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.



(a) Exp. 3 (b) Exp. 4

Figure 2.14: Comparison of experiments: inflation rate (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.



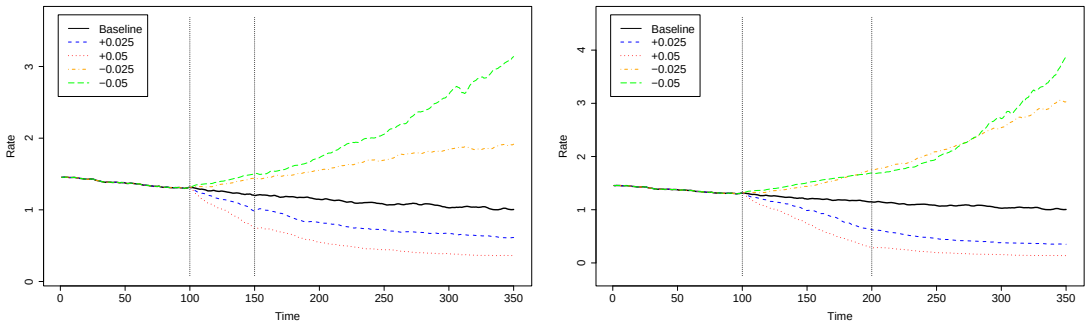
(a) Exp. 3 (b) Exp. 4

Figure 2.15: Comparison of experiments: nominal interest rate (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

The dynamics of the nominal and real exchange rates, reported in figures 2.16 and 2.17 respectively, shows that they are affected in opposite directions by a shock in $\hat{p}_x$. The nominal exchange rate tends to appreciate when there is a positive shock in $\hat{p}_x$ due to the trade surplus and the higher nominal interest rate (similarly to what occurred after a shock in g_x). Yet, such a decrease in the nominal exchange rate is not enough to offset the strong effect of higher foreign prices on the real exchange rate, which increases with higher levels of $\hat{p}_x$. Thus, despite the nominal appreciation of the domestic currency and the increase in the domestic inflation rate, the domestic economy becomes more competitive relative to the foreign sector. Given that such increase in the real exchange rate during the shock results from the effect of $\hat{p}_x$ more than compensating the nominal exchange rate appreciation and the increase in domestic prices, this compensation is no longer observed in the period after the shock and the real exchange rate stabilizes. Nevertheless, there remains a tendency of nominal exchange rate appreciation, since the level of the real exchange rate determines the dynamics of imports and exports. In the case of negative shocks on $\hat{p}_x$, the opposite occurs and the nominal exchange rate increases due to

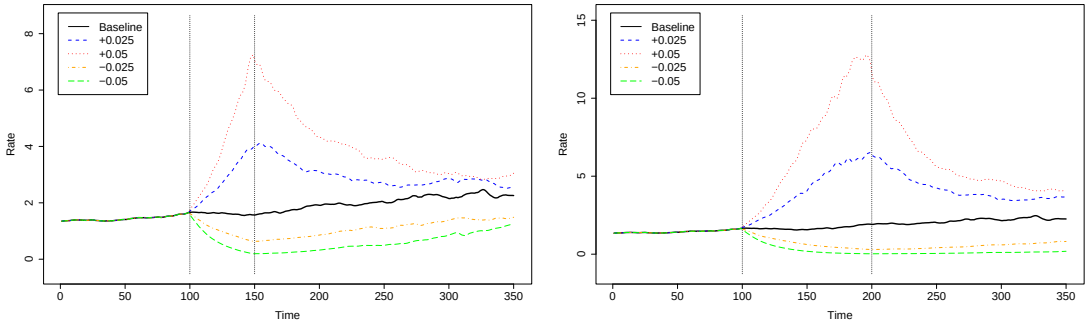
the decrease in trade surplus and the lower nominal interest rate, while the real exchange rate decreases due to the predominant effect of a lower $\hat{p}_x$.



(a) Exp. 3 (b) Exp. 4

Figure 2.16: Comparison of experiments: nominal exchange rate (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.



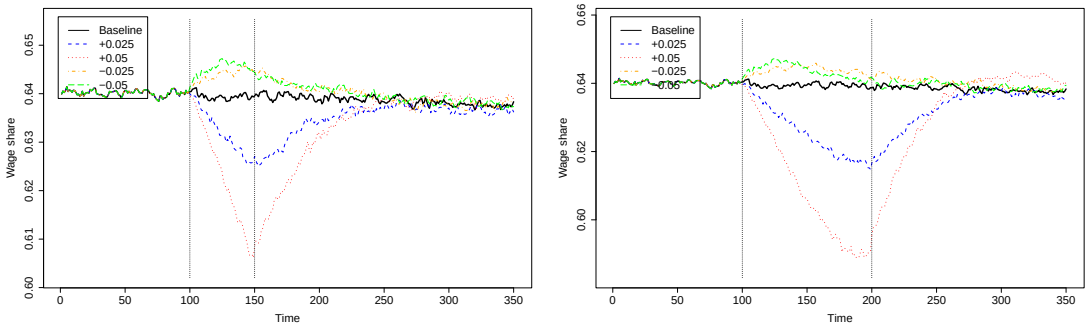
(a) Exp. 3 (b) Exp. 4

Figure 2.17: Comparison of experiments: real exchange rates (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

In terms of income distribution, the effect of a shock on the foreign inflation rate is markedly different from that in the previous experiment. Indeed, a positive shock on $\hat{p}_x$ is associated with a lower wage share and a higher income Gini coefficient, as reported in figures 2.18 and 2.19 respectively. As mentioned, the decrease in unemployment rates benefits workers and improves their bargaining power, leading to higher nominal wages. Nevertheless, firms also benefit from their better position *vis-à-vis* foreign competitors, which allows them to adjust the mark-ups upward. In this coevolutionary dynamics, firms' mark-ups are negatively affected by the nominal wage adjustments, but positively (and more significantly) affected by the increase in their international competitiveness. An additional effect of the higher real exchange rate is to increase exporters' revenue (and profits) in domestic currency, which is the direct effect emphasized by Rossi and Galbraith (2016). As in the previous case, the dynamics in the

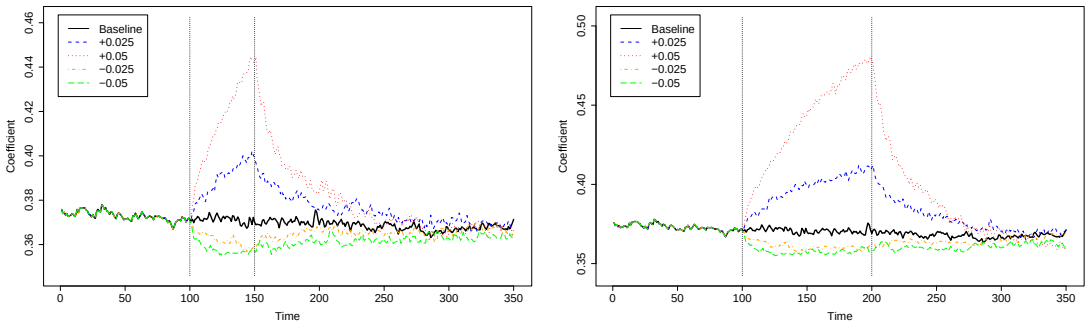
functional income distribution has implications for the personal income distribution, so there is a higher income Gini coefficient following the positive shocks on $\hat{p}_x$. In the case of negative shocks on $\hat{p}_x$, the effects are, once again, much milder. The dynamics of the wage share results from factors that tend to benefit firms (the weaker growth in unit costs due to the lower foreign price inflation) and that tend to benefit workers (the loss of international competitiveness and the real exchange rate appreciation). These factors seem to partially compensate each other, but the situation is somewhat more favorable to workers: there a small increase in the wage share and a slight decrease in the income Gini coefficient.



(a) Exp. 3 (b) Exp. 4

Figure 2.18: Comparison of experiments: wage share (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.



(a) Exp. 3 (b) Exp. 4

Figure 2.19: Comparison of experiments: income Gini coefficient (shocks on $\hat{p}_x$)

Note: vertical lines indicate the first and last period of the shock on the foreign variable. Series represent average of 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

Table 2.5 provides additional information concerning the effects of the shocks on our variables of interest during and after the shocks. When there is a positive shock on $\hat{p}_x$, there is an increase in the output growth rate during the period of the shock, since the improvement in terms of trade lead to an increase in exports, which grow as a share of output. Since a price

shock has a more direct effect on income distribution than a demand shock,[31] the changes on income distribution are already significant during the period of the shock, and an increase in inequality is observed. This change in income inequality persists in the long run (after the shock) in some cases, and so do the changes in exports and imports market shares, reflecting a lasting gain in international competitiveness that results from the level effect on the real exchange rate, as previously discussed. Nevertheless, output growth rates return to the baseline value (more precisely, are not statistically different from it). In most cases, this results from exports not being an output growth driver any longer, since export growth during the shock was stimulated by a gain in international competitiveness. When $\hat{p}_x$ returns to the baseline value, exports can no longer stimulate growth. However, differently from the previous case, now there is more inequality in the income distribution, preventing domestic consumption from becoming a stimulus for economic growth (exports share continue to represent a larger share of output and domestic consumption continues to represent a smaller share of output). Thus, when the growth stimulus represented by the gains in terms of trade is over, it is not replaced by any domestic component.

In the case of the negative shocks $\hat{p}_x$, lower output growth rates are obtained during the shocks in most cases, but they are not different from the baseline scenario in the periods after the shock. The loss in international price competitiveness leads to a reduction in domestic firms' market share of the foreign sector and an increase in the foreign sector's market share of the domestic sector even after the shocks. Yet, the negative effects of the increase in the share of imports and decrease in the share of exports in total output is somewhat attenuated by the slight increase in the wage share (only significant during the shock) and decrease in the income Gini coefficient (significant after the shock in most cases), which allow domestic consumption to compensate the negative effect of the weaker exporting dynamics.

[31] In the case of the demand shock, analyzed in the previous section, the distributional changes operated through the wage bargaining process and through the dynamics of the nominal exchange rate. In the case of a price shock, there is a direct and immediate effect on the numerator of the real exchange rate, which has implications for the exporters' revenues in domestic currency and, consequently, for their profits.

Table 2.5: Summary statistics for shocks on $\hat{p}_x$

Exp. 3 (Shock period: 50 to 100)																	
Period	Total	During								After							
Experiment	Baseline	+0.025		+0.05		-0.025		-0.05		+0.025		+0.05		-0.025		-0.05	
Variable	Average	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val
Output growth rate	0.0077	1.1233	0.0022	1.2010	0.0000	0.9536	0.2513	0.8798	0.0102	1.0267	0.3138	1.0066	0.7985	0.9922	0.7779	1.0016	0.9508
Unemployment rate	0.1856	0.9439	0.0549	0.8678	0.0000	1.0443	0.1087	1.0549	0.0325	0.9414	0.0318	0.8695	0.0000	1.0253	0.3157	1.0655	0.0062
Inflation rate	0.0046	2.4109	0.0000	4.1946	0.0000	0.1703	0.0000	-0.3594	0.0000	1.1980	0.0003	1.4670	0.0000	0.8205	0.0009	0.5867	0.0000
Interest rate	0.0069	2.0887	0.0000	3.6728	0.0000	0.5744	0.0000	0.3863	0.0000	1.2031	0.0000	1.4613	0.0000	0.8849	0.0010	0.7108	0.0000
Wage share	0.6392	0.9891	0.0857	0.9753	0.0018	1.0072	0.0772	1.0094	0.0121	0.9934	0.3115	0.9911	0.2419	1.0008	0.8552	1.0010	0.7889
Income Gini	0.3701	1.0509	0.0000	1.1190	0.0000	0.9791	0.0107	0.9678	0.0000	1.0134	0.2695	1.0226	0.0977	0.9875	0.1664	0.9780	0.0049
Market share exports	0.0023	1.1971	0.0183	1.3071	0.0002	0.8599	0.0914	0.6873	0.0001	1.1348	0.1362	1.2548	0.0051	0.6995	0.0007	0.4512	0.0000
Market share imports	0.2234	0.8851	0.0377	0.8032	0.0005	1.0766	0.1284	1.1585	0.0006	0.8928	0.0610	0.8258	0.0028	1.1288	0.0119	1.2285	0.0000
Domestic consumption share of output	0.8017	0.9613	0.0000	0.9402	0.0000	1.0263	0.0012	1.0585	0.0000	0.9850	0.0711	0.9676	0.0001	1.0610	0.0000	1.1061	0.0000
Exports share of output	0.1435	1.2140	0.0000	1.3332	0.0000	0.8559	0.0009	0.6803	0.0000	1.0844	0.0587	1.1835	0.0000	0.6636	0.0000	0.4130	0.0000
Imports share of output	0.2522	0.8357	0.0114	0.7320	0.0000	1.1130	0.0735	1.2437	0.0000	0.8795	0.0782	0.7926	0.0024	1.2229	0.0007	1.3869	0.0000
Exp. 4 (Shock period: 50 to 150)																	
Period	Total	During								After							
Experiment	Baseline	+0.025		+0.05		-0.025		-0.05		+0.025		+0.05		-0.025		-0.05	
Variable	Average	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val	Ratio	p-val
Output growth rate	0.0077	1.1540	0.0000	1.2312	0	0.9226	0.0328	0.9119	0.0171	1.0173	0.5434	1.0081	0.7633	0.9533	0.1223	1.0117	0.7131
Unemployment rate	0.1856	0.8808	0.0000	0.7130	0	1.0604	0.0194	1.0736	0.0009	0.8840	0.0001	0.7564	0.0000	1.0618	0.0082	1.0874	0.0000
Inflation rate	0.0046	2.6353	0.0000	5.0634	0	0.2220	0.0000	-0.1310	0.0000	1.3668	0.0000	1.8430	0.0000	0.7110	0.0000	0.4851	0.0000
Interest rate	0.0069	2.3223	0.0000	4.5850	0	0.5709	0.0000	0.4320	0.0000	1.3680	0.0000	1.8317	0.0000	0.7977	0.0000	0.6906	0.0000
Wage share	0.6392	0.9791	0.0085	0.9533	0	1.0072	0.0541	1.0069	0.0524	0.9901	0.2146	0.9895	0.2672	1.0011	0.7697	1.0000	0.9914
Income Gini	0.3701	1.0723	0.0000	1.1862	0	0.9758	0.0019	0.9671	0.0000	1.0213	0.1336	1.0401	0.0127	0.9842	0.0476	0.9751	0.0009
Market share exports	0.0023	1.2942	0.0005	1.4425	0	0.7048	0.0003	0.4522	0.0000	1.2654	0.0031	1.4499	0.0000	0.4766	0.0000	0.1222	0.0000
Market share imports	0.2234	0.8120	0.0008	0.6856	0	1.1414	0.0030	1.2386	0.0000	0.8209	0.0023	0.7076	0.0000	1.2159	0.0000	1.3274	0.0000
Domestic consumption share of output	0.8017	0.9476	0.0000	0.9219	0	1.0569	0.0000	1.1020	0.0000	0.9664	0.0000	0.9468	0.0000	1.1027	0.0000	1.1630	0.0000
Exports share of output	0.1435	1.2906	0.0000	1.4406	0	0.6861	0.0000	0.4374	0.0000	1.1893	0.0000	1.3032	0.0000	0.4327	0.0000	0.0966	0.0000
Imports share of output	0.2522	0.7492	0.0001	0.5994	0	1.2235	0.0003	1.3937	0.0000	0.7855	0.0018	0.6522	0.0000	1.3717	0.0000	1.5807	0.0000

Note: Averages across 100 Monte Carlo runs for each scenario. Ratios with respect to baseline scenario. Source: author's own elaboration based on simulation results.

2.5.3 Summary of the main findings

The previous sections discussed the effects of two types of foreign shocks that alter the international trade dynamics of the domestic economy. While we find that positive shocks on the foreign output growth rate and on foreign inflation rate exert a positive (and in most cases temporary) effect on the domestic output growth rate and a persistent effect on its level, the distributive implications of each type of shock differ considerably, with more equality following the positive shocks on the foreign output growth rate and more inequality following the positive shocks on the foreign inflation rate. Table 2.6 presents the main properties of each type of shock in order to summarize the key mechanisms driving the results in each case.

Table 2.6: Summary of main results

Type of shock	Output growth	Unemployment rate	Inflation rate	Nominal exchange rate	Real exchange rate	Wage share	Gini coefficient
$\Delta g_x > 0$	+	-	+	-	-	+	-
$\Delta \hat{p}_x > 0$	+	-	+	-	+	-	+

Note: + indicates that the variable increases in comparison to the baseline scenario (either during or after the shock) and - indicates that the variable decreases in comparison to the baseline scenario (either during or after the shock).
Source: author's own elaboration.

Both types of shocks lead to an increase in the output growth rate (which is temporary in most cases), triggering a decrease in the unemployment rate. Also a higher inflation rate follows in both cases, which is related to the lower unemployment rate that tends to favor workers in the wage bargaining process and to increase the growth rates of nominal wages. Yet, in the case of the shock on the foreign output growth rate the increase in domestic prices is somewhat attenuated by the decrease in the nominal exchange rate, which reduces the growth rate of imported goods prices, while in the case of the shock on the foreign inflation rate the increase in domestic prices is reinforced by the strong increase in the growth rate of imported goods prices (captured by the increase in the real exchange rate). Thus, the nature of the inflationary processes triggered by the foreign shocks differ considerably depending on the type of shock.

The dynamics of the nominal and real exchange rates is key to understanding the differences in the distributive implications of each scenario. Since both scenarios are associated with an increase in employment, which induce higher growth rates of nominal costs and lower mark-up rates (equation 2.14) and an increase in exports growth, which increases the exporter firms' mark-up rates (equation 2.17), the key differences between them are related to the dynamics of the real exchange rate. Indeed, the nominal exchange rate appreciation (determined by the trade balance surplus and the increase in nominal interest rates) obtained in both cases is associated with a real exchange rate appreciation when there is a shock in the foreign output growth rate (due to a combination of the lower nominal exchange rate and the increase of the domestic price inflation in comparison with the foreign price inflation) and with a real exchange rate depreciation when there is a shock on the foreign inflation rate (since the increase of the foreign inflation rate relative to the domestic inflation rate compensates the decrease of the nominal exchange rate). The currency real appreciation in the former case means that domestic

firms face more competition in the domestic and foreign markets and that exporters' revenue per good in domestic currency reduces,[32] thus leading to a higher wage share and a lower income Gini. On the other hand, the currency real depreciation in the latter case has the opposite effect and the increase in the domestic firms' competitiveness relative to the foreign sector and the increase in the exporters' revenues induce a worsening in the income distribution.

The duration (or persistence) of the macroeconomic and distributive effects of the shocks is also strongly dependent on the type of shock. Indeed, since the shocks on the foreign inflation rates have a strong and immediate effect on the exporters' revenue, the differences in income distribution are statistically significant already during the period when the shock is applied. On the other hand, the distributive implications of the shocks on the foreign output growth rate operate through less automatic mechanisms, and thus take longer to lead to statistically significant differences. Yet, in the former case the differences are not always statistically significant after the period of the shock is over, and the unemployment rates quickly rise back to the baseline level. In the latter case, the duration of the effect on the income distribution is considerably longer, with a slower convergence of the unemployment rates back to the baseline level. As already mentioned, the key mechanism explaining this dynamics is the fact that the improvement in income distribution after the shocks in the foreign output growth rate induce a replacement of foreign demand by domestic consumption when the shock is over, which is not the case when there is a shock on the foreign inflation rate. This improvement in aggregate demand is likely to also exert a feedback effect on income distribution through the lower unemployment rates, thus contributing to the persistence of the effect on distribution (in particular for the wage share).

These results indicate that gains in international competitiveness are not enough to induce higher output growth rates in the long run if they are accompanied by a worsening in the income distribution. Nevertheless, a similar remark applies to the scenarios in which more equality is obtained, since it is not guaranteed that the higher output growth rate persists after the period of the shock, although this is a valid possibility. Thus, while the shift towards more equality may help to sustain higher output growth rates because domestic consumption replaces exports when the shock is over, the loss in international competitiveness may play a countervailing role. In sum, the interplay between domestic consumption and international competitiveness is key to the relation between output growth and income distribution arising from the foreign shocks, while also indicating that the real exchange rate may have different relations with output depending on the dynamics of income distribution.

[32] Exporters follow the pricing to market strategy and thus there is a price component that is determined by the foreign price level and the nominal exchange rate (equation 2.18).

2.6 Transmission mechanisms and foreign shocks

The experiments reported in the previous section explored how foreign shocks of different types can affect output growth, income distribution, and inflation in small open economies. In addition, the results highlight the role of income distribution as a transmission mechanism of foreign shocks, which was an important characteristic for the long-run behavior of output growth in some scenarios. In order to explore how the foreign shocks affect different economic structures, in this section we explore the model results for scenarios with different values of key parameters capturing the determinants of income distribution and the relation between the domestic economy and the foreign sector: the sensitivity of the mark-up rate to changes in unit labor costs (parameter ν_3 in equation 2.14), the sensitivity of the mark-up rate to the growth rate of exports (parameter ν_5 in equation 2.17), the sensitivity of exporters' market share of the foreign market to price competitiveness (parameter ι_3 in equation 2.19), and the sensitivity of the foreign sector's market share of the domestic market to price competitiveness (parameter ι_5 in equation 2.28). These parameters influence the dynamics of the social conflict over the income distribution and, thus, represent transmission mechanisms of the foreign shocks that are key for the inequality dynamics. For each parameter value, we estimate a scenario in which there are no shocks, a scenario in which there is a shock in the foreign output growth rate equal to +0.004, and a scenario in which there is a shock in the foreign inflation rate equal to +0.025. When the shocks are applied, they last from period 50 to 150 of the considered simulation periods (i.e., after the transient phase). The different values of the structural parameters are reported in table 2.7.[33]

Table 2.7: Design of experiments (structural parameters)

Experiment	Parameter	Description	Values
5	ν_3	sensitivity of mark-up rate to unit labor costs	0, 0.1, 0.2
6	ν_5	sensitivity of the mark-up rate to the growth rate of exports	0, 0.2, 0.4
7	ι_3	sensitivity of exporters' market share of foreign market to price competitiveness	0.6, 0.8, 1
8	ι_5	sensitivity of the foreign sector's market share of domestic market to price competitiveness	0.6, 0.8, 1

Note: Source: author's own elaboration.

Tables 2.8 to 2.11 report the effects of shocks on the foreign growth rate and inflation rate on the scenarios with different values of ν_3, ν_5, ι_3, and ι_5 respectively. Overall, the effect on income distribution is on the same direction as that reported in the experiments in section 2.5: positive shocks on g_x are associated with a higher wage share and a lower income Gini coefficient in the long run (but no significant effect in the short run), while positive shocks on $\hat{p}_x$ tend to be associated with a lower wage share and a higher income Gini coefficient in the short run (with only a few cases in which the difference is significant in the long run). In terms

[33] Note that the intermediate value of the parameters is that of the baseline scenario. Given the scope of our work, this section's research question does not concern the effect of each parameter by itself, but rather how foreign shocks propagate in different economic structures. Therefore, our analysis does not consist on the comparison between the average values for each parameter while keeping the shocks constant.

of the magnitude of the effects, the shocks on g_x tend to lead to a larger increase of the wage share and smaller decrease of the Gini coefficient in the long run when ν_3 is higher, which is expected because mark-ups become more sensitive to the increasing unit costs. Conversely, the higher values of ι_3 and ι_5 tend to reduce the magnitude of the distributive impacts of the shocks on g_x, while ν_5 presents a non-linear effect. With respect to the shocks on $\hat{p}_x$, only in a few parameters settings the distributive impact persists in the period after the shock: when $\nu_3 = 0$, $\nu_5 = 0$, and $\iota_5 = 0.6$. This suggests that low values of these parameters tend to deactivate mechanisms that compensated the worsening in income inequality that was observed during the shock and that contributed to the convergence of the values after the shock in the direction of the scenario with no shock. Nevertheless, some of the parameters do have a clear effect on income distribution during the period of the shock on $\hat{p}_x$. Inequality tends to increase less when ν_3 is higher, indicating that if the mark-ups are more sensitive to unit costs, the increase in employment rates and in workers' bargaining power may partially counteract the mechanisms that tend to concentrate income after such shock. A similar setting is observed when ι_5 increases, because the foreign sector's loss of competitiveness implies larger decreases in unemployment rates when its market share is more sensitive to price competitiveness and there is an increase in $\hat{p}_x$, which tends to increase workers' bargaining power and thus compensates part of the tendency of worsening in income distribution.

Table 2.8: Summary statistics for shocks on g_x and $\hat{p}_x$ for different values of parameter ν_3

Shock on g_x															
Parameter	0					0.1					0.2				
Shock	0	+0.004				0	+0.004				0	+0.004			
Period	Total	During		After		Total	During		After		Total	During		After	
Variable	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val
Output growth rate	0.0077	1.0680	0.0468	1.0230	0.4286	0.0076	1.1260	0.0004	1.0383	0.1934	0.0080	1.0918	0.0015	1.0343	0.1820
Unemployment rate	0.2030	0.8622	0.0000	0.8314	0.0000	0.1888	0.8581	0.0000	0.8350	0.0000	0.1888	0.8360	0.0000	0.7981	0.0000
Inflation rate	0.0045	1.3884	0.0000	1.1974	0.0009	0.0046	1.2383	0.0003	1.1534	0.0073	0.0042	1.3753	0.0000	1.2256	0.0007
Interest rate	0.0071	1.3144	0.0000	1.2154	0.0000	0.0068	1.2200	0.0000	1.1686	0.0001	0.0064	1.3206	0.0000	1.2293	0.0000
Wage share	0.6213	0.9991	0.8667	1.0067	0.1535	0.6394	1.0017	0.7129	1.0110	0.0086	0.6480	1.0076	0.3314	1.0220	0.0059
Income Gini	0.3886	1.0092	0.3142	0.9824	0.0504	0.3705	0.9985	0.8684	0.9635	0.0001	0.3589	0.9889	0.4374	0.9437	0.0003
Market share exports	0.0025	0.9055	0.2375	0.6466	0.0000	0.0024	0.9194	0.3122	0.6807	0.0001	0.0027	0.9178	0.2784	0.6869	0.0001
Market share imports	0.2082	1.0503	0.3985	1.1969	0.0006	0.2204	1.0371	0.4764	1.1542	0.0016	0.1974	1.0648	0.3346	1.2120	0.0010
Domestic consumption share of output	0.7945	0.9882	0.1545	1.0355	0.0001	0.7977	0.9899	0.2138	1.0343	0.0001	0.7928	0.9904	0.2212	1.0352	0.0001
Exports share of output	0.1497	1.0676	0.1070	0.8241	0.0002	0.1473	1.0593	0.1609	0.8251	0.0002	0.1521	1.0548	0.1615	0.8286	0.0002
Imports share of output	0.2313	1.0499	0.4914	1.2757	0.0001	0.2464	1.0388	0.5455	1.2243	0.0004	0.2180	1.0694	0.3873	1.2905	0.0003
Shock on $\hat{p}_x$															
Parameter	0					0.1					0.2				
Shock	0	+0.025				0	+0.025				0	+0.025			
Period	Total	During		After		Total	During		After		Total	During		After	
Variable	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val
Output growth rate	0.0077	1.0693	0.0280	0.9912	0.7602	0.0076	1.1679	0.0000	1.0296	0.2949	0.0080	1.1763	0.0000	1.0112	0.6206
Unemployment rate	0.2030	0.8605	0.0000	0.8758	0.0000	0.1888	0.8659	0.0000	0.8691	0.0000	0.1888	0.8454	0.0000	0.8825	0.0003
Inflation rate	0.0045	2.7696	0.0000	1.3279	0.0000	0.0046	2.6360	0.0000	1.3672	0.0000	0.0042	2.6806	0.0000	1.4037	0.0000
Interest rate	0.0071	2.3963	0.0000	1.3211	0.0000	0.0068	2.3469	0.0000	1.3825	0.0000	0.0064	2.3690	0.0000	1.3934	0.0000
Wage share	0.6213	0.9661	0.0000	0.9723	0.0004	0.6394	0.9788	0.0068	0.9898	0.1953	0.6480	0.9804	0.0781	0.9906	0.4084
Income Gini	0.3886	1.0940	0.0000	1.0519	0.0001	0.3705	1.0712	0.0000	1.0201	0.1475	0.3589	1.0595	0.0018	1.0164	0.4329
Market share exports	0.0025	1.1986	0.0139	1.1406	0.0985	0.0024	1.2627	0.0010	1.2345	0.0062	0.0027	1.2237	0.0020	1.2548	0.0009
Market share imports	0.2082	0.8392	0.0117	0.8710	0.0475	0.2204	0.8229	0.0016	0.8319	0.0040	0.1974	0.8078	0.0048	0.7613	0.0008
Domestic consumption share of output	0.7945	0.9534	0.0000	0.9740	0.0015	0.7977	0.9524	0.0000	0.9713	0.0003	0.7928	0.9599	0.0000	0.9757	0.0008
Exports share of output	0.1497	1.2503	0.0000	1.1415	0.0007	0.1473	1.2571	0.0000	1.1584	0.0001	0.1521	1.2090	0.0000	1.1287	0.0004
Imports share of output	0.2313	0.7883	0.0040	0.8511	0.0517	0.2464	0.7670	0.0003	0.8042	0.0044	0.2180	0.7497	0.0012	0.7241	0.0007

Note: Averages across 100 Monte Carlo runs for each scenario. Ratios with respect to scenario with no shock.
Source: author's own elaboration based on simulation results.

Table 2.9: Summary statistics for shocks on g_x and $\hat{p}_x$ for different values of parameter ν_5

Shock on g_x															
Parameter	0					0.2					0.4				
Shock	0	+0.004				0	+0.004				0	+0.004			
Period	Total	During		After		Total	During		After		Total	During		After	
Variable	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val
Output growth rate	0.0078	1.0583	0.0700	1.0073	0.7701	0.0076	1.1260	0.0004	1.0383	0.1934	0.0075	1.0987	0.0081	1.0335	0.2731
Unemployment rate	0.1977	0.8538	0.0000	0.8117	0.0000	0.1888	0.8581	0.0000	0.8350	0.0000	0.1933	0.8489	0.0000	0.8342	0.0000
Inflation rate	0.0045	1.3596	0.0000	1.2192	0.0002	0.0046	1.2383	0.0003	1.1534	0.0073	0.0045	1.3302	0.0000	1.2089	0.0007
Interest rate	0.0067	1.2940	0.0000	1.2476	0.0000	0.0068	1.2200	0.0000	1.1686	0.0001	0.0068	1.2805	0.0000	1.2197	0.0000
Wage share	0.6350	1.0026	0.6989	1.0130	0.0424	0.6394	1.0017	0.7129	1.0110	0.0086	0.6340	1.0037	0.5370	1.0165	0.0017
Income Gini	0.3751	0.9983	0.8815	0.9699	0.0110	0.3705	0.9985	0.8684	0.9635	0.0001	0.3760	0.9958	0.6861	0.9626	0.0002
Market share exports	0.0028	0.9245	0.3091	0.6737	0.0000	0.0024	0.9194	0.3122	0.6807	0.0001	0.0025	0.9178	0.3363	0.6853	0.0003
Market share imports	0.1957	1.0584	0.3654	1.2245	0.0004	0.2204	1.0371	0.4764	1.1542	0.0016	0.2123	1.0472	0.4178	1.1585	0.0046
Domestic consumption share of output	0.7875	0.9884	0.1561	1.0350	0.0002	0.7977	0.9899	0.2138	1.0343	0.0001	0.8002	0.9897	0.2069	1.0309	0.0007
Exports share of output	0.1569	1.0634	0.1056	0.8365	0.0003	0.1473	1.0593	0.1609	0.8251	0.0002	0.1447	1.0625	0.1472	0.8391	0.0009
Imports share of output	0.2132	1.0606	0.4422	1.3171	0.0001	0.2464	1.0388	0.5455	1.2243	0.0004	0.2379	1.0478	0.4966	1.2246	0.0014
Shock on $\hat{p}_x$															
Parameter	0					0.2					0.4				
Shock	0	+0.025				0	+0.025				0	+0.025			
Period	Total	During		After		Total	During		After		Total	During		After	
Variable	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val
Output growth rate	0.0078	1.1116	0.0004	1.0175	0.5204	0.0076	1.1679	0.0000	1.0296	0.2949	0.0075	1.1542	0.0000	1.0606	0.0545
Unemployment rate	0.1977	0.8440	0.0000	0.8612	0.0000	0.1888	0.8659	0.0000	0.8691	0.0000	0.1933	0.8461	0.0000	0.8680	0.0000
Inflation rate	0.0045	2.7699	0.0000	1.3534	0.0000	0.0046	2.6360	0.0000	1.3672	0.0000	0.0045	2.6041	0.0000	1.3349	0.0000
Interest rate	0.0067	2.4905	0.0000	1.3818	0.0000	0.0068	2.3469	0.0000	1.3825	0.0000	0.0068	2.3190	0.0000	1.3431	0.0000
Wage share	0.6350	0.9742	0.0095	0.9840	0.0906	0.6394	0.9788	0.0068	0.9898	0.1953	0.6340	0.9753	0.0080	0.9857	0.1184
Income Gini	0.3751	1.0779	0.0000	1.0309	0.0577	0.3705	1.0712	0.0000	1.0201	0.1475	0.3760	1.0745	0.0000	1.0219	0.1676
Market share exports	0.0028	1.2064	0.0045	1.1776	0.0239	0.0024	1.2627	0.0010	1.2345	0.0062	0.0025	1.2194	0.0098	1.2109	0.0207
Market share imports	0.1957	0.8259	0.0097	0.8319	0.0163	0.2204	0.8229	0.0016	0.8319	0.0040	0.2123	0.8422	0.0106	0.8415	0.0149
Domestic consumption share of output	0.7875	0.9566	0.0000	0.9784	0.0090	0.7977	0.9524	0.0000	0.9713	0.0003	0.8002	0.9567	0.0000	0.9771	0.0041
Exports share of output	0.1569	1.2203	0.0000	1.1127	0.0049	0.1473	1.2571	0.0000	1.1584	0.0001	0.1447	1.2411	0.0000	1.1297	0.0022
Imports share of output	0.2132	0.7733	0.0037	0.8165	0.0272	0.2464	0.7670	0.0003	0.8042	0.0044	0.2379	0.7909	0.0033	0.8227	0.0192

Note: Averages across 100 Monte Carlo runs for each scenario. Ratios with respect to scenario with no shock.

Source: author's own elaboration based on simulation results.

Also in the case of the output growth rate the main properties observed in section 2.5 are observed in the scenarios with the different parameter values, so both types of shocks lead to a higher output growth rate during the shock, since they stimulate output growth. Yet, since in most cases this effect is not sustained in the period after the shock, in general both shocks have solely a level effect on output.[34] While the ν_3 and ν_5 parameters present a non-linear relation with the magnitude of the effect of g_x on the output growth rate during the shock, ν_3 tends to increase the magnitude of the effect on $\hat{p}_x$ and ν_5 also presents a non-linear effect. Also the parameters ι_3 and ι_5 present a non-linear relation with the magnitude of the effect of the shocks on $\hat{p}_x$ on the output growth rate during the shock, and the same is observed for the ι_5 parameter's effect on the magnitude of the effect of the shocks on g_x on the output growth rate. Additionally, increases in the ι_5 parameter tend to increase the output growth rate during the period of the shock on g_x, and when $\iota_5 = 1$ a higher output growth rate is obtained even after the shock is over, indicating that domestic demand is able to induce a higher output growth rate when exports growth decreases. This highlights the interplay between domestic consumption, which is stimulated by income redistribution, and the international competitiveness identified in section 2.5.

[34] In case of a level effect, the output growth rate is only temporarily (i.e., during the shock, when the foreign stimulus is active) different from that observed for the scenario with no shock and is not statistically different from it after the shock.

Table 2.10: Summary statistics for shocks on g_x and $\hat{p}_x$ for different values of parameter ι_3

Shock on g_x															
Parameter	0.6					0.8					1				
Shock	0	+0.004				0	+0.004				0	+0.004			
Period	Total	During		After		Total	During		After		Total	During		After	
Variable	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val
Output growth rate	0.0079	1.1105	0.0007	1.0204	0.4685	0.0076	1.1260	0.0004	1.0383	0.1934	0.0076	1.1341	0.0004	1.0723	0.0205
Unemployment rate	0.1802	0.8282	0.0000	0.8256	0.0000	0.1888	0.8581	0.0000	0.8350	0.0000	0.1945	0.8764	0.0000	0.8699	0.0000
Inflation rate	0.0051	1.3341	0.0000	1.1614	0.0062	0.0046	1.2383	0.0003	1.1534	0.0073	0.0043	1.2354	0.0004	1.0746	0.1479
Interest rate	0.0077	1.3118	0.0000	1.1652	0.0002	0.0068	1.2200	0.0000	1.1686	0.0001	0.0063	1.2351	0.0000	1.1419	0.0002
Wage share	0.6384	1.0051	0.2859	1.0125	0.0074	0.6394	1.0017	0.7129	1.0110	0.0086	0.6393	1.0035	0.4584	1.0104	0.0249
Income Gini	0.3695	0.9973	0.7808	0.9621	0.0002	0.3705	0.9985	0.8684	0.9635	0.0001	0.3702	0.9949	0.5834	0.9671	0.0005
Market share exports	0.0023	0.9196	0.3340	0.6666	0.0001	0.0024	0.9194	0.3122	0.6807	0.0001	0.0023	0.9093	0.2811	0.6753	0.0001
Market share imports	0.2213	1.0545	0.3352	1.1594	0.0028	0.2204	1.0371	0.4764	1.1542	0.0016	0.2203	1.0479	0.3379	1.1539	0.0012
Domestic consumption share of output	0.8056	0.9893	0.2355	1.0352	0.0002	0.7977	0.9899	0.2138	1.0343	0.0001	0.7947	0.9916	0.2403	1.0369	0.0000
Exports share of output	0.1397	1.0677	0.1751	0.8084	0.0003	0.1473	1.0593	0.1609	0.8251	0.0002	0.1500	1.0470	0.1939	0.8128	0.0000
Imports share of output	0.2535	1.0543	0.4297	1.2189	0.0010	0.2464	1.0388	0.5455	1.2243	0.0004	0.2439	1.0525	0.3865	1.2278	0.0002
Shock on $\hat{p}_x$															
Parameter	0.6					0.8					1				
Shock	0	+0.025				0	+0.025				0	+0.025			
Period	Total	During		After		Total	During		After		Total	During		After	
Variable	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val
Output growth rate	0.0079	1.0915	0.0035	1.0249	0.3030	0.0076	1.1679	0.0000	1.0296	0.2949	0.0076	1.1200	0.0001	0.9959	0.8816
Unemployment rate	0.1802	0.8670	0.0002	0.9259	0.0378	0.1888	0.8659	0.0000	0.8691	0.0000	0.1945	0.8154	0.0000	0.8543	0.0000
Inflation rate	0.0051	2.2808	0.0000	1.2733	0.0000	0.0046	2.6360	0.0000	1.3672	0.0000	0.0043	3.0505	0.0000	1.4793	0.0000
Interest rate	0.0077	2.0314	0.0000	1.2703	0.0000	0.0068	2.3469	0.0000	1.3825	0.0000	0.0063	2.7196	0.0000	1.4631	0.0000
Wage share	0.6384	0.9829	0.0248	0.9876	0.1078	0.6394	0.9788	0.0068	0.9898	0.1953	0.6393	0.9833	0.0281	0.9951	0.5084
Income Gini	0.3695	1.0581	0.0000	1.0212	0.1476	0.3705	1.0712	0.0000	1.0201	0.1475	0.3702	1.0727	0.0000	1.0131	0.3321
Market share exports	0.0023	1.2123	0.0101	1.2344	0.0083	0.0024	1.2627	0.0010	1.2345	0.0062	0.0023	1.2770	0.0011	1.2152	0.0193
Market share imports	0.2213	0.8812	0.0531	0.8264	0.0058	0.2204	0.8229	0.0016	0.8319	0.0040	0.2203	0.8395	0.0025	0.8591	0.0122
Domestic consumption share of output	0.8056	0.9603	0.0000	0.9758	0.0057	0.7977	0.9524	0.0000	0.9713	0.0003	0.7947	0.9443	0.0000	0.9748	0.0006
Exports share of output	0.1397	1.2299	0.0000	1.1398	0.0038	0.1473	1.2571	0.0000	1.1584	0.0001	0.1500	1.2969	0.0000	1.1378	0.0002
Imports share of output	0.2535	0.8398	0.0234	0.8014	0.0071	0.2464	0.7670	0.0003	0.8042	0.0044	0.2439	0.7720	0.0002	0.8360	0.0130

Note: Averages across 100 Monte Carlo runs for each scenario. Ratios with respect to scenario with no shock.

Source: author's own elaboration based on simulation results.

Table 2.11: Summary statistics for shocks on g_x and $\hat{p}_x$ for different values of parameter ι_5

Shock on g_x															
Parameter	0.6					0.8					1				
Shock	0	+0.004				0	+0.004				0	+0.004			
Period	Total	During		After		Total	During		After		Total	During		After	
Variable	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val
Output growth rate	0.0078	1.0847	0.0044	1.0312	0.2586	0.0077	1.1125	0.0017	1.0259	0.3818	0.0079	1.0607	0.0675	1.0148	0.6184
Unemployment rate	0.1982	0.8555	3e-04	0.8117	0	0.1856	0.8728	0	0.8494	0	0.1882	0.8777	0	0.8569	0
Inflation rate	0.0045	1.2553	1e-04	1.1101	0.0939	0.0046	1.238	3e-04	1.1531	0.0087	0.0045	1.3389	0	1.1499	0.0075
Interest rate	0.0068	1.1977	1e-04	1.1251	0.0077	0.0069	1.2072	0	1.1563	2e-04	0.0069	1.2599	0	1.1619	0
Wage share	0.6207	1.0046	0.7166	1.023	0.0498	0.6392	1.002	0.6829	1.0112	0.0108	0.644	1.0015	0.4994	1.0096	0
Income Gini	0.3893	0.9956	0.8406	0.9552	0.0327	0.3701	0.9996	0.9669	0.9646	2e-04	0.3647	1.0026	0.6179	0.9744	0
Market share exports	0.0024	0.9468	0.5425	0.7034	0.001	0.0023	0.9423	0.4909	0.6978	4e-04	0.0026	0.946	0.4456	0.6815	0
Market share imports	0.2091	1.027	0.6515	1.1632	0.0047	0.2234	1.0233	0.6561	1.1389	0.0048	0.2115	1.0431	0.4263	1.2035	1e-04
Domestic consumption share of output	0.7908	0.9825	0.1507	1.0313	0.0142	0.8017	0.9849	0.0723	1.0291	0.0015	0.7958	0.9823	0.0124	1.0268	8e-04
Exports share of output	0.1533	1.095	0.1133	0.8515	0.0187	0.1435	1.0875	0.0521	0.8471	0.002	0.1491	1.0981	0.007	0.8666	0.0012
Imports share of output	0.2346	1.0168	0.8193	1.2253	0.0021	0.2522	1.0147	0.8185	1.1959	0.0018	0.2337	1.03	0.6558	1.2683	0
Shock on $\hat{p}_x$															
Parameter	0.6					0.8					1				
Shock	0	+0.025				0	+0.025				0	+0.025			
Period	Total	During		After		Total	During		After		Total	During		After	
Variable	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val	Avg.	Ratio	p-val	Ratio	p-val
Output growth rate	0.0077	1.1290	0.0000	1.0140	0.5706	0.0076	1.1679	0.0000	1.0296	0.2949	0.0079	1.1261	0.0004	1.0118	0.6325
Unemployment rate	0.2013	0.9222	0.0670	0.9280	0.0990	0.1888	0.8659	0.0000	0.8691	0.0000	0.1910	0.8114	0.0000	0.8488	0.0000
Inflation rate	0.0046	2.5549	0.0000	1.2740	0.0000	0.0046	2.6360	0.0000	1.3672	0.0000	0.0045	2.8044	0.0000	1.3809	0.0000
Interest rate	0.0069	2.2747	0.0000	1.2743	0.0000	0.0068	2.3469	0.0000	1.3825	0.0000	0.0068	2.5080	0.0000	1.3953	0.0000
Wage share	0.6223	0.9572	0.0134	0.9598	0.0212	0.6394	0.9788	0.0068	0.9898	0.1953	0.6437	0.9864	0.0009	1.0016	0.6865
Income Gini	0.3886	1.0948	0.0006	1.0668	0.0224	0.3705	1.0712	0.0000	1.0201	0.1475	0.3654	1.0645	0.0000	0.9991	0.9049
Market share exports	0.0025	1.2288	0.0059	1.2431	0.0052	0.0024	1.2627	0.0010	1.2345	0.0062	0.0026	1.2340	0.0006	1.2044	0.0050
Market share imports	0.2070	0.8429	0.0097	0.8256	0.0056	0.2204	0.8229	0.0016	0.8319	0.0040	0.2090	0.7949	0.0005	0.8259	0.0036
Domestic consumption share of output	0.7878	0.9507	0.0000	0.9586	0.0003	0.7977	0.9524	0.0000	0.9713	0.0003	0.7923	0.9556	0.0000	0.9792	0.0013
Exports share of output	0.1562	1.2453	0.0000	1.2084	0.0002	0.1473	1.2571	0.0000	1.1584	0.0001	0.1524	1.2338	0.0000	1.1130	0.0005
Imports share of output	0.2298	0.7865	0.0028	0.7887	0.0050	0.2464	0.7670	0.0003	0.8042	0.0044	0.2287	0.7396	0.0001	0.7949	0.0039

Note: Averages across 100 Monte Carlo runs for each scenario. Ratios with respect to scenario with no shock.

Source: author's own elaboration based on simulation results.

2.7 Conclusions

This chapter compared the effects of two shocks that frequently affect open economies. In general, external shocks on open economies are analyzed through their effects on the output dynamics of the domestic economy or, as in the more recent literature, on income distribution. By dealing simultaneously with these two dimensions and relating them to the inflation dynamics, we also explore how income distribution can be one of the many mechanisms through which external shocks affect the macroeconomic dynamics of open economies.

Our results indicate that both demand and price shocks have a positive effect on the domestic output level and growth rates since they stimulate exports. They are also associated with higher inflation rates, but while in both cases the lower unemployment rate is a factor inducing higher inflation rates (as it strengthens the distributive conflict), in the second case there is also an important imported inflation component. In this sense, the model is able to capture two important factors driving inflation rates in open economies.

The distributive implications of these shocks differ considerably. In the case of a shock on g_x, the increase in economic activity and the nominal and real currency appreciations tend to favor the lower classes and more equality in the functional and personal income distribution is achieved. This contributes to a shift in demand towards domestic demand as lower

classes present a higher propensity to consume, which contributes to sustaining the output levels even when the period of higher g_x ends. A shock on the foreign inflation rate, by having a direct effect on the real exchange rate, stimulates domestic output through the gain in international competitiveness for domestic firms. While this leads to lower unemployment rates and a nominal exchange rate appreciation, the interplay between these factors tends to benefit firms and high-income classes relatively more. Consequently, in this case the functional and personal income distribution are more unequal. Thus, when the shock in $\hat{p}_x$ is over, these economies do not have this positive stimulus from domestic consumption.

In sum, our results contribute to the understanding of the diversity of results from the empirical literature concerned with the effects of international trade on income distribution. The comparison between the experiments indicates that the type of external shock that leads to increases in exports and/or decreases in imports matters for how income distribution will be affected. Also the structure of the economy (captured through the different parameters discussed in section 2.6) influences the magnitude and length of the changes in distribution and output growth. Indeed, the short- and long-run relation between income distribution and output growth is markedly different depending on the type of foreign shock and the underlying structure of the economy. Moreover, the results indicate that also the relation between the real exchange rate and the output dynamics depends on the source of shock driving the changes in the former, with income distribution being an important factor explaining their relationship.

Chapter 3

Labor market regulations and redistributive policies for inclusive growth

3.1 Introduction

The economic policy debate often contrasts different conceptual economic structures with respect to their implications for key economic variables. While for a long time there was a focus solely on the output dynamics, more recently there is a growing concern with the harmful effects of income inequality. This has been especially the case since the 2007/8 economic crisis, which exposed the negative consequences of income inequality and fostered the economic debate on the topic (Berg et al., 2018, Ostry et al., 2019, IMF, 2014).

Yet, even if there is a growing concern with income inequality and even an emerging consensus acknowledging that inequality can be harmful for economic growth (Berg et al., 2018), there is much less consensus with respect to what type of economic policies and institutions should be used to alter the income distribution and even less consensus with respect to what extent income inequality should be reduced. Arguably, there are numerous ways by which the government can affect the income distribution, be it through redistributive policies (transfers and taxes) that affect the net income distribution or regulations that affect the wage bargaining process directly and, thus, the gross income distribution. Yet, since these policies and regulations are interpreted as sources of rigidities, inefficiencies, or misallocations, many authors believe that they may prevent the economy from reaching an optimum market equilibrium. This view has largely derived from contributions that argued in favor of labor market flexibility, such as the OECD's (1994) Job Study Report.

Proponents of labor market flexibility argue that any rigidity caused by regulations or institutions prevents adjustments in the labor market that would reduce unemployment rates. As argued by Berg (2015), this interpretation is based on the understanding that unemployment is a problem that arises (and can be potentially solved) in the labor market. Yet, from a Keynesian perspective, the level of employment is not determined in the labor market, but rather by the level of aggregate demand.[1] This opens the possibility that policies that help to sustain aggregate

[1] More precisely, the demand for labor is not determined in the labor market and depends on aggregate demand. Yet, employment does depend on interactions that take place in the labor market after the demand for labor is set.

demand can be useful to sustaining employment, without the need of removing or reducing regulations in the labor market. Nevertheless, even from this perspective there is still little investigation with respect to the effectiveness of the different tools in redistributing income and to whether the type of policy matters for how changes in inequality affect growth.[2]

Inspired by this debate, this chapter compares different structures characterized by different degrees and types of policies and regulations on the distribution of income and analyzes what are the implications of such policies and regulations for the output and employment dynamics. The analysis is undertaken within the open economy AB model reported in chapter 2, so the effects on the domestic economy's international competitiveness are also captured. This is important due to the possibility of a higher wage share (when associated with increases in the price level) leading to a loss of international competitiveness, which can exert a negative impact on the trade balance and hence on aggregate demand and output (Blecker, 1989). Our analysis of the contribution of each tool reflects our understanding that these tools cannot be categorized individually as either good or bad, since their effects depend on their interaction with other tools and on the specific economic context.

The structure of the chapter is organized to capture the contribution of a set of policies and regulations in the transition from a pro-market state towards a pro-labor state and, consequently, compare different understandings with respect to whether and how the government should endeavor to shape the income distribution of a given economy. We start by discussing the transition from the pro-market scenario, wherein the government does not rely on any tools to influence the income distribution, towards the redistributive scenario, wherein redistributive policies (unemployment benefits and progressive taxation) are progressively added with the aim of reducing the inequality levels generated by the (unregulated) bargaining process between agents in the labor market. Yet, in the redistributive scenario the government still does not rely on labor market regulations to avoid efficiency losses. Then, we move from the redistributive scenario towards the pro-labor scenario, wherein in addition to the redistributive policies there are also more regulations protecting workers in the wage bargaining process (downward nominal wage rigidity, an active minimum wage policy, and higher workers' bargaining power independently from the employment level). Since our analysis deals with the effects of each type of labor market regulation and redistributive policy, the results also provide new insights into the interaction between the policies and their contribution to the main macroeconomic and distributive variables. Overall, our results show that an equitable society does not result automatically and spontaneously from market forces, but rather from adequate institutions and practices created by society (Berg, 2015). At the same time, since these policies tend to sustain

[2]It should be noted that there is a literature addressing the effect of redistribution on growth but, as emphasized by Berg et al. (2018), this literature focuses on measures such as taxes and government spending, without necessarily analyzing how redistribution affects growth indirectly through inequality. This strand of the literature is related to the effect of fiscal policy, and results indicate that higher tax or subsidy rates hamper growth (Barro, 1990, Jaimovich and Rebelo, 2012). Yet, the empirical findings in Berg et al. (2018) challenge this view, since they find that the indirect effect of redistributive policies (through reduced inequality) tend to support and sustain higher output per capita growth rates (except for very large-scale redistribution).

aggregate demand, they have a positive effect on the output dynamics and employment levels. Thus, the transition from the pro-market state towards the pro-labor state generates both equality and growth.

The complexity economics approach provided by the AB framework has the advantage of capturing the immediate and feedback effects of altering each labor market institution and redistributive policy. This provides more precise information about the effect of such policies on the output dynamics and means that the overall comparison between the scenarios is composed of two sets of effects: a) the direct effect of the policy on macroeconomic variables, and b) the effect of the policy on inequality, which then affects these macroeconomic variables once again. In addition, this framework allows us to identify and differentiate what is the relationship of the macroeconomic variables with income distribution measured through different variables, thus offering important insights into the role of the personal and functional income distribution. In this sense, our results also relate to the literature that stresses the importance of the personal income distribution to output dynamics (Carvalho and Rezai, 2016, Rolim, 2019). We are also able to provide an overall assessment with respect to the effectiveness of redistributive policies and labor market regulations in achieving more equality. Our results are thus in line with empirical works that measure the effectiveness of specific policy instruments to reduce income inequality (Causa and Hermansen, 2017).

The remaining of this chapter is organized as follows. Section 3.2 presents the related literature. Section 3.3 discusses the different views on the selected regulations and policies and shows how they have been implemented in the model structure outlined in chapter 2. Section 3.4 presents and discusses the results of the experiments. Concluding remarks are presented in section 3.5.

3.2 Related literature

AB models are an important tool for analyzing income distribution and for studying the effect of policy interventions. Therefore, we find in the literature important contributions that investigate the effect of specific policies and regulations on the dynamics of inequality and output.

For instance, Dosi et al. (2018) investigate the role of labor market reforms on output and inequality. They compare the Fordist regime with the Competitive regime, with the main difference between them being that in the latter labor market conditions and individual employment history are crucial to the wage dynamics. Thus, wages become more sensitive to the unemployment rate and to the labor demand by firms. The results indicate that more flexibility is associated with more unemployment, lower output growth rates, and more inequality in the functional and personal income distribution.

Palagi et al. (2017) analyze the relation between fiscal policies and income distribution. The model is subject to exogenous inequality shocks of different intensities that alter

the share of income accruing to the bottom of the population. The resulting increased inequality levels are associated with a decrease in aggregate income since households become financially constrained and cannot maintain the desired consumption level (which is a fixed level in the model configuration). In addition, the authors explore the effect of these shock in different policy scenarios, since government spending acts as a parachute against the reduction in household incomes. The results show that the type of fiscal policy matters for its effectiveness, with more targeted fiscal policies (such as subsidies to low-income households) being associated with a higher fiscal multipliers.

Similarly, Caiani et al. (2019b) analyze the effect of redistributive policies on income distribution and output performance. Their results show that the introduction of a progressive tax system stimulates output and productivity growth, while also leading to a reduction in the income inequality. The authors also use the adjustment of middle and low tier workers' desired wage as a proxy to the degree of labor market flexibility. They find that when downward wage adjustments are more likely, there is a reduction in real output and an increase in income and wealth inequality levels. Overall, their results suggest that despite a progressive tax system being effective in redistributing income, a labor market framework that protects workers provides a significant improvement to such result.

Finally, Seppecher (2012) deals with the macroeconomic and distributive implications of wage flexibility and the effect of the minimum wage. The author shows that more wage flexibility can create a deflationary spiral by which an initial decrease in nominal wages leads to a cycle of lower aggregate demand, lower prices, lower production, and higher unemployment rates, which trigger new nominal wage cuts. Since in this framework wages decrease faster than profits, there is also an increase in the profit share. In addition, the results indicate that in the existence of a minimum wage (introduced a few periods after the wage flexibility shock), such a deflationary spiral can be stopped and demand and unemployment recover, while the functional income distribution returns to that of the baseline scenario. Therefore, the main takeaway from the set of experiments presented in the paper is the role of nominal wage downward rigidity and the minimum wage in sustaining aggregate demand levels and contributing to the macroeconomic stability.

Relative to these previous works, this chapter's contribution to the literature is threefold. Firstly, we expand the range of institutional frameworks and policies that lead to endogenous changes in the income distribution and discuss how they interact with each other. Secondly, our analysis is undertaken in an open economy structure in which the wage dynamics, determined by the wage bargaining process put forward in chapter 1, also has implications for the domestic economy's international competitiveness. In this sense, an additional (and very relevant) channel through which changes in the income distribution affect output is considered. Thirdly, in addition to exploring the effect of each policy in the long run, we also investigate whether they alter the cyclical (short-run) relation between distribution and economic activity.

3.3 Labor market regulations and redistributive policies

In order to explore different frameworks of protection to workers and interference in the wage bargaining process, we select two types of redistributive policies (unemployment benefits and progressive taxation) and three types of pro-labor regulations (downward nominal wage rigidity, an active minimum wage policy, and high sensitivity of workers' bargaining power to the employment rate). In what follows, these regulations and policies and their inclusion in the model outlined in chapter 2 are discussed in detail.

3.3.1 Taxation policy

According to the IMF (2014), redistribution is one of the three main objectives of fiscal policy and it is explicitly preferred to wage and employment regulations for presumably compromising less efficiency. It can take the form of provision of public goods, social transfers or progressive taxation (ILO, 2008). The importance of these tools to redistribute income has led many analysts to argue that the decrease in the size of social benefits and in the degree of progressivity of taxation in many economies has caused a reduction in the redistributive impact of fiscal policy (Gerber et al., 2020, IMF, 2014, OCDE, 2011, Sabirianova Peter et al., 2010).

A progressive tax system can be a complementary tool for redistributing income, especially by affecting incomes at the upper end of the distribution, while transfers can be more efficient to affect the bottom of the distribution (Gerber et al., 2020). This system is characterized by an increasing average tax rate as income rises. In its simplest form, it requires defining the number of income groups, the difference in the tax rate between the groups, and the income thresholds dividing the groups. Yet, more complex progressive tax systems can also be based on the type of income (e.g., profit dividends and wages).[3] The relevance of any tax system to the income distribution largely depends on the pretax distribution, since if income is already evenly distributed, the measured progressivity of the system will be much lower than what would be observed if the same system was applied to a more unequal pretax income distribution.[4]

Progressive taxation can contribute to reducing inequality by having a direct effect on disposable incomes (IMF, 2014). While this leads to a reduction in the net income inequality, there is also evidence that progressive taxation affects gross income inequality and leads to a

[3] Since capital incomes are often taxed at lower rates than labor income (Gerber et al., 2020), tax systems based on the type of income may be regressive.

[4] This relates to the so-called median-voter hypothesis, according to which if inequality is higher the median-voter will be relatively poorer and thus more supportive of redistributive policies (Meltzer and Richard, 1981). Although there is evidence that more unequal countries redistribute more to the poor, this does not necessarily mean that the middle class is a net beneficiary of redistributive polices, which puts this hypothesis into question (Milanovic, 2000). Indeed, the differences in pretax distribution may offer an explanation for the relation between inequality levels and redistributive policies. To disentangle empirically the effect of pretax distribution from the progressivity of the tax system, Gerber et al. (2020) suggest a new measure of the progressive capacity of the tax system. In line with previous works (Sabirianova Peter et al., 2010), this new measure captures a decrease in income tax progressivity in the 1980s and 1990s.

reduction in the gross income Gini coefficient (Gerber et al., 2020). A key concern in conventional analyses is that progressive taxation may cause a distortion in the economic system and thus affect negatively economic growth, but there is no evidence that reducing the progressivity of the tax system induces higher growth rates (Gerber et al., 2020). The findings by Berg et al. (2018) go in the same direction by showing that redistributive policies (taxation and transfers) can be benign for growth.

In the model, we introduce two types of systems for income taxation.[5] In the flat tax system, all households pay the same tax rate τ and the unemployment benefit is tax-exempted.[6] In the progressive tax system, there are three tax groups that are divided according to the their average income levels: incomes up to one minimum wage and the unemployment dole are tax-exempt, while incomes above the minimum wage are divided into two tax systems. The amount of income above the minimum wage and up to $n^{mw} > 1$ multiples of the minimum wage is taxed at the low tax rate (τ_t^{low}) and the amount above n^{mw} multiples of the minimum wage is taxed at the high tax rate (τ_t^{high}). In order to isolate the effect of different compositions in the tax revenue, which is the aim of progressive taxation, from the effect of different levels of the tax rate, we assume that the tax rates in the progressive tax system are set so that the average tax rate out of wages and profits is equal to τ.[7] Accordingly, given the desired difference in the tax rates (τ^{dif}) and the income threshold separating the low- and high-tax rate groups, we have the following tax rates for each group respectively:

$$\tau_t^{low} = \frac{\tau - \tau^{dif}(Y_{H,t-1}^{high,\$}/Y_{H,t-1}^{\$})}{(Y_{H,t-1}^{low,\$} + Y_{H,t-1}^{high,\$})/Y_{H,t-1}^{\$}} \tag{3.1}$$

$$\tau_t^{high} = \tau_t^{low} + \tau^{dif} \tag{3.2}$$

where $Y_{H,t-1}^{low,\$}$ and $Y_{H,t-1}^{high,\$}$ are the aggregate profit and labor incomes taxed at the low tax rate and at the high tax rate respectively and $Y_{H,t-1}^{\$}$ is the total profit and labor incomes (all referring to the previous period). Note that $Y_{H,t-1}^{\$} - Y_{H,t-1}^{low,\$} - Y_{H,t-1}^{high,\$}$ is the amount of profit and labor incomes that is tax-exempted.

3.3.2 Transfers

Transfers are another type of fiscal policy tool used to redistribute income. Since they have a direct influence on low-income households, they tend to contribute more to reducing inequality than taxes (ILO, 2008, IMF, 2014, Mahler and Jesuit, 2006). Indeed, while transfers (in particular conditional cash transfers) were a key factor reducing inequality in Latin America in

[5] Admittedly, tax revenues are based on many sources that can also affect the progressivity of taxation. For example, consumption taxes are known to be regressive (Sabirianova Peter et al., 2010). Nevertheless, for simplicity, in this chapter we focus on income taxation as a specific type of progressive taxation.

[6] This tax system considers only wages and profits, since interest payments are taxed at a constant tax rate (τ^i) in all scenarios.

[7] A similar strategy is adopted in Caiani et al. (2019b).

the recent years (Berg, 2015), in OCDE countries cuts in transfers are considered the predominant explanation for the reduction of the redistributive effect of fiscal policy (OCDE, 2011).

In our AB model, this policy tool is represented by the unemployment benefit, which is a cash transfer from the government to unemployed workers. In the conventional view, unemployment benefits are perceived as a helpful policy for providing workers' with an income when facing temporary unemployment, but also as a disincentive for workers to accept new job offers, which would increase the time length they spend out of work (Abbring et al., 2005, Meyer, 2002). As such, it is argued that its duration should not be too long in order to avoid a negative effect on labor supply (IMF, 2014).

Since unemployment benefits offer an income maintenance to unemployed workers, the literature finds that they help to smooth their consumption (Meyer, 2002). In macroeconomic terms, by sustaining consumption levels, unemployment benefits may also be helpful to sustain higher output levels. In addition, this type of transfer tends to reduce income inequality, since the benefits are usually lower than wages.[8]

In order to test what is the effect of unemployment benefits in our economy, we experiment with different rules for the number of periods a worker is entitled to earn an unemployment benefit when unemployed. The scenarios are as follows: four periods, two periods, one period, and the absence of unemployment benefits (zero periods). While we have framed the experiments with progressive taxation to guarantee that the same average tax rate is obtained in all cases, unemployment benefits inevitably represent an increase in government expenditure. Thus, in this case, we are also testing the effect of expansionary fiscal policies and the results are not directly comparable with the progressive tax rate system.

3.3.3 Minimum wage

Minimum wages represent a legal restriction to the wage level in the market. Their effect on inequality is thus largely determined by their bindingness (Engbom and Moser, 2021), especially when formalization rates are high. This means that increases in minimum wages have a direct effect on wages that would have been lower in the absence of this threshold and, consequently, entail changes in the income distribution through the effect on low-wage workers (bottom of the income distribution). In addition to this direct effect, the literature has identified other mechanisms by which the minimum wage affects the wage structure. Minimum wages can be a reference to wages in the entire wage distribution, such as the case of wages that are equal to a certain times the minimum wage and, thus, tend to increase proportionally to the minimum wage (Neri et al., 2001). Nevertheless, even in the informal labor market, where the minimum wage is not a legal restriction, it can act as a reference value in wage negotiations and thus have

[8] Meyer (2002) finds evidence supporting the redistributive effect of unemployment benefits, while Jaumotte et al. (2013) do not find a statistically significant effect of the generosity of unemployment benefits on inequality. It should be noted that albeit having implications for inequality, the primary aim of this policy is not a redistributive one, but rather to attenuate fluctuations in workers' incomes.

strong implications for the overall income inequality. In the literature, this has been defined as the "lighthouse" effect of minimum wages (Baltar and Souza, 1979).[9]

Overall, the "lighthouse" effect of minimum wages on the informal labor market and on wages above the legal minimum is considered a spillover effect of the minimum wage on the entire income distribution. Naturally, the effect of minimum wages on distribution depends on the labor market conditions. If wage negotiations result in wages growing faster than the minimum wage, it will not be a binding constraint. If that is not the case, on the other hand, minimum wages will be more important to shaping of the income distribution. Thus, the effectiveness of the minimum wage also depends on how it is determined and on how it interacts with other labor market regulations and policies that influence the wage negotiation process. Also, government transfers that are associated to the minimum wage (for instance, unemployment benefits) will be affected by the dynamics of the latter and, consequently, can be a mechanism through which it affects the income distribution.

Since the overall effect of the minimum wage on the income structure will depend on its bindingness and on these spillover effects, the literature finds a diversity in the magnitude of the effect of the minimum wage across countries.[10] Yet, despite of the different magnitudes, it tends to find that minimum wages reduce inequality (Autor et al., 2016, Lee, 1999a), without significant changes in employment levels (Card and Krueger, 1995, Dube, 2019, Engbom and Moser, 2021, Rutkowski, 2003).

In our experiments, we test two different types of rules for the revision of the value of the minimum wage. In the active rule, the minimum wage is set so that the real minimum wage grows at the same rate as the average productivity growth. Therefore, the nominal minimum wage is corrected by the inflation rate and the average productivity growth rate from the previous period. In the passive rule, the minimum wage grows at the same rate as the average nominal wage growth in the economy.[11] Thus, while in the active rule there is an autonomous source of increase in the minimum wage, meaning that it may lead the wage negotiation process, the passive rule keeps a constant ratio between the minimum and average wages so that the minimum wage is a less efficient instrument to induce changes in wage distribution and lags the dynamics determined by the wage negotiations.[12] Nevertheless, even in the active rule the minimum wage may be lagging the nominal wage if workers' bargaining power is strong enough to secure real wage growth above productivity growth.

[9] Depending on the structure of the economy and the institutional framework, minimum wages can be more effective in the informal labor market than in the formal labor market (Neri et al., 2001).

[10] For instance, spillover effects are relatively stronger in Brazil (up to the 90th percentile) than in the U.S. (up to the 20th percentile) (Autor et al., 2016, Engbom and Moser, 2021).

[11] In both cases, the minimum wage cannot be adjusted downward when there is also downward nominal wage rigidity.

[12] This has been the case in France, for instance, wherein the causality ran from general wage settings to the minimum wage (Freeman, 1996).

3.3.4 Workers' bargaining power

In addition to the low minimum wage adjustments, Jaumotte and Buitron (2015) argue that the most important labor market institution for the recent inequality dynamics has been the decrease in union density.[13] The literature stresses three main effects of unions on wage inequality (Card et al., 2004, Freeman, 1980, Freeman and Medoff, 1979). Firstly, by negotiating a standard wage rate across and within firms, they tend to reduce the wage dispersion within the unionized sector. Secondly, by negotiating a higher wage level for organized workers, they tend to increase the wage difference between unionized and nonunionized workers. Finally, because union members usually are "blue-collar" workers, who earn less than "white-collar" workers, unions tend to reduce the wage gap between the former and the latter. From the first and third effect, one would expect unions to decrease wage inequality, while the second effect is expected to increase wage inequality. While the overall effect is theoretically ambiguous, the empirical evidence shows that the negative effects of unions on wage inequality compensates the positive effect, so unions usually tend to reduce wage inequality (Card et al., 2004, Freeman, 1980).[14]

When it comes to the effect of unions on income inequality, additional aspects are taken into consideration (Herzer, 2016). Naturally, it depends on how unions affect wage dispersion and, as mentioned, they tend to reduce it. Yet, it also depends on whether unions have an impact on employment and thus affect the proportion of people receiving unemployment benefits (which tend to be lower than wages). This effect is considered ambiguous. The impact of unions on wages and employment also determines its effect on the wage share, which is another channel through which income distribution is affected. As capital income is more unequally distributed than wage income (Glyn, 2011), an increase in the wage share is expected to decrease income inequality. Finally, unions can influence redistributive policies in the political arena. Thus, unions can have ambiguous effects on income inequality and empirical studies tend to find mixed results. Herzer (2016), for instance, shows that for a sample of 20 countries from 1986 to 2010, union density was negatively associated with income inequality in the long run, but there is considerable heterogeneity across countries and this relation was positive for 40% of the cases.

In our model we proxy the degree of union density (or collective agreements) through the parameter capturing the sensitivity of workers' bargaining power to the employment rate.[15] This proxy connects the wage desired by workers to that set by firms and thus captures the idea that unions provide workers with a vehicle for collective voice (Freeman and Medoff, 1979). Formally, this is captured through the ϕ parameter in equation 3.3, which indicates how close the wage set by firms gets to the wage desired by workers:

[13] It should be noted that the findings by the ILO (2008, ch. 3) with respect to union density provide a different view: while union density and collective bargaining coverage explain differences in inequality across countries, they do not have a statistically significant effect in explaining changes within countries through time.

[14] In a study that investigates the effects for both men and women, Card et al. (2004) find that this effect is clearer for men than for women.

[15] In the AB models literature, also Dosi et al. (2018) use a proxy for labor unions. For a model that explicitly models labor unions, see Dosi et al. (2021).

$$w_{f,t}^{j,\$} = (1 - \phi\eta_t) w_{f,t}^{j,d,\$} + \phi\eta_t w_{f,t}^{j,s,\$} \tag{3.3}$$

where $1 > \phi > 0$ is a fixed parameter capturing the sensitivity of workers' bargaining power to the employment rate (η_t), $w_{f,t}^{j,d,\$}$ is the wage desired by firms, and $w_{f,t}^{j,s,\$}$ is the wage desired by workers (assessed through a random survey). In this framework, $\phi\eta_t$ is workers' bargaining power, which consists of a fixed component (ϕ) that can be interpreted as the structural strength of unions or workers in a given context and a variable (and cyclical) component that depends on the employment rate (η_t) and that captures the idea that individual and collective bargaining power weakens when unemployment increases (Berg, 2015, Blanchflower and Oswald, 1994). Overall, this framework can be considered a proxy to union density for capturing the outcome of union activity on the wage determination process, among other factors.[16]

3.3.5 Downward nominal wage rigidity

Downward nominal wage rigidity may occur because workers do not accept reductions in nominal wages or because institutional regulations restrict this practice. It is argued that cutting nominal wages reduces workers' morale, leads to resistance, and can lead to adverse selection problems, making it a rare practice by firms (Bewley, 2007, Fabiani et al., 2010). Similar concerns also affect how firms set wages for newly hired employees: these workers' wages tend to be as rigid as those of the firms' current employees because firms aim to follow internal pay structures due to fairness and efficiency considerations (Galuscak et al., 2012). On the institutional side, labor market regulations or collective agreements can be a source of downward nominal wage rigidity.

In more conventional economic approaches, downward nominal wage rigidity is considered to prevent efficient labor market adjustments during recessions. It is assumed that rigid nominal wages prevent workers from adjusting to recessions, especially if that occurs in a context of low inflation rates.[17] Consequently, workers do not look for jobs in other sectors for not facing a wage reduction and firms delay creating new job positions when the situation improves due to the high costs associated with doing so (Daly et al., 2012). In line with this theoretical framework, many authors associate recent unemployment experiences with the large presence of downward nominal wage rigidity (Daly et al., 2012, Schmitt-Grohé and Uribe, 2013).[18]

[16] For instance, this framework allows wages to follow more closely the inflation rate, which is one of the effects of stronger unions (Dickens et al., 2007).

[17] Low inflation rates with rigid nominal wages entail rigidity also in real wages, so workers do not experience a loss in their purchasing power.

[18] There is an ongoing debate with respect to the prevalence of downward nominal wage rigidity. Noting that most of the evidence on this phenomenon is based on the U.S. economy, Jardim et al. (2019) argue that the data used in these studies may overestimate this type of rigidity and find more evidence supporting nominal wage cuts using an alternative database for Washington state. On the other hand, for the European Union countries, which have stronger regulation, there is robust evidence that wage cuts are very rare (Fabiani et al., 2010).

Nominal wage flexibility can, nonetheless, introduce wage disparities since workers' exposure to business cycle fluctuations is very heterogeneous, with low-wage workers' employment rates fluctuating more than that of high-wage workers (Clark and Summers, 1980, Kydland, 1984). Thus, in recessions nominal wage flexibility may lead to more negative wage adjustment for groups that already have lower wage levels. Also, in case the reduction in costs following the reduction in wages is not entirely passed on to prices, it can lead to an increase in the share of profits, which could also have implications for inequality since profits are earned by high-income households. These distributive consequences may have implications for the output and employment dynamics, given that low-income households tend to consume more out of their income. In this case, and contrary to the conventional view, downward nominal wage rigidity can be a means to prevent a larger fall in aggregate demand during recessions.

In order to explore the implications of downward nominal wage rigidity for income distribution and output dynamics, we introduce in the model an institutional regulation that prohibits nominal wage cuts by firms, while also affecting how workers' desired wages are formed and the minimum wage rules.[19] This institutional framework is compared with the baseline scenario, in which nominal wage cuts are allowed to take place.

3.4 Experiments

This section evaluates and compares three stylized economic structures that reflect different understanding of what is the role of the state in shaping the income distribution. We start from the pro-market scenario, in which government intervention in the economy is close to neutral, and progressively move towards the redistributive scenario. This structure encompasses only redistributive policies (unemployment benefits and progressive taxation) aimed to attenuate inequalities generated by the wage setting process. In name of efficiency, however, the government refrains itself from interfering in how nominal wages are determined so to avoid creating (too many) distortions (IMF, 2014). We then move from the redistributive scenario towards the pro-labor scenario, wherein regulations and policies aiming to protect workers' in wage negotiations are active and strong, complementing the redistributive policies.

The archetypes of each scenario are presented in table 3.1. In section 3.4.1, we start with the pro-market scenario and progressively add the redistributive policies in the direction of the redistributive scenario, wherein the main influence of the government in the income distribution is through transfers and taxes. Then, in section 3.4.2 each type of labor market regulation is progressively strengthened towards the pro-labor scenario.[20]

[19] When it is institutionally prohibited to cut nominal wages, the nominal minimum wage cannot be reduced and workers do not consider negative inflation levels when adjusting their desired wages.

[20] Arguably, the ordering of the scenarios is relevant for the conclusions obtained in this chapter. In other words, adding first the labor market regulations could lead to different results, in particular with respect to the magnitude of the effects. Yet, the ordering chosen in this chapter reflects, to some extent, how the debate has been framed in the literature. For instance, while the IMF (2014) argues that redistributive policies should be preferred to

Table 3.1: Design of experiments: archetypes of each scenario

Scenario	Downward nominal wage rigidity	Minimum wage adjustment rule	Workers' bargaining power	Taxation policy	Unemployment benefit
Pro-market (Exp. 1)	No	Passive rule	Low	Flat	No
Redistributive (Exp. 8)	No	Passive rule	Low	Progressive	4 periods
Pro-labor (Exp. 15)	Yes	Active rule	High	Progressive	4 periods

Note: Source: author's own elaboration.

In what follows, all scenarios are simulated for 400 periods (200 transient periods and 200 considered periods).[21] The reported results refer to the average of the 100 Monte Carlo runs for each scenario. The model is robust in reproducing the key stylized facts that were presented in chapter 2.[22] The analysis of the results consists on discussing the effects of introducing each redistributive policy (in section 3.4.1) and each regulation (in section 3.4.2) in different contexts. Therefore, the analysis is based on a comparison of the scenarios in which the specific policy or regulation is active (or strong) with the scenarios in which it is absent (or weak). Nevertheless, the statistical tests refer solely to the comparison of each scenario with the baseline scenario for each section.

3.4.1 Towards the redistributive state

We start our analysis with the archetype of the pro-market scenario, wherein no labor market regulations or redistributive policies are in place. The role of the redistributive policies (taxes and transfers) is analyzed by progressively adding these policies in the direction of the archetypal redistributive scenario to attenuate the inequalities generated by the (unregulated) bargaining process between agents. More specifically, we investigate the effect of adding an unemployment benefits scheme, increasing the maximum number of periods of unemployment benefits that unemployed workers can receive, and comparing the progressive (PT) and the flat (FT) tax systems. All these experiments take place in an economic structure characterized by no downward nominal wage rigidity, a passive minimum adjustment rule, and low workers' bargaining power. The experiments are described below in table 3.2.

labor market regulations, it is rare to find support for a framework characterized by no redistributive policies at the same time as labor market regulations are strong. This reflects the view that labor market regulations lead to rigidities that should be avoided and that, if income distribution is a concern, redistributive policies should tackle this issue. Therefore, the ordering adopted herein allows us to investigate whether redistributive policies are enough to promote inclusive growth in the absence of strong labor market regulations.

[21] The parameters for the baseline scenario are reported in Appendix D.

[22] Given this similarity, these stylized facts are not discussed in this chapter.

Table 3.2: Design of experiments: redistributive policies

Scenario	Unemployment benefit periods	Taxation policy
Exp. 1	0 (UBP = 0)	$\tau_{dif} = 0$ (FT)
Exp. 2	1 (UBP = 1)	$\tau_{dif} = 0$ (FT)
Exp. 3	2 (UBP = 2)	$\tau_{dif} = 0$ (FT)
Exp. 4	4 (UBP = 4)	$\tau_{dif} = 0$ (FT)
Exp. 5	0 (UBP = 0)	$\tau_{dif} = 0.1$ (PT)
Exp. 6	1 (UBP = 1)	$\tau_{dif} = 0.1$ (PT)
Exp. 7	2 (UBP = 2)	$\tau_{dif} = 0.1$ (PT)
Exp. 8	4 (UBP = 4)	$\tau_{dif} = 0.1$ (PT)

Note: Experiment 1 is the baseline scenario in this section. When reporting the results below, the acronyms within parenthesis are used to identify the characteristics of each experiment. Source: author's own elaboration.

3.4.1.1 Income distribution and macroeconomic results

Figures 3.1 and 3.2 present the main results of the experiments. The baseline scenario (experiment 1) for this set of experiments is the archetype of the pro-market state, wherein the labor market regulations are weak and there are no redistributive policies. Indeed, in this scenario, the coverage of unemployment benefits is equal to zero, since this type of redistributive policy is not in place. Also, the tax rate for the different tax groups is the same, since a flat tax rate system is adopted. Although there is a considerable percentage of the population not paying any taxes, this share is similar to the unemployment rate, thus indicating that those not paying taxes are the unemployed workers, whose income is equal to zero.[23] This indicates that all households that are earning some sort of income are paying the same tax rate. Consequently, the Reynolds-Smolensky (RS) indexes are equal to zero, indicating that fiscal policy does not have any effect in reducing the personal income inequality.[24] The ratio of the minimum wage relative to the average wage in this economy is stable across the scenarios and it is not binding in any of the scenarios,[25] thus indicating that the growth rate of the nominal minimum wage just lags the growth rate of the nominal average wage, without driving the dynamics of the latter. Overall,

[23]These shares concern only the income taxation (wages, profits, and unemployment benefit). Interest payments taxation is not considered because the tax rate on deposits is the same for all households and in all scenarios.

[24]The RS index provides information with respect to the extent to which government activity (transfers and taxation) alters the income distribution that would be determined solely by "market forces" (Reynolds and Smolensky, 1977). By identifying the decrease in the Gini coefficients that is arithmetically attributable to government transfers and taxes through the comparison of the gross and net Gini coefficients, it indicates the progressivity of fiscal policy. Formally, the RS index is equal to the gross income Gini coefficient minus the net income Gini coefficient. Similarly to Mahler and Jesuit (2006), we decompose the RS index into an index for transfers (comparison of the Gini index before and after transfers only) and an index for taxes (comparison of the Gini before taxes with the Gini index after transfers and taxes) in order to have a broader and more detailed understanding of the drivers of income inequality.

[25]The minimum wage bindingness is calculated as the share of employed workers whose wage is equal to the minimum wage. Therefore, it aims to capture the share of workers whose wages could have been lower in the absence of this legal floor.

these factors lead to a high inequality in the income distribution in this scenario, as measured by the gross and net income Gini coefficients.

As expected, the increase in the maximum number of periods that an unemployed worker can receive the unemployment benefit leads to an increase in the coverage of unemployment benefits (percentage of unemployed workers receiving the unemployment benefit) and in the progressivity of the fiscal policy.[26] While the increase in the RS index for transfers is a direct implication of the increase in unemployed workers' net income, there is also a small increase in the progressivity of taxes due to the fact that unemployment benefits earners do not pay any taxes. This creates more equality in the income distribution, in particular in income after transfers and in net income. Therefore, despite the absence of a statistically significant difference between the gross Gini coefficients, the increase in the unemployment benefit periods is associated with a significant decrease in the net income Gini. The stability of the gross Gini coefficient is due to the large similarity with respect to key variables that could affect wage negotiations across the scenarios, such as the employment rate and the output growth rate. This indicates that, under the conditions of the experiments performed in this section, changes in transfers are not enough to induce changes in the output growth rate. Actually, in some cases the growth rates are even lower than in the baseline scenario. Yet, there is a significant effect on the output per capita in some cases,[27] indicating that more periods of unemployment benefit are associated with a higher level of output, especially because this transfer represents an increase in government expenditure.

[26] To investigate the effect of the maximum number of periods of unemployment benefits regardless of the taxation type, we compare the experiments divided into two groups: experiment 1 to 4 and 5 to 8.

[27] Since the population size is the same across the experiments, the comparison between output and output per capita is equivalent.

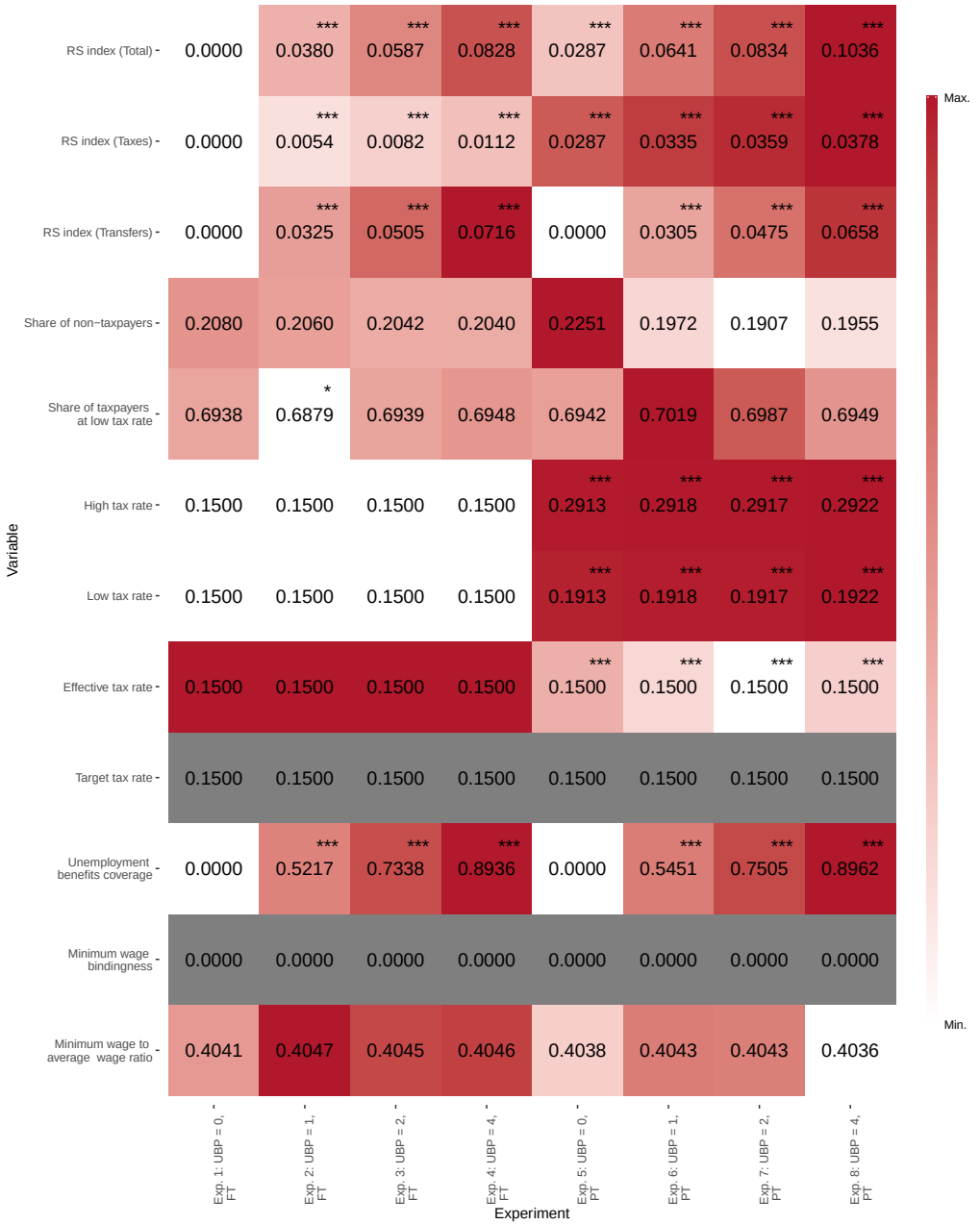


Figure 3.1: Comparison of experiments: labor market regulations and redistributive policies (pro-market to redistributive scenario)

Note: Averages across 100 Monte Carlo runs for each scenario. Significance levels: * 10%, ** 5% and *** 1%. Statistical tests refer to the comparison with the baseline scenario. Grey squares identify variables that are constant across all experiments. Source: author's own elaboration based on simulation results.

With respect to the progressive taxation, we find that the mechanism described in section 3.3.1 is able to keep the effective tax rate very close to the target rate.[28] Given that taxpayers do not pay any taxes on their income up to one minimum wage, incomes above this threshold pay a relatively high tax rate, which is even higher for incomes above the threshold

[28] To investigate the effect of the progressive taxation while keeping the maximum number of periods of unemployment benefits constant, the following pairs of experiment are compared: 1 and 5, 2 and 6, 3 and 7, and 4 and 8.

given by n^{mw} multiplied by the minimum wage. Yet, the majority of taxpayers are taxed at the low tax rate. The share of households that are not taxpayers is close to the unemployment rate, which is expected since nominal wages tend to be above the minimum wage and the income received by unemployed workers is tax-exempted.

The effect of the progressive taxation is also more relevant to the net income distribution. The transition to a progressive tax system significantly increases the RS index for taxes, thus increasing the progressivity of fiscal policy. Since the share of taxpayers that are taxed at the low tax rate is similar across the experiments, the increase in the redistributive effect of taxation is mostly due to the difference in the tax rates between the different tax groups. There is also an interaction between taxation and the unemployment benefits scheme: when the coverage of unemployment benefits increases, there are more workers earning a tax-exempted income, which has implications for the progressivity of taxes. Consequently, when the periods of unemployment benefits is at its maximum and there is a progressive tax system (experiment 8), the RS index achieves its largest value in this set of experiments. In this case, the RS index for transfers is much larger than the RS for taxes, indicating that transfers are the most important redistributive tool for fiscal policy, which is in line with the empirical evidence (Mahler and Jesuit, 2006).

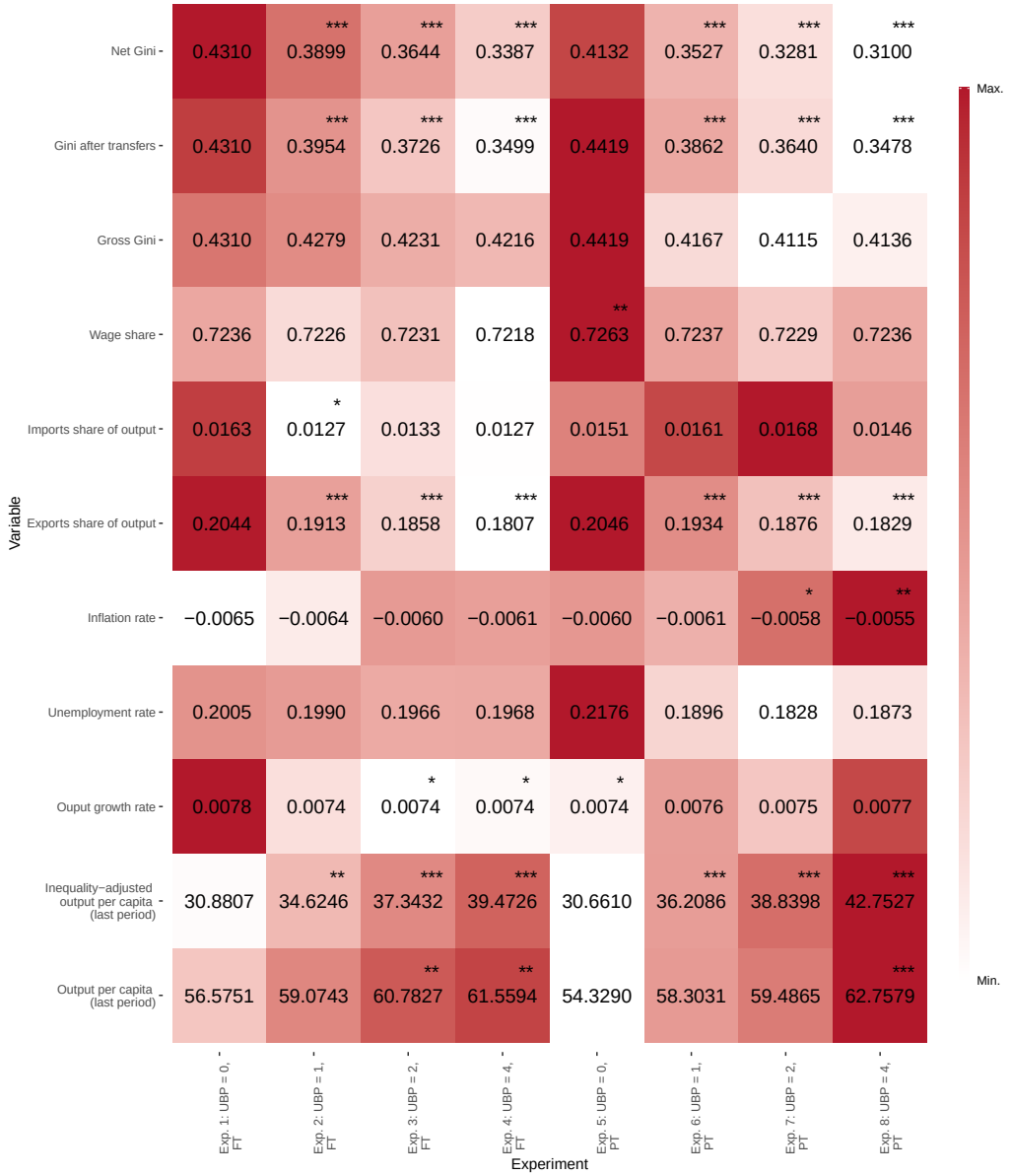


Figure 3.2: Comparison of experiments: income distribution and macroeconomic variables (pro-market to redistributive scenario)

Note: Averages across 100 Monte Carlo runs for each scenario. Significance levels: * 10%, ** 5% and *** 1%. Statistical tests refer to the comparison with the baseline scenario. Source: author's own elaboration based on simulation results.

Also in this case, we observe that the change in the taxation system does not lead to consistent differences in the unemployment rate or output growth rate, leading to a rather stable gross income Gini coefficient. Yet, there are significant differences in the net income Gini coefficient, which decreases with a progressive tax system. Indeed, the scenario characterized by more equality in the income distribution is the scenario in which there is a progressive tax system and unemployment benefits are paid up to four periods (experiment 8).

In sum, the results indicate that relying solely on redistributive policies in a context of weak labor market regulations is helpful to redistribute income, but may be ineffective to

promote output growth and employment. There is also a certain degree of interaction between the redistributive policies, since the redistributive effect of taxes and transfers varies depending on the combination of policies. Since these policies have a small effect on the gross income distribution, in this set of experiments there is a clear pattern by which the differences across the experiments in the net income Gini coefficient are larger than in the gross income Gini coefficient.

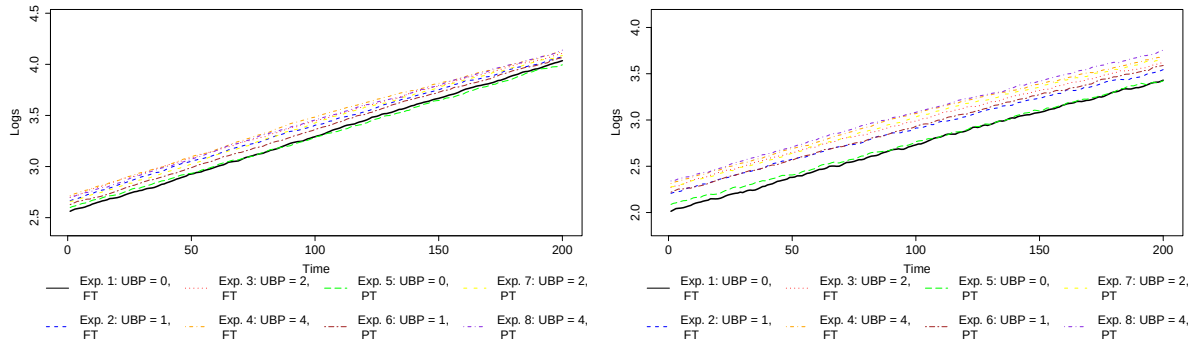
3.4.1.2 Combining economic growth with more income equality

In this section we explore how the redistributive policies affect the relationship between output growth and income inequality in the short run (cyclical relationship) and long run. While the previous section showed no statistically significant difference in the output growth rates across the experiments or showed even a lower growth rate in some cases, there was a difference in the level of the output, which tends to be higher when the redistributive policies are active, in particular the unemployment benefit (figure 3.3a). This derives from the positive direct effect that unemployment benefits exert on aggregate demand, since they represent an increase in government expenditure. Thus, to some extent, these results are not directly comparable with the smaller effect of the progressive taxation system, which is only weakly related to the output levels, since it leads to a different composition of the government revenue that would be only indirectly associated with aggregate demand through the class-specific propensities to consume. Yet, overall these results are indicative of a level effect of the unemployment benefits, and inconsistent effects on the growth rate. The comparison between the archetype of the pro-market scenario (experiment 1) and the archetype of the redistributive scenario (experiment 8) suggests that the growth rates are not statistically different, but the level of output per capita is larger in the latter.

In the long-term analysis, we investigate what are the prospects of each scenario to combining economic growth with more equality in a sustainable way. In order to have a synthetic measure of both economic activity and income inequality, we calculate the inequality-adjusted output per capita and compare it with the unadjusted output per capita. The differences between the scenarios become much larger when the inequality-adjusted output per capita is considered (figure 3.3b).[29] Indeed, in this case we observe that the redistributive policies contribute to combining higher levels of economic activity with more equality in the income distribution in the long run. In this sense, the archetype of the redistribute state (experiment 8) performs considerably better than the archetype of the pro-market state (experiment 1).[30]

[29] This variable derives from the inequality-adjusted human development index (Hicks, 1997), which is a synthetic measure that provides more information on the overall well-being of the society, since it penalizes societies with high levels of inequality. It is equal to the $(1 - Gini_{net})Y/N^h$.

[30] The data reported in figure 3.2 indicates that the differences in the inequality-adjusted output per capita relative to the baseline are statistically significant.



(a) Output per capita

(b) Inequality-adjusted output per capita

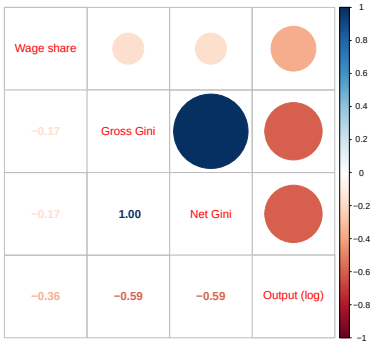
Figure 3.3: Comparison of experiments: output per capita (pro-market to redistributive scenario)
Note: Series represent averages across 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

The redistributive policies investigated in this section also exert an influence, even if small, on more cyclical characteristics of this artificial economy, which are analyzed through the correlations between specific income distribution variables and the output level reported in figure 3.4. These correlations capture the cyclical (or short-run) relation between the selected variables, and thus ought to be interpreted as providing information with respect to their relation within each experiment, in contrast to the relations across the experiments that were explored so far. Overall, the correlations have the same sign and a similar magnitude across the experiments. The net and gross Gini coefficients are positively correlated and this correlation increases with the reduction of the unemployment benefit periods and the flat tax system, becoming a perfect correlation in the absence of the unemployment benefits (experiments 1 and 5). The wage share is negatively correlated with the Gini coefficients, indicating a positive association between equality levels in the personal and functional income distribution. Both the net and the gross income Gini coefficients are negatively correlated with output, and the correlation of the net income Gini with output decreases when its correlation with the gross Gini decreases, suggesting that the relation between the gross Gini coefficient and the output is the more robust relationship. Finally, the wage share is negatively correlated with output, in line with its countercyclical behavior.[31]

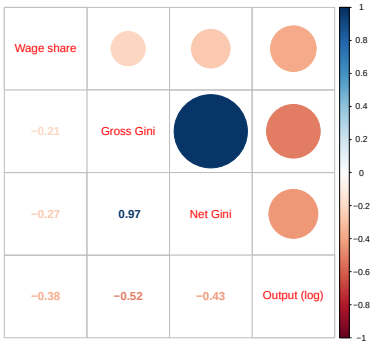
In sum, the redistributive policies discussed in this section do not seem to alter the nature of the structural relationship between economic activity and income distribution, which is captured by the correlations presented in figure 3.4. Also, these correlations seem to be in the same sense as the relation between income distribution and output reported in figure 3.3, indicating a negative relation between output and the Gini coefficient. Yet, there is a negative relation between output and the wage share that was not identified in the experiments and seems to pertain only to their cyclical relationship. Overall, by affecting more directly the personal

[31] The countercyclical behavior the wage share has been investigated in chapter 1 and derives from the presence of overhead labor.

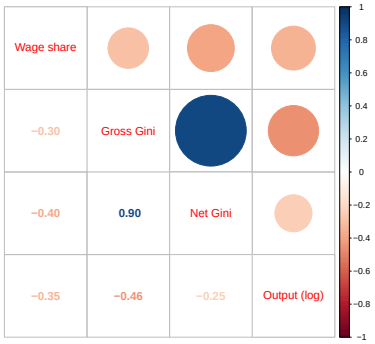
income distribution than the functional income distribution, the redistributive policies discussed in this section emphasize the positive relation between more equality in the personal income distribution and higher levels of economic activity.



(a) Exp. 1 (UBP = 0, FT)

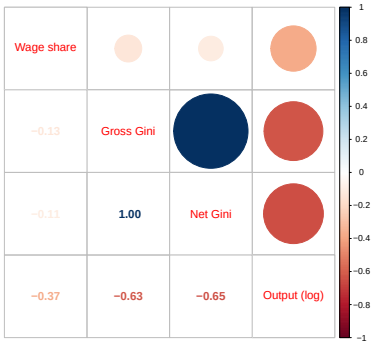


(b) Exp. 2 (UBP = 1, FT)

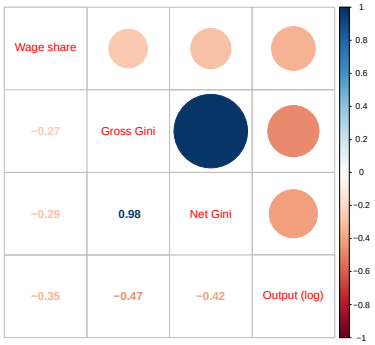


(c) Exp. 3 (UBP = 2, FT)

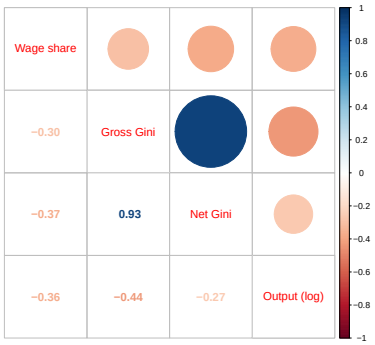
(d) Exp. 4 (UBP = 4, FT)



(e) Exp. 5 (UBP = 0, PT)



(f) Exp. 6 (UBP = 1, PT)



(g) Exp. 7 (UBP = 2, PT)

(h) Exp. 8 (UBP = 4, PT)

Figure 3.4: Comparison of experiments: correlations between output growth and income distribution variables (pro-market to redistributive scenario)

Note: Average correlations across 100 Monte Carlo runs for each scenario. All series are bandpass-filtered (6,32,12). Source: author's own elaboration based on simulation results.

3.4.2 Towards the pro-labor state

Having explored the dynamics of income distribution in the presence of redistributive policies, in this section we discuss the effect of labor market regulations to understand the consequences of improving the support and protection to workers in wage negotiations. In order to do so, we progressively move from the redistributive scenario (experiment 8), wherein the only active redistributive role of the state is represented by taxation and transfers, towards the pro-labor scenario (experiment 15), wherein labor market regulations are active and strong.[32] The experiments are described in table 3.3 below.

Table 3.3: Design of experiments: labor market regulations

Experiment	Downward nominal wage rigidity	Minimum wage adjustment rule	Workers' bargaining power
Exp. 8	No (No DNWR)	Passive (PMW)	$\phi = 0.4$ (LWBP)
Exp. 9	Yes (DNWR)	Passive (PMW)	$\phi = 0.4$ (LWBP)
Exp. 10	No (No DNWR)	Active (AMW)	$\phi = 0.4$ (LWBP)
Exp. 11	Yes (DNWR)	Active (AMW)	$\phi = 0.4$ (LWBP)
Exp. 12	No (No DNWR)	Passive (PMW)	$\phi = 0.8$ (HWBP)
Exp. 13	Yes (DNWR)	Passive (PMW)	$\phi = 0.8$ (HWBP)
Exp. 14	No (No DNWR)	Active (AMW)	$\phi = 0.8$ (HWBP)
Exp. 15	Yes (DNWR)	Active (AMW)	$\phi = 0.8$ (HWBP)

Note: Experiment 8 is the baseline scenario in this section. When reporting the results below, the acronyms within parenthesis are used to identify the characteristics of each experiment. Source: author's own elaboration.

3.4.2.1 Income distribution and macroeconomic results

Figures 3.6 and 3.5 present the main results of the experiments. The downward nominal wage rigidity leads to a higher ratio between the minimum wage relative to the average wage in all cases, thus increasing the minimum wage bindingness when the active minimum wage adjustment rule is in place.[33] This tends to reduce income inequality, which is further reduced by the nominal wage adjustments dynamics that lead to an increase in the wage share. Therefore, when the other regulations are kept constant, the downward nominal wage rigidity tends to be associated with a higher wage share and a lower gross and net income Gini coefficients in all cases. Yet, this effect is relatively larger when the sensitivity of workers' bargaining power to the employment rate is lower.

[32] Transfers and taxation are kept constant across the experiments, with four periods of unemployment benefits and progressive taxation.

[33] To investigate the effect of downward nominal wage rigidity while the other regulations are kept constant, we compare the following pairs of experiments: 8 and 9, 10 and 11, 12 and 13, and 14 and 15.

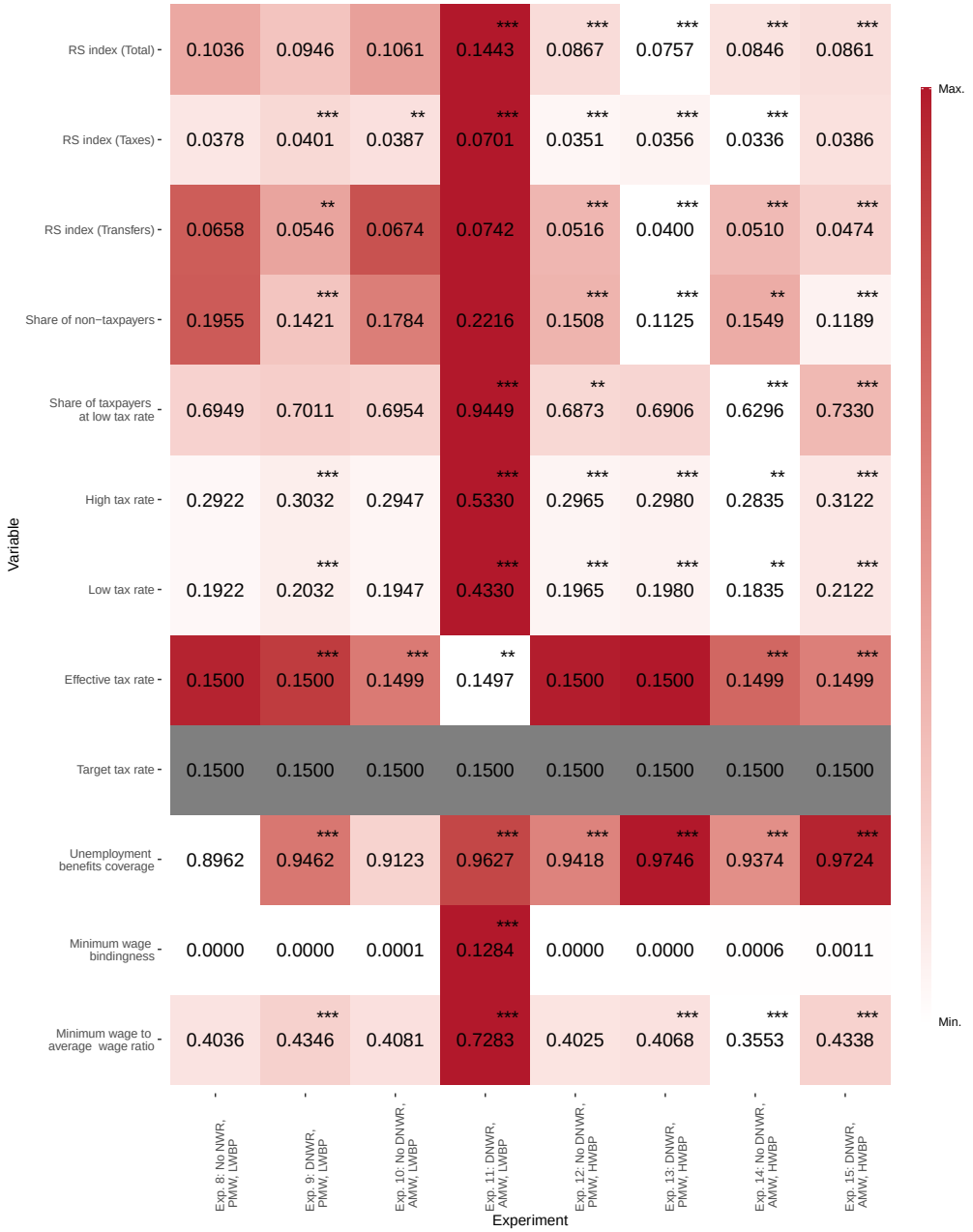


Figure 3.5: Comparison of experiments: labor market regulations and redistributive policies (redistributive to pro-labor scenario)

Note: Averages across 100 Monte Carlo runs for each scenario. Significance levels: * 10%, ** 5% and *** 1%. Statistical tests refer to the comparison with the baseline scenario. Grey squares identify variables that are constant across all experiments. Source: author's own elaboration based on simulation results.

The downward nominal wage rigidity also interacts with the redistributive policies, altering the progressivity of fiscal policy. Since the unemployment rate decreases in the presence of downward nominal wage rigidity, there is also an increase in the coverage of unemployment benefits.[34] The combination of these features exerts a non-linear effect on the progressivity of transfers, and in most cases the downward nominal wage rigidity is associated with a lower RS

[34]The maximum number of periods of the unemployment benefits is kept fixed, but a lower unemployment rate may indicate that workers are unemployed for fewer periods and thus more workers find a job before losing this benefit.

index for transfers. The progressivity of taxation increases in all cases, reflecting the decrease in the share of non-taxpayers (except from experiment 10 to experiment 11) and the increase in the share of taxpayers at the low tax rate. While the decrease in the share of non-taxpayers is strongly associated with the decrease in the unemployment rate,[35] the increase in the share of taxpayers at the low tax rate is associated with the effect of downward nominal wage rigidity on the minimum wage: since it becomes closer to the average wage in the economy, fewer households fall in the group taxed at the higher tax rate, which is defined in proportion to the minimum wage. The increase of taxpayers at the low tax rate leads to a increase in both the high and low tax rates: since a smaller share of income is taxed at the high tax rate, these rates need to be increased so that the target tax rate is achieved. The overall progressivity of fiscal policy (RS index total) results from the interplay between these changes in taxation and transfers, so it may decrease or increase with downward nominal wage rigidity.

With respect to the macroeconomic implications of downward nominal wage rigidity, we find that in most cases when this regulation is active, the output growth rate and the level of the output per capita are higher (except from experiment 12 to 13) and the unemployment rate is lower than in the scenarios where nominal wage cuts are allowed. This indicates that protecting workers from wage cuts during recessions may be effective in sustaining aggregate demand and thus output and employment levels. Yet, this is also associated with a relatively higher inflation rate, as expected from the impact of lower unemployment rates on workers' bargaining power and the impossibility of reducing nominal wages. Indeed, deflationary scenarios emerge when there are no restrictions to nominal wage cuts - and even in one of the scenarios in which this restriction is in place, but wherein the other labor market regulations are weak (experiment 9). Following the mechanisms described in chapter 2, lower inflation rates tend to be associated with more international price competitiveness for domestic firms, thus the scenarios in which nominal wage cuts are allowed are associated with a higher share of exports and a lower share of imports in output. Yet, this foreign stimulus through the trade balance is insufficient to compensate the negative effects of more inequality on domestic consumption.

[35] Except in the comparison between experiments 10 and 11 because in experiment 11 the minimum wage to average wage ratio is much higher and, consequently, many workers may be tax-exempted.

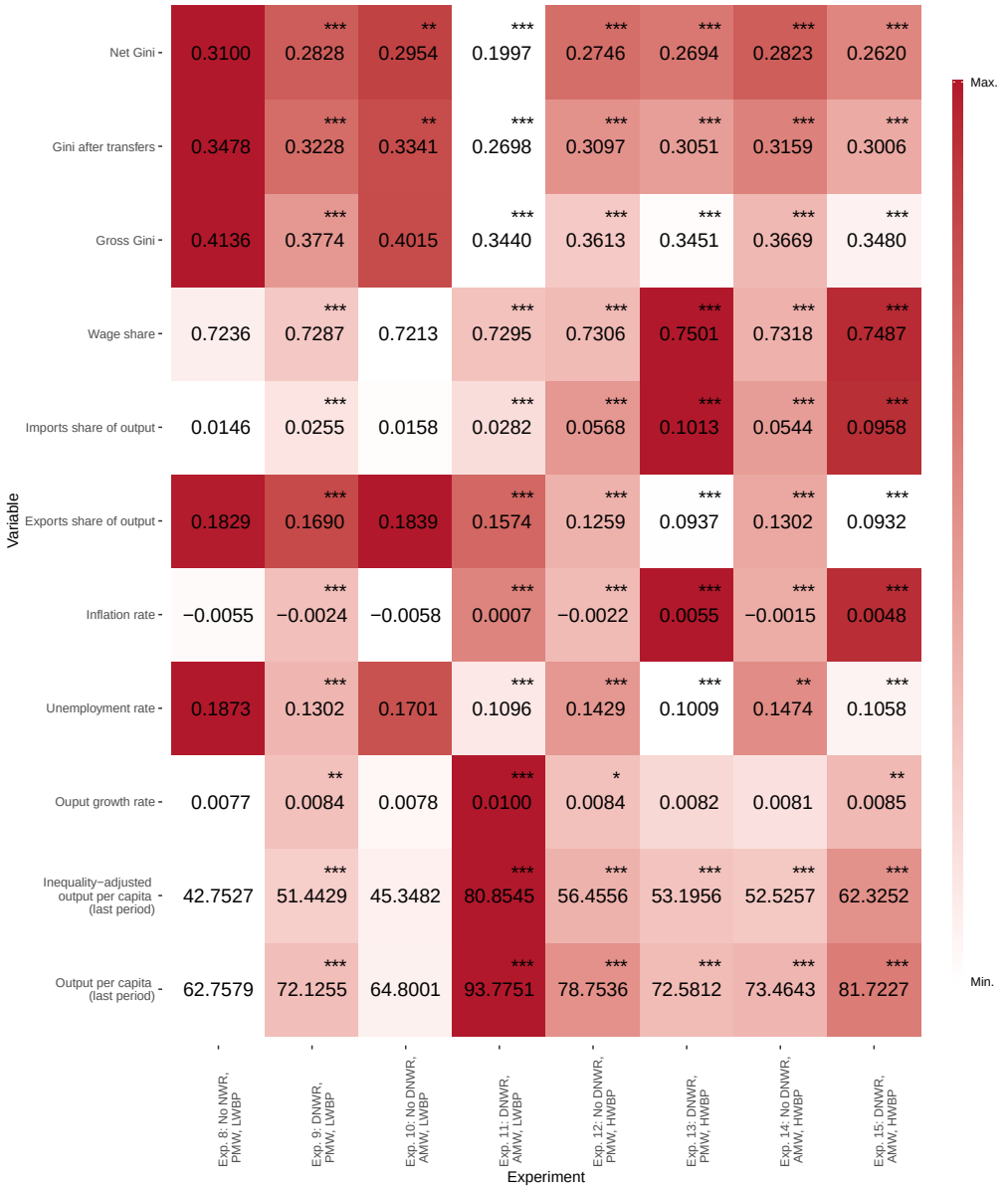


Figure 3.6: Comparison of experiments: income distribution and macroeconomic variables (redistributive to pro-labor scenario)

Note: Averages across 100 Monte Carlo runs for each scenario. Significance levels: * 10%, ** 5% and *** 1%. Statistical tests refer to the comparison with the baseline scenario. Source: author's own elaboration based on simulation results.

The active minimum wage rule tends to be associated with lower gross and net Gini coefficients, except in the scenarios with high workers' bargaining power and downward nominal wage rigidity (from experiment 12 to 14).[36] As the wage share does not change much between each pair of scenarios, the experiments suggest that the minimum wage has a more significant effect on the personal income distribution than on the functional income distribution, which makes sense since the minimum wage affects incomes at the bottom of the income distribution.

[36]To investigate the effect of the active minimum wage rule while the other regulations are kept constant, we compare the following pairs of experiments: 8 and 10, 9 and 11, 12 and 14, and 13 and 15.

In the experiments, the minimum wage is a binding constraint only when it follows an active adjustment rule; otherwise, it represents a floor that just follows the nominal wage dynamics. This also explains why in the scenarios with the passive adjustment rule the minimum wage represents less of the average wage than when there is an active minimum wage rule, but this is not observed in all comparisons. Indeed, in experiment 14 (active minimum wage adjustment rule), the ratio is lower than in experiment 12 (passive minimum wage adjustment rule), probably because in the former workers' bargaining power is strong enough to induce wage growth above the growth rate of the minimum wage. Similarly, from experiment 8 to experiment 10, the low workers' bargaining power in a context where nominal wages can be cut renders the type of adjustment rule for the minimum wage less relevant.

In addition to being a legal floor to wage levels, the minimum wage has a direct effect on the progressivity of fiscal policy. It affects the value of government transfers (unemployment benefits) and, consequently, when there is an active minimum wage rule, transfers tend to be more progressive (except in the comparison between experiments 12 and 14, which present very similar RS index for transfers). It also affects the progressivity of taxation in most cases. This is due to the increase of the minimum wage to average wage ratio, which tends to increase the share of tax payers at the low tax rate. Therefore, when the minimum wage to average wage ratio decreases (from experiment 12 to 14), taxes become less progressive. Also in this case the total progressivity of fiscal policy depends on the interplay between these factors and it tends to increase slightly in most cases.

The macroeconomic effects of the minimum wage present a non-trivial nature. When workers' bargaining power is high (scenarios 12 to 15), the active minimum wage rule does not seem to be a further stimulus to economic activity or contribute to reducing unemployment rates. Actually, the output growth rate even decreases from experiment 12 to 14, while increasing from experiment 13 to 15. On the other hand, when workers' bargaining power is low (scenarios 8 to 11), the active minimum wage rule is associated with a higher output growth rate and a lower unemployment rate (which is significant in the comparison between experiments 9 and 11). This suggests that the minimum wages compensate for the lower workers' bargaining power, as if it was only activated in this case. Given this dynamics of the output growth rate, the level of the output per capita also tends to be higher when there is an active minimum wage policy. Once again, experiment 12 and experiment 14 are the exception in this case. Across these scenarios, there is a small change in the share of exports and imports in output, probably due to the weak effects of this rule on inflation. This indicates that the redistributive impact of the minimum wage is accompanied by lower inflationary pressures, since it partially operates through changes in within-wage inequality.

Finally, higher sensitivity of workers' bargaining power to the employment rate is associated with a higher wage share in all combinations of the other labor market regulations.[37]

[37] To investigate the effect of the sensitivity of workers' bargaining power to the employment rate (ϕ) while the other regulations are kept constant, we compare the following pairs of experiments: 8 and 12, 9 and 13, 10 and 14,

Yet, the higher wage share associated with the increase in workers' bargaining power is not necessarily followed by more equality in the personal income distribution, although this occurs in most cases. Indeed, when workers' bargaining power increases but there is an active minimum wage adjustment rule and downward nominal wage rigidity, both the gross and the net Gini coefficients increase (comparison between experiments 11 and 15). The increase is particularly relevant for the net Gini coefficient, indicating a strong effect of the redistributive policies. Since in this case the adjustment rule of the minimum wage does not depend on the dynamics of wage negotiations between workers and firms (as would be the case in the passive rule), the minimum wage increases more than wages that are above the minimum wage. This dynamics reduces the wage inequality and also considerably increases the value of the unemployment benefit and the number of households paying the low-tax rate, with strong implications for income inequality. This mechanism is actually present in all scenarios, since the minimum wage tends to represent more of the average wage in all scenarios with lower sensitivity of workers' bargaining power to the employment rate, but it only plays a dominant role in income distribution dynamics in this specific case.

Relatedly, the increase in the sensitivity of workers' bargaining power to the employment rate leads to less progressivity of the fiscal policy in all cases. The dynamics of the unemployment rate is responsible for this in the case of transfers (less workers receiving unemployment benefits) and taxation (fewer tax-exempt households). The decrease in the progressivity of taxes is also related to the decrease in the share of households taxed at the low tax rate when workers' bargaining power is high, since wages are more distant from the minimum wage and, consequently, more workers earn a wage above the threshold for the high tax rate. This is in line with the finding that societies that are more equal will rely less on taxation and transfers as a means to redistribute income (Berg, 2015, Berg et al., 2018), even when they have the institutional framework for doing so.[38] Indeed, in our experiments the increase in workers' bargaining power reduces the reliance on the redistributive policies.

The interactions with other policies lead to different relations between the sensitivity of workers' bargaining power to the employment rate and the output growth rate. While in some cases there is no clear difference, in the comparison between experiments 11 and 15, a higher output growth rate is observed when workers' bargaining power is lower, due to the strong improvement in the personal income distribution described above. Conversely, the comparison between experiments 8 and 12 shows that the increase in workers' bargaining power leads to a higher output growth rate. This indicates that when the other labor market regulations are not in place, workers' bargaining power has a more significant role in sustaining output growth. It

and 11 and 15. In chapter 1, we also analyzed the effect of changes in the parameter capturing the sensitivity of workers' bargaining power to the employment rate. The results presented in this chapter revisit those results and add new insights into the interaction of workers' bargaining power with the other labor market regulations in an open economy framework.

[38] The decrease in inequality also reduces the redistributive effect of transfers more than it reduces that of taxes, in line with the predominance of transfers as a redistributive policy.

is also in the comparison between these two experiments that we find the largest difference in unemployment rates, although unemployment is always lower when workers' bargaining power is higher.

The experiments reported in this section provide important insights into the effect of labor market regulations and their interaction. Overall, all the regulations are associated with more equality in the income distribution, with the active minimum wage rule and downward nominal wage rigidity having a predominant impact on the personal income distribution and workers' bargaining power having a predominant impact on the functional income distribution. Thus, by affecting the wage structure and wage negotiations in different ways, the regulations differ with respect to their effect on the functional and personal income distribution. Moreover, our experiments capture a specific situation when less equality in the functional income distribution takes place at the same time as there is more equality in the personal income distribution (experiments 11 and 15), which arises due to the effect of wage inequality on the personal income distribution and, more importantly, the effect of the redistributive policies (as the gross Gini is quite similar). Therefore, we are able to capture a counterintuitive situation that emerges from the interaction between the labor market regulations and redistributive policies..

Most of the combinations of strong labor market regulations are associated with more equality in the income distribution, lower unemployment rates, and higher output growth rates and levels. Nevertheless, there are important exceptions that draw attention to the interaction effects between these regulations and the existing non-linearities. Overall, the comparison between the archetypal redistributive scenario (experiment 8) and the archetypal pro-labor scenario (experiment 15) suggests that the introduction of strong labor market regulations is helpful to improve the income distribution and for economic growth, in line with studies that show that weak labor market regulations do not improve efficiency or promote employment (Betcherman, 2012).

The interaction between these regulations is also key to understanding the specific effect of each of them. We observe that there is a considerable degree of overlapping between them. In general, the effect of each regulation on income distribution and unemployment is larger when the other regulations are not in place. Thus, while the regulations complement each other and more equality is obtained when all (or most) of them are active, the marginal effect of introducing each new regulation when the others are already active decreases. An important example of this is the low bindingness of the minimum wage in most scenarios, even when it follows the active adjustment rule. This indicates that the other labor market regulations in place (downward nominal rigidity and high workers' bargaining power) are strong enough to prevent nominal wages from falling towards the legal floor represented by the minimum wage. Yet, since in this framework most unemployed workers receive the unemployment benefit from the government and the value of this transfer is equal to the minimum wage, the active minimum wage adjustment rule does have important implications for inequality and aggregate demand.

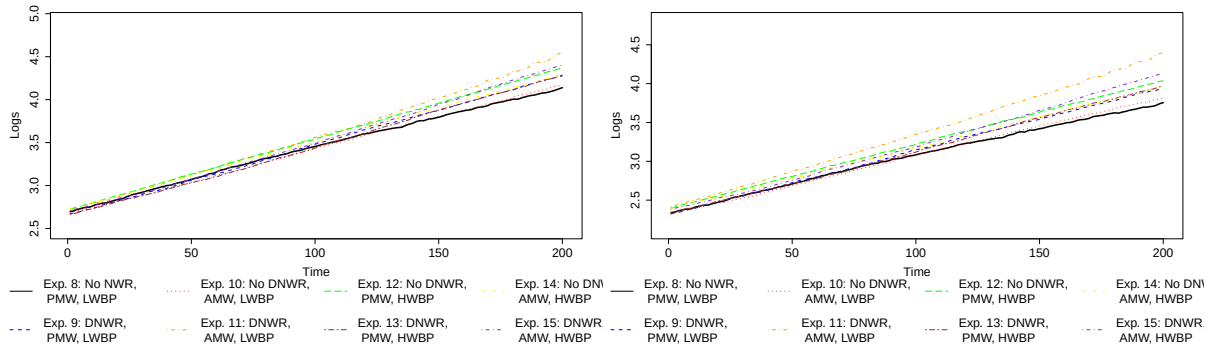
Our results also indicate an interaction between the labor market regulations and the redistributive policies (transfers and taxation). The strengthening of the regulations (and the consequent decrease in unemployment rates) reduces the number of workers that receive unemployment benefits, which tends to decrease the progressivity of transfers and taxes, as discussed above. Nevertheless, the downward nominal wage rigidity and the active minimum wage policy make the fiscal policies more progressive by changing the value of the unemployment benefit or the income threshold for the tax rate groups. Consequently, when these regulations are strong, fiscal policy may be more or less progressive, while when workers' bargaining power is high, it is always less progressive (due to the reduction in transfers). Indeed, the sensitivity of workers' bargaining power to the employment rate does not alter the main aspects determining the functioning of these policies, which is not the case with the other regulations. The influence of these regulations on the progressivity of fiscal policy also seems to explain why in some cases the difference in the net Gini coefficient is larger than the difference in the gross income Gini coefficient. While the expected result of these policies was to alter the nominal wage dynamics and thus have a stronger effect on the gross income Gini coefficient that would be attenuated by the fiscal policies and become a smaller difference in terms of the net income Gini coefficient, in some cases this seems to be intensified by the change in the progressivity of fiscal policy in the same direction.

3.4.2.2 Combining economic growth with more income equality

A key result obtained in the experiments discussed above is the relation between the labor market regulations and a lower income inequality and higher output growth rate or output per capita level. This indicates a positive relation between more equality and the level of economic activity, despite of the loss of international competitiveness associated with the lower income inequality (and higher inflation rates) in most cases. Therefore, the results suggest that the economic stimulus provided by more equality in the income distribution compensates the negative effects associated with the increase in the imports share and decrease in the exports share. We now explore further the relationship between economic growth and income inequality in a long-term and cyclical perspective in order to understand how the regulations investigated above alter this relationship.

As reported in figure 3.7a and in line with the different growth rates previously discussed, the experiments in which labor market regulations are stronger are associated with higher output per capita levels, while the opposite is observed in the scenarios with weak labor market regulations. Also, as reported in figure 3.7b, the scenarios that are able to combine more equality with economic growth perform even better when evaluated through the inequality-adjusted output per capita. Indeed, since in general the scenarios with more equality in our experiments are those with higher output levels, they become even better relative to the other

scenarios in this case.[39] Consequently, the highest output per capita and inequality-adjusted output per capita levels are obtained when all or most labor market regulations are active (experiments 11, 12, and 15).



(a) Output per capita (b) Inequality-adjusted output per capita

Figure 3.7: Comparison of experiments: output per capita (redistributive to pro-labor scenario)
Note: Series represent averages across 100 Monte Carlo runs for each scenario. Source: author's own elaboration based on simulation results.

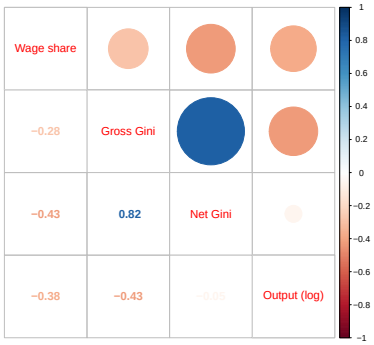
Also in this case we observe differences in more structural characteristics of this artificial economy, as indicated by the correlations reported in figure 3.8. As expected, the correlation between the net and the gross Gini coefficients is positive in all cases. Nevertheless, it is relatively lower in the experiment in which there is downward nominal wage rigidity, an active minimum wage rule, and low workers' bargaining power (experiment 11). This is probably associated with the expressive progressivity of fiscal policy in this case, which is responsible for the decoupling between both coefficients. Despite of these differences, in all cases we find a negative correlation between the wage share and the Gini coefficients, confirming the positive association between equality levels in the personal and functional income distribution identified in section 3.4.1.

The cyclical relation between income inequality and output level is clear in the case of the gross income Gini coefficient, indicating a negative relation in all experiments, which is in line with the relation obtained in the comparison across the experiments. Yet, the net Gini coefficient is only weakly correlated with the output level. While in most cases this is a negative correlation, experiment 11 emerges as an important exception in which higher output levels are correlated with more inequality in the net income distribution, probably resulting from the strong dynamics of the minimum wage in this case, which decouples the dynamics of the net Gini index from the output level.[40] Also the wage share is negatively correlated with output levels, as had been previously identified.

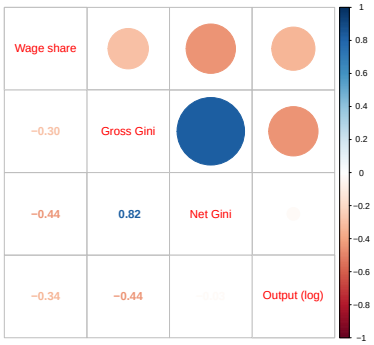
[39] The data reported in figure 3.6 indicates that the differences in the inequality-adjusted output per capita relative to the baseline are statistically significant.

[40] As in most cases reported in figure 3.8, there is usually a negative relation between the Gini coefficient and the output level. This is discussed in more detail in chapter 1 and one of the explanations for this is that when unemployment increases in the downturn of the cycle, more workers receive unemployment benefits, which tend

to be lower than average wages. This explanation would be relatively more important for the net income Gini coefficient, which is the index that considers transfers, and explains why its negative relation with output is lost in experiment 11: since the bindingness of the minimum wage and the ratio between the minimum wage and the average wage are much higher in this experiment, when workers lose their job the income loss is much lower.

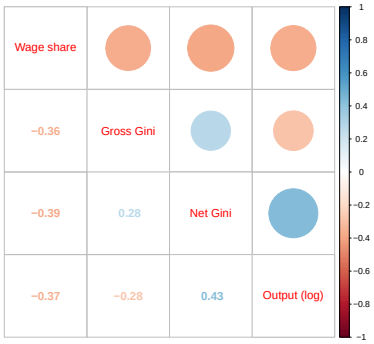


(a) Exp. 8 (No NWNR, PMW, LWBP)



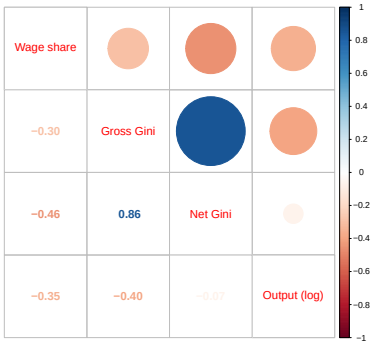
(b) Exp. 9 (DWNR, PMW, LWBP)

(c) Exp. 10 (No DWNR, AMW, LWBP)

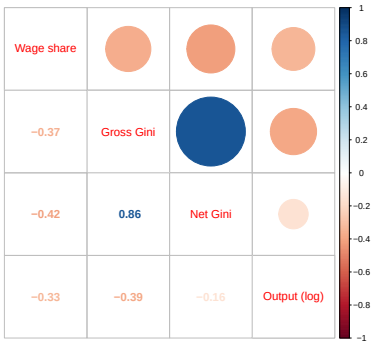


(d) Exp. 11 (DWNR, AMW, LWBP)

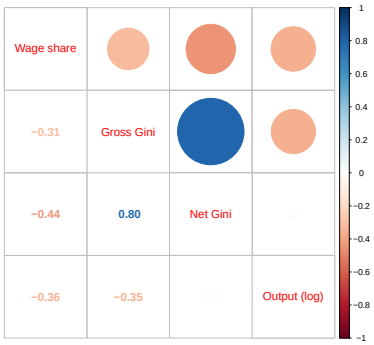
(e) Exp. 12 (No DWNR, PMW, HWBP)



(f) Exp. 13 (DWNR, PMW, HWBP)



(g) Exp. 14 (No DWNR, AMW, HWBP)



(h) Exp. 15 (DWNR, AMW, HWBP)

Figure 3.8: Comparison of experiments: correlations between output growth and income distribution variables (redistributive to pro-labor scenario)

Note: Average correlations across 100 Monte Carlo runs for each scenario. All series are bandpass-filtered (6,32,12). Source: author's own elaboration based on simulation results.

In sum, by comparing the relation between income inequality and output growth within and across the experiments, our results provide important additional insights. While the relation between the gross income Gini coefficient and output is consistently negative, in some cases there is a positive correlation between output and the net Gini coefficient that did not appear in the comparison between the experiments. Also, the experiments suggest a more blurred long-run relation between the wage share and output, while the correlations are consistently negative within each experiment. This suggests that the cyclical behavior of these variables provides little information with respect to what would happen if there were changes in the labor market regulations aiming at increasing the wage share or reducing inequality.

3.4.3 Summary of the main findings

This chapter aimed to compare the archetype of the pro-market, redistributive, and pro-labor scenarios and investigate the contribution of each policy and regulation in the transition from the pro-market to the pro-labor scenario. Overall, the results identify many non-linear relations arising from the interaction between the different tools implemented. We find a considerable degree of overlapping between the regulations and also identify specific cases in which more active policy tools are not necessarily related with an improvement in income distribution or more economic growth. This reflects the very complex nature of the relations governing both variables in an open economy.

Nevertheless, the comparison between the three archetypal scenarios described in table 3.1 does offer important overall conclusions, which are summarized in figure 3.9. On the one hand, we find that the redistributive scenario is characterized by lower inequality in the net income distribution in comparison with the pro-market scenario, but it fails to induce lower unemployment rates or higher output growth rates. Yet, it is helpful to conciliate a higher level of output per capital with more equality. On the other hand, we find that the combination of redistributive policies with strong labor market regulations allows for inclusive economic growth in the sense that lower inequality is combined with higher output growth rates and lower unemployment rates. In this sense, the results offer a strong support for the combination of these policy tools in order to promote inclusive economic growth.

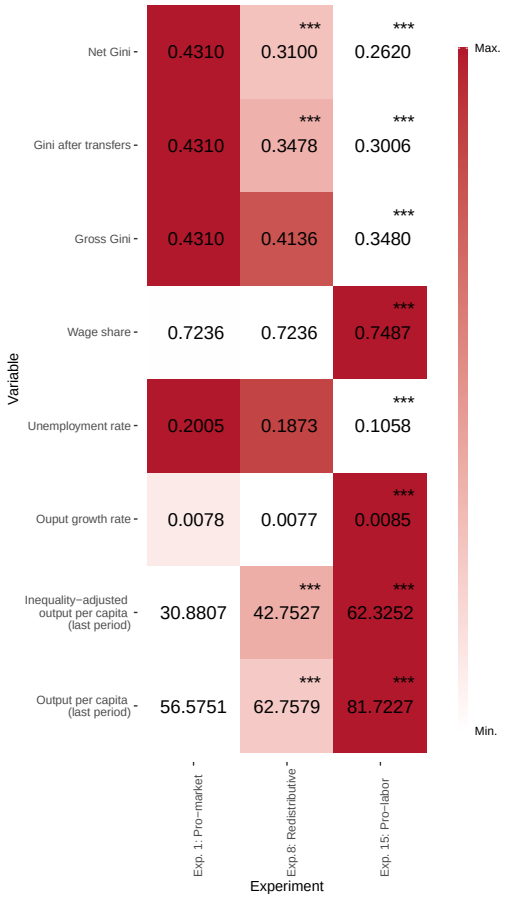


Figure 3.9: Summary of main results of the archetypal scenarios

Note: Source: author's own elaboration based on simulation results.

Our results also offer new insights into the relationship between economic growth and income distribution. Figure 3.9 suggests that more equality in both the functional and personal income distribution tends to be associated with higher output growth rates and levels. This indicates that inclusive economic growth is a feasible possibility in the economic structure reproduced by the model. While this captures the relationship between more equality and economic activity in a long-run perspective, we have also analyzed the cyclical relationship between the variables, which provides information with respect to their short-run relation. In this case, we find that the different scenarios tend to present the same pattern by which the wage share and the Gini coefficients are negatively correlated with output.

The comparison between these short- and long-run effects is relevant for a comprehensive understanding of their complex relationship.[41] The short-run relationships that are captured by the correlations indicate both the effect of output on income distribution and the effect of income distribution on output, while the long-run relations that are summarized by the average values in figure 3.9 indicate whether exogenous factors, such as policies and regulations,

[41] In the post-Keynesian literature, a similar discussion is undertaken by Blecker (2016) and Rolim (2021). Also Cauvel (2022) and Lavoie (2017) investigate the feedback effects between income distribution and economic activity.

can simultaneously stimulate output growth and induce more equality in the income distribution in a sustainable way. In this latter case, the effect of these exogenous factors not necessarily operates on output through changes in income distribution, although this is likely to be a relevant transmission mechanism.[42] Be it as it may, the latter relations are much more informative about the possibilities of combining economic growth with more equality in the income distribution.

3.5 Conclusion

This chapter investigated the dynamics of economic growth and income distribution when strong labor market regulations and redistributive policies are progressively added to a pro-market scenario. The results discussed above are supportive of the effectiveness of combining these policy tools to achieve inclusive economic growth: the transition from the archetype of the pro-market scenario towards the archetype of the pro-labor scenario leads to lower inequality in the functional and personal income distribution, lower unemployment rate, and higher output growth rate. In addition to capturing a positive correlation between equality, economic activity, and employment, these results also suggest that labor market regulations and redistributive policies are required to sustain a more equal income distribution that is associated with the better economic performance in terms of employment and output.

Nevertheless, the results also reveal the complex nature regulating the relationship between labor market regulations and redistributive policies and income distribution. We find that there is a significant degree of complementarity between the different policy tools, but there is also a significant overlapping of their effects and, in specific cases, even a reversal of their individual effects when they are combined. In general, the addition of strong labor market regulations reduces the actual progressivity of fiscal policy and the marginal effect of each labor market regulation falls with the strength of the other regulations. This confirms our intuition that the effect of these tools depends on their interaction with other tools and on the specific economic context. It also stresses the need of carefully designing and combining regulations and policies targeting more income equality.

In addition, we identify a complex relationship between income distribution and the considered macroeconomic variables. Not only there are numerous non-linearities governing the relationship between output and inequality, their overall relationship is also the result of their reciprocal effects on each other. Yet, in general, the results point to a positive association between more equality in the personal income distribution and output levels and growth rates, in particular when labor market regulations are strong. We also find that more equality in the functional income distribution is only associated with output growth when there is a simultaneous reduction in inequality in the personal income distribution.[43] Conversely, the relationship between income

[42] In other words, the distinction between correlation and causality, which is certainly key for the short-run relationships, should also be considered in the analysis of the long-run relationships.

[43] To some extent, this finding corroborates empirical analyses found in the literature, such as Carvalho and Rezai (2016), Carvalho and Rugitsky (2015), and Rolim (2019).

distribution and inflation rates is clearer for the case of the functional than for the personal income distribution, since the former is more directly affecting (and being affected by) the pricing decisions decisions by firms.

In sum, the results indicate that the type of labor market regulation and redistributive policy matters for how and to which the extent income distribution is affected, but there are also more qualitative aspects that are quite relevant. Indeed, each type of policy tool activates different mechanisms in this complex system, so the nature of the distributive changes differs and so does the dynamics of output and inflation, which may result from mechanisms operating through income distribution or from mechanisms that simultaneously affect output and distribution. Despite of the complexity of these relations, the main conclusion derived in this chapter is that labor market regulations and redistributive policies tend to contribute to inclusive economic growth.

Conclusion

This dissertation explored the macroeconomic dimensions of income distribution through a novel AB model featuring a novel and richer wage bargaining process, a novel and more comprehensive strategic mark-up adjustment rule, and a three-class social structure for households both in a closed economy and in an economy open to international trade. It explored how income distribution is affected by the dynamics of key macroeconomic variables, thus capturing some of the numerous determinants of income disparities in complex economic and social systems. Moreover, the effect of income distribution on macroeconomic variables such as output and inflation has also been investigated to explore our main research question: under which conditions is inclusive economic growth possible?

The topics that have been dealt with in each chapter consist of specific layers of the complex relationship between the macroeconomic dimension and income distribution. These different layers of analysis complement each other and combined they indicate that the possibility of achieving and sustaining inclusive economic growth depends, at least partially, on the interplay between endogenous mechanisms determining the relative strength of each class, on the type of exogenous shocks altering the international trade relations, and on the specific set of regulations and policies in place. Therefore, the complex nature of the economic system and, in particular, of the two-way relationship between income distribution and output determine the specific conditions allowing for inclusive economic growth.

Chapter 1 investigated the two-way interplay between productivity growth and workers' bargaining power and showed that the source of economic stimulus is key to the nature of the relationship between income distribution and economic growth. The analysis was based on the premise that the increasing wage-productivity gap and lower wage share observed in many economies resulted from a reduction in workers' bargaining power in a context of high labor productivity growth. This would be the case because productivity growth tends to favor firms and allows for increases in their mark-up rates, thus leading to more inequality, while workers' bargaining power can exert a counteracting force and contribute to more equality in income distribution. In addition to finding strong support for this hypothesis from the results obtained from the AB model for a closed economy put forward in this chapter, we also find that both higher productivity growth and higher workers' bargaining power are associated with higher output levels and growth rates. Thus, the results indicate that inclusive economic growth may not be obtained if the key driver of economic growth is productivity growth, while its likelihood increases when workers' bargaining power is higher. Consequently, the chapter also identified the possibility of a policy dilemma between promoting both productivity and output growth and

improving income equality. Nevertheless, it indicated that this dilemma is alleviated if workers' bargaining power is increased simultaneously to the higher innovation dynamics leading to productivity growth.

Chapter 2 dealt with the effect of foreign trade shocks and explored how the nature of these shocks can be a factor influencing the possibility of inclusive economic growth. To do so, the AB model structure was extended to an economy open to international trade and a foreign sector was added. The chapter analyzed the effect of different types of foreign shocks (demand and price), with different lengths, magnitudes, and signs on output, inflation, and income distribution. While the positive shocks on the foreign output growth rate and foreign inflation rate stimulate domestic output through their positive effects on exports, their distributive implications are quite different. Indeed, we find that the former shock tends to generate more equality in the income distribution, but the latter shock is associated with a worsening in income distribution that is mainly caused by the dynamics of the real exchange rate. Thus, the results indicate that the relation between output and distribution is also largely dependent on the nature of the foreign shocks. The chapter also showed the importance of the interaction between the domestic and foreign demand to the dynamics of the domestic output, with this interaction being mediated in a complex fashion by the relationship between income distribution and international competitiveness. Indeed, such a relationship presents important implications for output growth in the long run and for the relationship between the output dynamics and the real exchange rate. Moreover, both foreign shocks tend to generate inflationary processes in the domestic economy. Since there is an imported inflation component simultaneously to the inflationary pressures from domestic price and wage adjustments in a context of lower unemployment rates, these processes have different natures and thus indicate that the model structure offers a more realistic treatment of the inflation dynamics in open economies.

Finally, chapter 3 was dedicated to exploring what could be done to tackle the high inequality levels that characterize capitalist societies and whether specific policy tools can be framed to induce inclusive economic growth. The open economy model structure put forward in chapter 2 was employed to test the effect of redistributive policies and labor market regulations aiming to promote less unequal distribution of income. The analysis carried out compared three stylized structures: a pro-market scenario, a redistributive scenario, and a pro-labor scenario. The results were supportive of the effectiveness of combining redistributive policies and labor market regulations to achieve inclusive economic growth: the transition from the archetypal pro-market scenario towards the archetypal pro-labor scenario leads to lower inequality in the functional and the personal income distribution, lower unemployment rate, and higher output growth rate. Yet, the results also highlighted the complex nature of the relationship between these policy tools, income inequality, and output growth, since many non-linearities and important two- and three-way interaction effects were captured. Therefore, while providing strong and robust support for regulations and policies aiming to combine more income equality and higher

output growth, the results are also suggestive of the need of carefully designing and combining these tools.

In sum, our results indicate that, while capitalist economic systems are prone to generating inequalities endogenously, this distributive outcome can be influenced by external shocks and inequality can be attenuated or mitigated by regulations and policies. Moreover, the complex nature of the relationship between the level of economic activity and the distribution of income shows that inclusive economic growth is not an inherent, and hence inevitable, property of the system. Therefore, combining economic growth with more equality in the income distribution requires active and adequate market regulations and well-designed policies as a prerequisite for achieving such a desirable objective.

Bibliography

Abbring JH, Berg GJ, Ours JC (2005) The Effect of Unemployment Insurance Sanctions on the Transition Rate from Unemployment to Employment. The Economic Journal 115(505):602–630

Agenor PR, McDermott CJ, Prasad ES (2000) Macroeconomic Fluctuations in Developing Countries: Some Stylized Facts. The World Bank Economic Review 14(2):251–285

Atkinson AB (1970) On the measurement of inequality. Journal of Economic Theory 2(3):244–263

Atkinson AB (2009) Factor shares: The principal problem of political economy? Oxford Review of Economic Policy 25(1):3–16

Aucremanne L, Druant M (2005) Price-Setting Behaviour in Belgium: What Can Be Learned from an Ad Hoc Survey ? SSRN Electronic Journal

Autor D, Dorn D, Katz LF, Patterson C, Van Reenen J (2020) The fall of the labor share and the rise of superstar firms. The Quarterly Journal of Economics 135(2):645–709

Autor DH, Manning A, Smith CL (2016) The Contribution of the Minimum Wage to US Wage Inequality over Three Decades: A Reassessment. American Economic Journal: Applied Economics 8(1):58–99

Baker D, Bivens J, Schieder J (2019) Reining in CEO compensation and curbing the rise of inequality. Economic Policy Institute Report

Baltar CT, Rolim LN (2018) Desigualdade e vulnerabilidade no mundo do trabalho. In: Krein J, Gimenez D, dos Santos A (eds.) Dimensões críticas da reforma trabalhista no Brasil, Curt Nimuendajú, Campinas, SP, pp. 243–274

Baltar PEA, Souza PRC (1979) Salário Mínimo e Taxa de Salários no Brasil. Pesquisa e Planejamento Econômico

Barro RJ (1990) Government Spending in a Simple Model of Endogeneous Growth. Journal of Political Economy 98(5):103–125

Barth E, Bryson A, Davis JC, Freeman R (2016) It's where you work: Increases in the dispersion of earnings across establishments and Individuals in the United States. Journal of Labor Economics 34(2):67–97

Basu S, House C (2016) Allocative and remitted wages: New facts and challenges for Keynesian models. In: Taylor JB, Uhlig H (eds.) Handbook of Macroeconomics, Elsevier, vol. 2A, pp. 297–354

Berg A, Ostry JD, Tsangarides CG, Yakhshilikov Y (2018) Redistribution, inequality, and growth: New evidence. Journal of Economic Growth 23(3):259–305

Berg J (2015) Labour markets institutions: The building blocks of just societies. In: Berg J (ed.) Labour Markets, Institutions and Inequality: Building Just Societies in the 21st Century, Edward Elgar Publishing ; International Labour Office, Cheltenham, UK ; Northampton, MA, USA : Geneva, Switzerland, pp. 1–35

Berman N, Martin P, Mayer T (2012) How do Different Exporters React to Exchange Rate Changes? The Quarterly Journal of Economics 127(1):437–492

Bernard AB, Eaton J, Jensen JB, Kortum S (2003) Plants and Productivity in International Trade. The American Economic Review 93(4):94

Bernard AB, Jensen JB, Lawrence RZ (1995) Exporters, Jobs, and Wages in U.S. Manufacturing: 1976-1987. Brookings Papers on Economic Activity Microeconomics 1995:67–119

Bernard AB, Jensen JB, Redding SJ, Schott PK (2012) The Empirics of Firm Heterogeneity and International Trade. Annual Review of Economics 4(1):283–313

Bertola G, Dabusinskas A, Hoeberichts M, Izquierdo M, Kwapil C, Montornès J, Radowski D (2012) Price, wage and employment response to shocks: Evidence from the WDN survey. Labour Economics 19(5):783–791

Betcherman G (2012) Labor Market Institutions: A Review of the Literature. No. 6276 in Policy Research Working Papers, The World Bank

Bewley TF (2007) Insights gained from conversations with labor market decision makers. European Central Bank Working Paper Series 776

Bhaduri A, Marglin S (1990) Unemployment and the real wage: The economic basis for contesting political ideologies. Cambridge Journal of Economics 14:375–393

Bils MJ (1985) Real wages over the business cycle: Evidence from panel data. Journal of Political Economy 93(4):666–689

Bivens J, Mishel L (2015) Understanding the historic divergence between productivity and a typical worker's pay: Why it matters and why it's real. Economic Policy Institute Briefing Paper 406:1–30

Blanchflower DG (1991) Fear, Unemployment and Pay Flexibility. The Economic Journal 101(406):483–496

Blanchflower DG, Oswald AJ (1994) The Wage Curve. MIT Press, Cambridge, Mass

Blecker R (1989) International Competition, Income Distribution and Economic Growth. Cambridge Journal of Economics 13(3):395–412

Blecker RA (2016) Wage-led versus profit-led demand regimes : The long and the short of it. Review of Keynesian Economics 4(4):373–390

Bobeica E, Jarocinski M (2019) Missing Disinflation and Missing Inflation: A VAR Perspective. International Journal of Central Banking 15(1):34

Boneva L, Cloyne J, Weale M, Wieladek T (2020) Firms' Price, Cost and Activity Expectations: Evidence from Micro Data. The Economic Journal 130(627):555–586

Borio CEV, Filardo AJ (2007) Globalisation and Inflation: New Cross-Country Evidence on the Global Determinants of Domestic Inflation. BIS Working Papers 227

Bottazzi G, Secchi A (2003) Common Properties and Sectoral Specificities in the Dynamics of U.S. Manufacturing Companies. Review of Industrial Organization 23(3/4):217–232

Bourdieu P (1986) The forms of capital. In: Richardson J (ed.) Handbook of Theory and Research for the Sociology of Education, Greenwood, Westport, CT, pp. 241–258

Brzozowski M, Gervais M, Klein P, Suzuki M (2010) Consumption, income, and wealth inequality in Canada. Review of Economic Dynamics 13(1):52–75

Busato MI, Possas ML (2016) Restrição externa e crescimento simulando um modelo multissetorial aberto. Economia e Sociedade 25(2):279–313

Caiani A, Catullo E, Gallegati M (2018) The effects of fiscal targets in a monetary union: A Multi-Country Agent-Based Stock Flow Consistent model. Industrial and Corporate Change 27(6):1123–1154

Caiani A, Catullo E, Gallegati M (2019a) The effects of alternative wage regimes in a monetary union: A multi-country agent based-stock flow consistent model. Journal of Economic Behavior & Organization 162:389–416

Caiani A, Godin A, Caverzasi E, Gallegati M, Kinsella S, Stiglitz JE (2016) Agent based-stock flow consistent macroeconomics: Towards a benchmark model. Journal of Economic Dynamics and Control 69:375–408

Caiani A, Russo A, Gallegati M (2019b) Does inequality hamper innovation and growth? An AB-SFC analysis. Journal of Evolutionary Economics 29(1):177–228

Caju PD, Kosma T, Lawless M, Messina J, Rõõm T (2015) Why Firms Avoid Cutting Wages. ILR Review 68(4):862–888

Card D, Krueger AB (1995) Myth and Measurement: The New Economics of the Minimum Wage. Princeton University Press

Card D, Lemieux T, Riddell WC (2004) Unions and wage inequality. Journal of Labor Research XXV(4):519–559

Cardaci A, Saraceno F (2018) Between Scylla and Charybdis: Income distribution, consumer credit, and business cycle. Economic Inquiry 57(2):953–971

Cardaci A, Saraceno F (2019) Inequality and imbalances: A monetary union agent-based model. Journal of Evolutionary Economics 29(3):853–890

Carlin W, Soskice D (2014) Macroeconomics: Institutions, Instability, and the Financial System. Oxford University Press, Oxford, UK

Carlsson M, Skans ON (2012) Evaluating Microfoundations for Aggregate Price Rigidities: Evidence from Matched Firm-Level Data on Product Prices and Unit Labor Cost. American Economic Review 102(4):1571–1595

Carroll CD (2000) Why Do the Rich Save So Much? In: Slemrod J (ed.) Does Atlas Shrug? The Economic Consequences of Taxing the Rich, Harvard University Press, Cambridge, MA, pp. 463–485

Carvalho L, Di Guilmi C (2020) Technological unemployment and income inequality: A stock-flow consistent agent-based approach. Journal of Evolutionary Economics 30:39–73

Carvalho L, Rezai A (2016) Personal income inequality and aggregate demand. Cambridge Journal of Economics 40(2):491–505

Carvalho L, Rugitsky F (2015) Growth and distribution in Brazil the 21st century. Working Papers, Department of Economics, University of São Paulo (25)

Causa O, Hermansen M (2017) Income redistribution through taxes and transfers across OECD countries. OECD Economics Department Working Papers 1453:85

Cauvel M (2022) The Neo-Goodwinian model reconsidered. European Journal of Economics and Economic Policies: Intervention (Advanced access):1–32

Chirinko RS, Fazzari SM, Meyer AP (1999) How responsive is business capital formation to its user cost? An exploration with micro data. Journal of Public Economics 74:53–80

Ciarli T, Lorentz A, Savona M, Valente M (2010) The Effect of Consumption and Production Structure on Growth and Distribution. a Micro to Macro Model. Metroeconomica 61(1):180–218

Ciarli T, Lorentz A, Valente M, Savona M (2019) Structural changes and growth regimes. Journal of Evolutionary Economics 29(1):119–176

Cioppa TM, Lucas TW (2007) Efficient Nearly Orthogonal and Space-Filling Latin Hypercubes. Technometrics 49(1):45–55

Clark KB, Summers LH (1980) Demographic differences in cyclical employment variation. NBER Working Paper Series 514:1–27

Cornia GA (2014) Income Inequality in Latin America: Recent Decline and Prospects for Its Further Reduction, vol. 149 of ECLAC - Macroeconomics of Development Series. UNU-WIDER

Correa A, Petrassi M, Santos R (2018) Price-Setting Behavior in Brazil: Survey Evidence. Journal of Business Cycle Research 14(2):283–310

Cynamon BZ, Fazzari SM (2008) Household Debt in the Consumer Age: Source of Growth–Risk of Collapse. Capitalism and Society 3(2):1–30

Daly M, Hobijn B, Lucking B (2012) Why Has Wage Growth Stayed Strong? FRBSF Economic Letter 2012–10

Daudey E, García-Peñalosa C (2007) The personal and the factor distributions of income in a cross-section of countries. The Journal of Development Studies 43(5):812–829

Dawid H, Delli Gatti D (2018) Agent-Based Macroeconomics. In: Hommes C, LeBaron B (eds.) Handbook of Computational Economics, Elsevier, Amsterdam, vol. 4, pp. 63–156

Dawid H, Harting P, Neugart M (2014) Economic convergence: Policy implications from a heterogeneous agent model. Journal of Economic Dynamics and Control 44:54–80

Dawid H, Harting P, van der Hoog S, Neugart M (2019) Macroeconomics with heterogeneous agent models: Fostering transparency, reproducibility and replication. Journal of Evolutionary Economics 29(1):467–538

Dawid H, Hepp J (2021) Distributional Effects of Technological Regime Changes: Hysteresis, Concentration and Inequality Dynamics. Universitat Bielefeld Faculty of Business Administration and Economics - Working Papers in Economics and Management 09–2021

De Loecker J, Eeckhout J, Unger G (2020) The Rise of Market Power and the Macroeconomic Implications. The Quarterly Journal of Economics 135(2):561–644

Deissenberg C, van der Hoog S, Dawid H (2008) EURACE: A massively parallel agent-based model of the European economy. Applied Mathematics and Computation 204(2):541–552

Dickens WT, Goette L, Holden S, Messina J, Turunen J, Ward ME (2007) How Wages Change: Micro Evidence from the International Wage Flexibility Project. Journal of Economic Perspectives 21(2):195–214

Doms M, Dunne T (1998) Capital Adjustment Patterns in Manufacturing Plants. Review of Economic Dynamics 1(2):409–429

Dorn F, Fuest C, Potrafke N (2017) Globalization and Income Inequality Revisited. European Economy Discussion Paper 56

Dosi G (2007) Statistical regularities in the evolution of industries: A guide through some evidence and challenges for the theory. In: Malerba F, Brusoni S (eds.) Perspectives on Innovation, Cambridge University Press, Cambridge, UK, pp. 153–186

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

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

Dosi G, Freeman RB, Pereira MC, Roventini A, Virgillito ME (2021) The impact of deunionization on the growth and dispersion of productivity and pay. Industrial and Corporate Change 30(2):377–408

Dosi G, Napoletano M, Roventini A, Stiglitz JE, Treibich T (2020) Rational Heuristics? Expectations and Behaviors in Evolving Economies with Heterogeneous Interacting Agents. Economic Inquiry 58(3):1487–1516

Dosi G, Pereira MC, Roventini A, Virgillito ME (2017) When more flexibility yields more fragility: The microfoundations of Keynesian aggregate unemployment. Journal of Economic Dynamics and Control 81:162–186

Dosi G, Pereira MC, Roventini A, Virgillito ME (2018) The effects of labour market reforms upon unemployment and income inequalities: An agent-based model. Socio-Economic Review 16(4):687–720

Dosi G, Roventini A (2019) More is different ... and complex! the case for agent-based macroeconomics. Journal of Evolutionary Economics 29(1):1–37

Dosi G, Roventini A, Russo E (2019) Endogenous growth and global divergence in a multi-country agent-based model. Journal of Economic Dynamics and Control 101:101–129

Dube A (2019) Impacts of Minimum Wages: Review of the International Evicence. Independent Report, UK Government Publication

Duesenberry J (1949) Income, Saving and the Theory of Consumption Behavior. Cambridge, MA: Harvard University Press

Dunne T, Foster L, Haltiwanger J, Troske KR (2004) Wage and Productivity Dispersion in United States Manufacturing: The Role of Computer Investment. Journal of Labor Economics 22(2):397–429

Dutt AK (1984) Stagnation, income distribution and monopoly power. Cambridge Journal of Economics 8(1):25–40

Dweck E (2006) Uma análise da interação micro-macro com base em um modelo dinâmico multissetorial de simulação Ph.D. Dissertation, Federal University of Rio de Janeiro

Dweck E, Vianna MT, Barbosa AdC (2020) Discussing the role of fiscal policy in a demand-led agent-based growth model. EconomiA 21(2):185–208

Dynan KE, Skinner J, Zeldes SP (2004) Do the Rich Save More? Journal of Political Economy 112(2):397–444

Engbom N, Moser C (2021) Earnings inequality and the minimum wage: Evidence from Brazil. NBER Working Paper Series 28831

Fabiani S, Druant M, Hernando I, Kwapil C, Landau B, Loupias C, Martins F, Matha T, Sabbatini R, Stahl H, Stokman A (2006) What Firms' Surveys Tell Us about Price-Setting Behavior in the Euro Area. International Journal of Central Banking 2(3):3–47

Fabiani S, Kwapil C, Rõõm T, Galuscak K, Lamo A (2010) Wage rigidities and labor market adjustment in Europe. Journal of the European Economic Association 8(2-3):497–505

Fagiolo G, Dosi G, Gabriele R (2004) Matching, bargaining, and wage setting in an evolutionary model of labor market and output daynamics. Advances in Complex Systems 7(2):157–186

Fagiolo G, Napoletano M, Roventini A (2008) Are output growth-rate distributions fat-tailed? some evidence from OECD countries. Journal of Applied Econometrics 23:639–669

Fagiolo G, Roventini A (2017) Macroeconomic Policy in DSGE and Agent- Based Models Redux: New Developments and Challenges Ahead p. 37

Fisher JD, Johnson DS, Smeeding TM (2013) Measuring the Trends in Inequality of Individuals and Families: Income and Consumption. American Economic Review 103(3):184–188

FitzGerald EVK (1996) The New Trade Regime, Macroeconomic Behaviour and Income Distribution in Latin America, Palgrave Macmillan UK, London, pp. 29–52

Freeman R, Medoff J (1979) The Two Faces of Unionism. NBER Working Paper Series 364

Freeman RB (1980) Unionism and the Dispersion of Wages. Industrial and Labor Relations Review 34(1):3–23

Freeman RB (1996) The Minimum Wage as a Redistributive Tool. The Economic Journal 106(436):639–649

Galuscak K, Keeney M, Nicolitsas D, Smets F, Strzelecki P, Vodopivec M (2012) The determination of wages of newly hired employees: Survey evidence on internal versus external factors. Labour Economics 19(5):802–812

Gennaioli N, Ma Y, Shleifer A (2016) Expectations and Investment. National Bureau of Economic Research Macroeconomics Annual 30(1):379–431

Gerber C, Klemm A, Liu L, Mylonas V (2020) Income Tax Progressivity: Trends and Implications. Oxford Bulletin of Economics and Statistics 82(2):365–386

Giovannoni O (2010) Functional Distribution of Income, Inequality and the Incidence of Poverty: Stylized Facts and the Role of Macroeconomic Policy. UTIP Working Paper 58

Glyn A (2011) Functional Distribution and Inequality. In: Nolan B, Salverda W, Smeeding TM (eds.) The Oxford Handbook of Economic Inequality, Oxford University Press

Godley W, Lavoie M (2012) Monetary Economics: An Integrated Approach to Credit, Money, Income, Production and Wealth. Palgrave MacMillan, Basingstoke, UK, 2nd edn.

Goldberg PK, Pavcnik N (2007) Distributional Effects of Globalization in Developing Countries. Journal of Economic Literature XLV:39–82

Guschanski A, Onaran Ö (2021) The decline in the wage share: Falling bargaining power of labour or technological progress? Industry-level evidence from the OECD. Socio-Economic Review pp. 1–34

Haldane AG, Turrell AE (2018) An interdisciplinary model for macroeconomics. Oxford Review of Economic Policy 34(1-2):219–251

Heathcote J, Perri F, Violante GL (2010) Unequal we stand: An empirical analysis of economic inequality in the United States, 1967–2006. Review of Economic Dynamics 13(1):15–51

Herzer D (2016) Unions and Income Inequality: A Heterogeneous Panel Co-integration and Causality Analysis. LABOUR 30(3):318–346

Hicks DA (1997) The inequality-adjusted human development index: A constructive proposal. World Development 25(8):1283–1298

ILO (2008) Global Wage Report 2008/09. International Labor Office, Geneva

ILO (ed.) (2008) World of Work Report. 2008: Income Inequalities in the Age of Financial Globalization

IMF (2014) Fiscal Policy and Income Inequality. Policy Papers 14

Jacobo AD, Marengo A (2020) Are the Business Cycles of Argentina and Brazil Different? New Features and Stylized Facts. Paradigma económico 12(2):5–38

Jaimovich N, Rebelo S (2012) Non-linear Effects of Taxation on Growth. NBER Working Paper Series 18473

Jardim ES, Solon G, Vigdor JL (2019) How prevalent is downward rigidity in nominal wages? Evidence from payroll records in Washington state. NBER Working Paper Series 25470

Jaumotte F, Buitron CO (2015) Inequality and Labor Market Institutions. IMF Staff Discussion Note 15/14

Jaumotte F, Lall S, Papageorgiou C (2013) Rising Income Inequality: Technology, or Trade and Financial Globalization? IMF Economic Review 61(2):271–309

Kalecki M (1971) Selected Essays on the Dynamics of the Capitalist Economy 1933-1970. Cambridge University Press, Cambridge, UK

Karanassou M, Sala H (2010) The Wage-Productivity Gap Revisited: Is the Labour Share Neutral to Employment? IZA Discussion Paper 5092:1–41

Kim YK, Setterfield M, Mei Y (2014) A theory of aggregate consumption. European Journal of Economics and Economic Policies: Intervention 11(1):31–49

Kim YK, Setterfield M, Mei Y (2015) Aggregate consumption and debt accumulation: An empirical examination of US household behaviour. Cambridge Journal of Economics 39(1):93–112

Krugman P (1986) Pricing to Market when the Exchange Rate Changes. NBER Working Paper Series 1926

Krugman P, Taylor L (1978) Contractionary effects of devaluation. Journal of International Economics 8:445–456

Kydland FE (1984) Labor-force heterogeneity and the business cycle. Carnegie-Rochester Conference Series on Public Policy 21:173–208

Lavoie M (2014) Post-Keynesian Economics: New Foundations. Edward Elgar, Cheltenham, UK

Lavoie M (2017) The origins and evolution of the debate on wage-led and profit-led regimes. European Journal of Economics and Economic Policies: Intervention 14(2):200–221

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

Lee DS (1999a) Wage inequality in the United States during the 1980s: Rising dispersion or falling minimum wage? The Quarterly Journal of Economics 114(3)

Lee FS (1999b) Post Keynesian Price Theory. Cambridge University Press

Machin S (2008) An Appraisal of Economic Research on Changes in Wage Inequality. Labour 22(1):7–26

Maestri V, Roventini A (2012) Inequality and Macroeconomic Factors: A Time-Series Analysis for a Set of OECD Countries. Laboratory of Economics and Management Paper Series 2012/21

Mahler VA, Jesuit DK (2006) Fiscal redistribution in the developed countries: New insights from the Luxembourg Income Study1. Socio-Economic Review 4(3):483–511

Melo TM, Possas ML, Dweck E (2016) Um modelo setorial baseado na abordagem kaleckiana da distribuição setorial funcional da renda e na teoria schumpeteriana da concorrência. Economia e Sociedade 25(1):109–145

Meltzer AH, Richard SF (1981) A Rational Theory of the Size of Government. Journal of Political Economy 89(5):914–927

Meyer BD (2002) Unemployment and workers' compensation programmes: Rationale, design, labour supply and income support. Fiscal Studies 23(1):1–49

Milanovic B (2000) The median-voter hypothesis, income inequality, and income redistribution: An empirical test with the required data. European Journal of Political Economy 16(3):367–410

Milanovic B (2005) Can We Discern the Effect of Globalization on Income Distribution? Evidence from Household Surveys. The World Bank Economic Review 19(1):21–44

Mishel L, Bivens J (2021) Identifying the policy levers generating wage suppression and wage inequality. Economic Policy Institute pp. 1–105

Mohun S (2006) Distributive shares in the US economy, 1964–2001. Cambridge Journal of Economics 30(3):347–370

Mohun S (2014) Unproductive labor in the U.S. economy 1964-2010. Review of Radical Political Economics 46(3):355–379

Mohun S (2016) Class structure and the US personal income distribution, 1918-2012. Metroeconomica 67(2):334–363

Nadir MI, Prucha IR (1996) Estimation of the depreciation rate of physical and R&D Capital in the U.S. total manufacturing sector. Economic Inquiry 34(1):43–56

Nelson RR, Winter SG (1982) An Evolutionary Theory of Economic Change. Belknap Press, Cambridge, MA

Neri M, Gonzaga G, Camargo JM (2001) Salário Mínimo, "Efeito-Farol" e Pobreza. Brazilian Journal of Political Economy 21(2):263–276

OCDE (2011) Divided We Stand: Why Inequality Keeps Rising. OECD Publishing

OECD (1994) OECD Jobs Study. Techinical Report, OECD

Oliveira AdRML, Lima GT, Carvalho L (2020) Of fairies and governments: An ABM evaluation of the expansionary austerity hypothesis. EconomiA 21(2):233–254

Ostry JD, Loungani P, Berg A (2019) Confronting Inequality - How Societies Can Choose Inclusive Growth. Columbia University Press

Palagi E, Napoletano M, Roventini A, Gaffard JL (2017) Inequality, Redistributive Policies and Multiplier Dynamics in an Agent-based Model with Credit Rationing. Italian Economic Journal 3(3):367–387

Pedrosa Í, Lang D (2021) To what extent does aggregate leverage determine financial fragility? New insights from an agent-based stock-flow consistent model. Journal of Evolutionary Economics 21:1221–1275

Petrović M, Ozel B, Teglio A, Raberto M, Cincotti S (2017) Eurace Open: An agent-based multi-country model. Working Paper Series of the Economics Department of the Universitat Jaume I, Castellón (Spain) 2017/09

Piketty T, Saez E (2006) The Evolution of Top Incomes: A Historical and International Perspective. American Economic Review 96(2):200–205

Possas ML, Dweck E (2004) A Multisectoral Micro-Macrodynamic Model. EconomiA 5(3):1–43

Possas ML, Dweck E, Vianna MT (2020) Technical Change and Effective Demand: Insights in a new simplified version of the Micro-Macro Multisectoral model. In: 48o Encontro Nacional de Economia, Brazil

Reynolds M, Smolensky E (1977) Post-fisc distributions of income in 1950, 1961 and 1970. Public Finance Quarterly 5(4):419–438

Ribeiro RS, McCombie JS, Lima GT (2020) Does real exchange rate undervaluation really promote economic growth? Structural Change and Economic Dynamics 52:408–417

Ribeiro RSM, McCombie JSL, Lima GT (2017) Some unpleasant currency-devaluation arithmetic in a post Keynesian macromodel. Journal of Post Keynesian Economics 40(2):145–167

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

Rodrik D (1997) Has Globalization Gone Too Far? Institute of International Economics, Washington D.C

Rodrik D (2021) A primer on trade and inequality. NBER Working Paper Series 29507:1–12

Rogoff K (1996) The Purchasing Power Parity Puzzle. Journal of Economic Literature 34(2):647–668

Rolim LN (2019) Overhead labour and feedback effects between capacity utilization and income distribution: Estimations for the USA economy. International Review of Applied Economics 33(6):756–773

Rolim LN (2021) A note on 'Wage-led versus profit-led demand regimes: The long and the short of it'. Review of Keynesian Economics 9(3):413–424

Rossi D, Galbraith J (2016) Exchange Rates and Industrial Wage Inequality in Open Economies. UTIP Working Paper 71:1–23

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

Rowthorn RE (1977) Conflict, inflation and money. Cambridge Journal of Economics 1:215–239

Rutkowski J (2003) The minimum wage: Curse or cure? Human Development Economics Europe and Central Asia Region, The World Bank

Sabirianova Peter K, Buttrick S, Duncan D (2010) Global reform of personal income taxation, 1981-2005: Evidence from 189 countries. National Tax Journal 63:447–78

Salle I, Yıldızoğlu M (2014) Efficient Sampling and Meta-Modeling for Computational Economic Models. Computational Economics 44(4):507–536

Saltelli A, Ratto M, Andres T, Campolongo F, Cariboni J, Gatelli D, Saisana M, Tarantola S (2008) Global Sensitivity Analysis: The Primer. John Wiley & Sons, Chichester, UK

Sánchez-Ancochea D (2021) The surprising reduction of inequality during a commodity boom: What do we learn from Latin America? Journal of Economic Policy Reform 24(2):95–118

Santoro JPC (2020) Conflito, inflação e distribuição: Três ensaios heterodoxos. Ph.D. Dissertation, University of Campinas

Schmitt-Grohé S, Uribe M (2013) Downward Nominal Wage Rigidity and the Case for Temporary Inflation in the Eurozone. Journal of Economic Perspectives 27(3):193–212

Schneider D (2011) The Labor Share: A Review of Theory and Evidence. SFB 649 Discussion Paper 2011–069

Seppecher P (2012) Flexibility of wages and macroeconomic instability in an agent-based computational model with endogenous money. Macroeconomic Dynamics 16(S2):284–297

Setterfield M (2021) Whatever Happened to the 'Goodwin Pattern'? Profit Squeeze Dynamics in the Modern American Labour Market. Review of Political Economy Ahead-of-print:1–24

Setterfield M, Blecker RA (2022) Structural change in the US Phillips curve, 1948-2021: The role of power and institutions. The New School for Social Research - Department of Economics Working Paper 01/2022

Sharpe SA, Suarez GA (2014) Why isn't Investment More Sensitive to Interest Rates: Evidence from Surveys. Finance and Economics Discussion Series 2:1–49

Silverberg G, Dosi G, Orsenigo L (1988) Innovation, Diversity and Diffusion: A Self-Organisation Model. The Economic Journal 98(393):1032–1054

Simon HA (1959) Theories of decision-making in economics and behavioural science. The American Economic Review 49(253–283)

Sobol I (2001) Global sensitivity indices for nonlinear mathematical models and their Monte Carlo estimates. Mathematics and Computers in Simulation 55(1-3):271–280

Solon G, Barsky R, Parker JA (1994) Measuring the Cyclicality of Real Wages: How Important is Composition Bias? The Quarterly Journal of Economics 109(1):1–25

Stanley MH, Buldyrev SV, Havlin S, Mantegna RN, Salinger MA, Eugene Stanley H (1995) Zipf plots and the size distribution of firms. Economics Letters 49(4):453–457

Stansbury A, Summers LH (2020) The Declining Worker Power Hypothesis: An explanation for the recent evolution of the American economy. NBER Working Paper Series 27193

Stiglitz JE (2012) The Price of Inequality. W.W. Norton and Co, New York

Stock JH, Watson MW (1999) Business Cycle Fluctuations in US Macroeconomic Time Series. In: Taylor J, Woodford M (eds.) Handbook of Macroeconomics, Elsevier, Amsterdam, vol. 1A, pp. 3–64

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

Stolper WF, Samuelson PA (1941) Protection and Real Wages. The Review of Economic Studies 9(1):58–73

Storm S (2022) Inflation in the Time of Corona and War. Institute for New Economic Thinking Working Papers 185

Summa R, Braga J (2019) The (conflict-augmented) Phillips curve is 'alive and well'. Discussion Paper UFRJ IE (003/2019)

Terranova R, Turco EM (2022) Concentration, stagnation and inequality: An agent-based approach. Journal of Economic Behavior and Organization 193:569–595

Tippet B, Onaran Ö, Wildauer R (2021) The Determinants of Wealth Inequality in the UK, USA and France. Greenwich Papers in Political Economy GPERC80

Toledo M (2008) Understanding Business Cycles in Latin America. Manuscript

Warmedinger T (2004) Import prices and pricing-to-market effects in the euro area. European Central Bank Working Paper Series 299

Wolff EN, Zacharias A (2013) Class structure and economic inequality. Cambridge Journal of Economics 37(6):1381–1406

Wolfson MH (1996) A Post Keynesian Theory of Credit Rationing. Journal of Post Keynesian Economics 18(3):443–470

Appendix A: Transaction flows matrix

The interactions between the agents in chapter 1 are represented by the transaction flows matrix in table A.1 . Aggregate values are calculated before the entry and exit of consumption goods firms takes place. These aggregate values are used to evaluate the consistency of the model by checking if the relations expressed by table A.1 hold. We also check for the consistency of real and nominal output from the income, expenditure, and production approaches.

Table A.1 : Transaction flows matrix

	Households	Consumption goods firms		Capital goods firm		Bank	Public sector	$\sum$
		Current	Capital	Current	Capital			
Consumption	$-C^{\$}_{H,t}$	$+Q^{s,\$}_{C,t}$						0
Investment			$-I^{\$}_{C,t}$	$+Q^{\$}_{k,t}$				0
Inventories		$+\Delta Q^{IN,\$}_{C,t}$	$-\Delta Q^{IN,\$}_{C,t}$					0
Wages	$+W^{\$}_{H,t}$	$-W^{\$}_{C,t}$		$-W^{\$}_{k,t}$			$-W^{\$}_{g,t}$	0
Profits	$+\Pi^{h,\$}_{H,t}$	$-\Pi^{n,\$}_{C,t}$	$+(\Pi^{n,\$}_{C,t} - \Pi^{h,\$}_{C,t})$	$-\Pi^{n,\$}_{k,t}$	$+(\Pi^{n,\$}_{k,t} - \Pi^{h,\$}_{k,t})$			0
Unemployment benefits	$+d^{\$}_{H,t}$						$-d^{\$}_{H,t}$	0
Taxes	$-\mathcal{T}^{\$}_{H,t}$						$+\mathcal{T}^{\$}_{H,t}$	0
Loan interest		$-i\Lambda^{\$}_{C,t-1}$				$+i\Lambda^{\$}_{C,t-1}$		0
Deposit interest	$+iD^{\$}_{H,t-1}$	$+iD^{\$}_{C,t-1}$		$+iD^{\$}_{k,t-1}$		$-iD^{\$}_{b,t-1}$		0
Bonds interest						$+iB^{\$}_{t-1}$	$-iB^{\$}_{t-1}$	0
Change in loans			$+\Delta\Lambda^{\$}_{C,t}$			$-\Delta\Lambda^{\$}_{C,t}$		0
Change in deposits	$-\Delta D^{\$}_{H,t}$		$-\Delta D^{\$}_{C,t}$		$-\Delta D^{\$}_{k,t}$	$+\Delta D^{\$}_{t}$		0
Change in bonds						$-\Delta B^{\$}_{t}$	$+\Delta B^{\$}_{t}$	0
$\sum$	0	0	0	0	0	0	0	0

Note: The subscripts H and C the aggregate values of the households and consumption goods firms sectors respectively. The $+$ sign identifies sources of funds and the $-$ sign identifies uses of funds. Source: author's own elaboration.

Appendix B: Model initialization and parameters

In chapter 1, the proportion of capitalists, indirect and direct workers reflect the Brazilian social structure reported by Baltar and Rolim (2018). Accordingly, the number of indirect workers and capitalists depends on the number of direct workers, as follows:

$$N^{ind} = \left\lceil \frac{N^{dir}}{n^{dir}} n^{ind} \right\rceil \tag{3.1}$$

$$N^{cap} = \left\lceil \frac{N^{dir}(1 - n^{dir} - n^{ind})/n^{dir}}{N^c + N^k} \right\rceil (N^c + N^k) \tag{3.2}$$

where N^{dir} is the number of direct workers, n^{dir} and n^{ind} are the proportion of direct and indirect workers respectively. The number of capitalists per firm is equal to $\rho_1 = N^{cap}/(N^c + N^k)$. The number of direct workers as public servants (L_g^{dir}) is given by a multiple n^g of the number of direct workers employed by the private sector in the model's initialization, while the number of indirect workers as public servants is given by $L_g^{ind} = L_g^{dir} \lceil N^{ind}/N^{dir} \rfloor$.

Workers' initial wages are set according to their class, as follows:

$$w^{dir,\$} = \varrho_1 w_0^{min,\$} \tag{3.3}$$

$$w^{ind,\$} = \varrho_2 w^{dir,\$} \tag{3.4}$$

where $\varrho_{1,2} > 1$ are parameters. These initial wages represent the initial desired wages by firms and workers as well as the wage paid by all sectors in $t = 0$. Firms start the simulation with a number of employees given by their initial production level and the government starts with the fixed number of employees (L_g^{ind} and L_g^{dir}). Workers who are employed in $t = 0$ are assumed to be working since $t = -3$, while unemployed workers in $t = 0$ are assumed to have had their last employment in $t = -4$.

Consumption goods firms start with the same full capacity production level ($Q_{c,0}^{fc}$). It is assumed that the machines were produced between $t = -T^k/2$ and $t = 0$ and that their productivity rates differ by a factor $\varrho_3 > 0$ per period.[44] Thus, each firm has a heterogeneous set of machines, but, as this heterogeneity is equal for all firms, there is a homogeneous composition

[44] For instance, if a machine is assumed to belong to a vintage from $t = -T^k/2$, its productivity will be equivalent to a ratio $(1 - \varrho_3)^{T^k/2}$ of the productivity of a machine produced in $t = 0$.

of the capital stock across firms. It is also assumed that firms' initial production and sales are equal to their desired capacity utilization level and that inventories are at the desired level. The capital goods firm's initial production is proportional to the number of capital goods owned by the consumption goods firms and their lifetime and it is assumed that there is no increase in productivity in the first time step. The bank's initial liabilities are equal to the sum of deposits held by all agents and its net worth (for simplicity, set at the same value as the sum of deposits). Its assets are equal to the consumption goods firms' initial loans (assumed to be equal to their production costs in $t = 0$) and the government bonds (whose value closes the bank's initial balance sheet). Thus, in the initial period the central bank does not hold any government bonds.

The parameters used in the baseline scenario are reported below:

Table B.1: Parameters and initial values in baseline scenario

Symbol	Description	Value
α, β	Beta distribution parameters (innovation)	(3, 3)
γ_1	sensitivity of desired wage by workers to inflation	1
γ_2	sensitivity of desired wage by workers to output growth rate	1
γ_3	sensitivity of reservation wage to periods of unemployment	0.05
γ_4	minimum difference between desired and reservation wages	0.1
δ	entrant firms' expected sales share of sector average sales (C sector)	0.5
ζ	search capability (K firm)	0.18
ϑ	employees turnover share	0.05
$\mu_{c,0}$	initial mark-up rate (C firms)	0.7
μ_k	mark-up rate (K firm)	0.6
ν_1	sensitivity of mark-up rate to market share (C firms)	0.04
ν_2	mark-up deviation persistence (C firms)	0.99
ν_3	sensitivity of mark-up deviation to unit costs (C firms)	0.25
ν_4	sensitivity of market share to competitiveness (C firms)	1
ρ_1	number of capitalists per firm*	1
ρ_2	proportion of revenue to R&D (K firms)	0.15
ρ_3	managers per direct workers (K firms)	0.24
ρ_4	indirect workers per direct worker (C firms)	0.28
ρ_5	indirect workers per direct worker at full capacity production (C firms)	0.09
ϱ_1	initial ratio between direct workers wage and minimum wage	2
ϱ_2	initial ratio between indirect workers wage and direct workers wage	2
ϱ_3	initial productivity difference between vintages	0.001

continued ...

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Symbol	Description	Value
τ	tax rate on income	0.05
ϕ	sensitivity of workers' bargaining power to employment rate	0.9
$\omega_{1,2,3,4}$	sensitivity of expected demand to past demand (C firms)	(0.4, 0.3, 0.2, 0.1)
b	payback rule threshold	2
c_1	real consumption persistence	0.9
$c_2^{dir,ind,cap}$	propensity to consume out of income (direct workers, indirect workers, capitalists)	(0.95, 0.85, 0.7)
h	sensitivity of productivity to unfilled demand for managers and supervisors	1
i	base interest rate	0.002
$L_g^{dir,ind}$	workers hired as public servants *	(287,116)
ms^{min}	minimum market share to stay in the market (C firms)	0.0005
N^c	number of consumption goods firms	200
$N^{dir,ind,cap}$	number of direct workers, indirect workers*, and capitalists*	(1754,707,201)
$n^{dir,ind}$	percentage of direct and indirect workers in total population	(0.67, 0.27)
n^g	proportion of public servants in total initial employment (direct workers)	0.2
n^{IN}	desired share of inventories	0.1
$n^{s,dir,ind}$	proportion of workers in survey	(0.15, 0.3)
n^w	number of hiring rounds per open position	1.5
$Q_{c,0}^{fc}$	initial full capacity production (C firms)	80
Q_m^{fc}	machines production at full capacity	2.5
R	maximum interest payments to cash flow ratio	0.1
T^c	number of periods before a new firm can exit the market	5
T^k	machines lifetime	20
u^d	desired capacity utilization level	0.8
$w_0^{min,\$}$	initial minimum wage	1
x	Beta distribution support parameter	0.1

Note: $\star$ identifies values determined in the model's initialization. Equation or section numbers in parentheses indicate where the parameters first appear in the text. Source: author's own elaboration.

Appendix C: Model parameters

The initial conditions for the open economy model are set following the procedure outlined for the closed economy model (Appendix A). The parameters used in the baseline scenario in chapter 2 are reported below:

Table C.1: Parameters and initial values in baseline scenario

Symbol	Description	Value
α, β	Beta distribution parameters (innovation)	(3, 3)
γ_1	sensitivity of desired wage by workers to inflation	1
γ_2	sensitivity of desired wage by employed workers to output growth rate	1
γ_5	sensitivity of desired wage by unemployed workers to periods of unemployment	0.01
γ_6	sensitivity of firms' desired wage to change in unemployment rate	0.5
γ_7	adjustment in offered wage in case of unfilled job positions	0.1
δ	entrant firms' expected sales share of sector average sales (C sector)	0.5
ζ	search capability (K firm)	0.034
ϑ	employees turnover share	0.05
λ_1	interest rate smoothing parameter	0.5
λ_2	interest rate sensitivity to inflation gap	0.5
λ_3	exchange rate sensitivity to trade balance	0.15
λ_4	exchange rate sensitivity to change in the interest rate differential	2
$\mu_{c,0}$	initial mark-up rate (C firms)	0.8
μ^{min}	minimum mark-up rate (C firms)	0.1
μ_k	mark-up rate (K firm)	0.6
ν_1	sensitivity of mark-up rate to market share (C firms)	0.04
ν_2	mark-up deviation persistence (C firms)	0.99
ν_3	sensitivity of mark-up rate to unit costs (C firms)	0.1
ν_4	sensitivity of market share to competitiveness (C firms)	1
ν_5	sensitivity of mark-up rate to exports growth (C firms)	0.2
ρ_1	number of capitalists per firm*	1

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Symbol	Description	Value
ρ_2	proportion of revenue to R&D (K firms)	0.15
ρ_3	managers per direct workers in (K firms)	0.24
ρ_4	indirect workers per direct worker (C firms)	0.24
ρ_5	indirect workers per direct worker at full capacity production (C firms)	0.1
ϱ_1	initial ratio between direct workers wage and minimum wage	1.5
ϱ_2	initial ratio between indirect workers wage and direct workers wage	1.5
ϱ_3	initial productivity difference between vintages	0.001
τ	tax rate on income	0.15
τ^i	tax rate on interest on deposits	0.15
ι_1	sensitivity of probability of exporting to domestic market share	100
ι_2	maximum domestic firms' market share of foreign market	8e-05
ι_3	sensitivity domestic firms' market share of foreign market to price competitiveness	0.8
ι_4	maximum foreign sector's market share of the domestic market	0.3
ι_5	sensitivity foreign sector's market share of the domestic market to price competitiveness	0.8
ϕ	sensitivity of surveyed wage weight in bargaining to employment rate	0.9
b	payback rule threshold	3
c_1	real consumption persistence	0.8
$c_2^{dir,ind,cap}$	propensity to consume out of income (direct workers, indirect workers, capitalists)	(0.95, 0.85, 0.75)
c_3	propensity to consume out of deposits	0.001
c_x	foreign sector's propensity to consume	0.8
g_x	foreign sector's real output growth rate	0.008
h	sensitivity of productivity to unfilled demand for managers and supervisors	1
i_0	initial base interest rate	0.01
i_{min}	minimum base interest rate	1e-07
i_x	foreign sector's interest rate	0.005
k	pricing to market parameter	0.1
$L_g^{dir,ind}$	workers hired as public servants *	(287, 116)
ms^{min}	minimum market share to stay in the market (C firms)	0.0005
ms^{exp}	minimum market share for accessing foreign market (exporters)	0.005

continued ...

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Symbol	Description	Value
N^c	number of consumption goods firms	200
$N^{dir,ind,cap}$	number of direct workers, indirect workers*, and capitalists*	(1754, 707, 201)
$n^{dir,ind}$	percentage of direct and indirect workers in total population	(0.67, 0.27)
n^g	proportion of public servants in total initial employment (direct workers)	0.2
n^{IN}	desired share of inventories	0.1
$n^{s,dir,ind}$	proportion of workers in survey	(0.15, 0.3)
n^w	number of hiring rounds per open position	1.5
$\hat{p}^T$	inflation rate target	0.005
$\hat{p}_x$	foreign sector's inflation rate	0.005
$Q_{c,0}^{fc}$	initial full capacity production (C firms)	80
Q_m^{fc}	machines production at full capacity	2.5
R	maximum interest payments to cash flow ratio	0.4
s	sensitivity of probability of on-the-job search to difference in wages	5
T^c	number of periods before a new firm can exit the market	5
T^e	number of periods in the exchange rate adjustment to a change in the interest rate differential	4
T^k	machines lifetime	20
T^p	number of periods in average inflation (inflation targeting regime)	1
T^u	number of periods of unemployment benefit	4
u^d	desired capacity utilization level	0.8
$w_0^{min,\$}$	initial minimum wage	1
v	expansion investment adjustment speed	0.5
$\hat{w}^{max}$	maximum desired wage real growth rate	0.1
x	Beta distribution support parameter	0.15

Note: $\star$ identifies values determined in the model's initialization. Source: author's own elaboration.

Appendix D: Model parameters

The initial conditions for the open economy model are set following the procedure outlined for the closed economy model (Appendix A). The parameters used in the baseline scenario in chapter 3 are reported below:

Table D.1: Parameters and initial values in baseline scenario

Symbol	Description	Value
α, β	Beta distribution parameters (innovation)	(3, 3)
γ_1	sensitivity of desired wage by workers to inflation	1
γ_2	sensitivity of desired wage by employed workers to output growth rate	1
γ_5	sensitivity of desired wage by unemployed workers to employment rate	0.001
γ_6	sensitivity of firms' desired wage to change in unemployment rate	0.1
γ_7	sensitivity of offered wage to hiring	0.1
δ	entrant firms' expected sales share of sector average sales (C sector)	0.5
ζ	search capability (K firm)	0.04
ϑ	employees turnover share	0.05
λ_1	interest rate smoothing parameter	0.2
λ_2	interest rate sensitivity to inflation gap	0.5
λ_3	exchange rate sensitivity to trade balance	0.1
λ_4	exchange rate sensitivity to interest rate differential	2
$\mu_{c,0}$	initial mark-up rate (C firms)	0.5
μ^{min}	minimum mark-up rate (C firms)	0.1
μ_k	mark-up rate (K firm)	0.6
ν_1	sensitivity of mark-up rate to market share (C firms)	0.04
ν_2	mark-up deviation persistence (C firms)	0.99
ν_3	sensitivity of mark-up rate to unit costs (C firms)	0.1
ν_4	sensitivity of market share to competitiveness (C firms)	1
ν_5	sensitivity of mark-up rate to exports growth (C firms)	0.2
ρ_1	number of capitalists per firm*	1
ρ_2	proportion of revenue to R&D (K firms)	0.15

continued ...

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Symbol	Description	Value
ρ_3	managers per direct workers in (K firms)	0.24
ρ_4	indirect workers per direct worker (C firms)	0.24
ρ_5	indirect workers per direct worker at full capacity production (C firms)	0.1
ϱ_1	initial ratio between direct workers wage and minimum wage	2
ϱ_2	initial ratio between indirect workers wage and direct workers wage	2
ϱ_3	initial productivity difference between vintages	0.001
τ	target tax rate on income	0.15
τ_{dif}	difference in the tax rates	0
τ^i	tax rate on interest on deposits	0.15
ι_1	sensitivity of probability of exporting to domestic market share	25
ι_2	maximum domestic firms' market share of foreign market	5e-05
ι_3	sensitivity domestic firms' market share of foreign market to price competitiveness	0.8
ι_4	maximum foreign sector's market share of the domestic market	0.15
ι_5	sensitivity foreign sector's market share of the domestic market to price competitiveness	0.8
ϕ	sensitivity of surveyed wage weight in bargaining to employment rate	0.4
b	payback rule threshold	3
c_1	real consumption persistence	0.8
$c_2^{dir,ind,cap}$	propensity to consume out of income (direct workers, indirect workers, capitalists)	(0.95, 0.85, 0.75)
c_3	propensity to consume out of deposits	0.005
c_x	foreign sector's propensity to consume	0.8
g_x	foreign sector's real output growth rate	0.008
h	sensitivity of productivity to unfilled demand for managers and supervisors	0.05
i_0	initial base interest rate	0.01
i_{min}	minimum base interest rate	1e-07
i_x	foreign sector's interest rate	0.005
k	pricing to market parameter (exports)	0
$L_g^{dir,ind}$	workers hired as public servants *	(287, 116)
ms^{min}	minimum market share to stay in the market (C firms)	0.0005
ms^{exp}	minimum market share for accessing foreign market (exporters)	0.005

continued ...

...continued

Symbol	Description	Value
N^c	number of consumption goods firms	200
$N^{dir,ind,cap}$	number of direct workers, indirect workers*, and capitalists*	(1754, 707, 201)
$n^{dir,ind}$	percentage of direct and indirect workers in total population	(0.67, 0.27)
n^g	proportion of public servants in total initial employment (direct workers)	0.2
n^{IN}	desired share of inventories	0.1
n^{mw}	threshold for high tax rate (multiples of the minimum wage)	3
$n^{s,dir,ind}$	proportion of workers in survey	(0.15, 0.3)
n^w	number of hiring rounds per open position	1.5
$\hat{p}^T$	inflation rate target	0.005
$\hat{p}_x$	foreign sector's inflation rate	0.005
$Q_{c,0}^{fc}$	initial full capacity production (C firms)	80
Q_m^{fc}	machines production at full capacity	2.5
R	maximum interest payments to cash flow ratio	0.1
s	sensitivity of probability of on-the-job search to difference in wages	5
T^c	number of periods before a new firm can exit the market	5
T^e	number of periods in the exchange rate adjustment to a change in the interest rate differential	4
T^k	machines lifetime	20
T^p	number of periods in average inflation (inflation targeting regime)	4
T^u	number of periods of unemployment benefit	0
u^d	desired capacity utilization level	0.8
$w_0^{min,\$}$	initial minimum wage	1
v	expansion investment adjustment speed	0.5
$\hat{w}^{max}$	maximum desired wage real growth rate	0.1
x	Beta distribution support parameter	0.15

Note: $\star$ identifies values determined in the model's initialization. Source: author's own elaboration.

Appendix E: Automating simulation runs

The AB model presented in this dissertation was built using the LSD program. In order to alter the parameters, create multiple scenarios, run and parallelize the simulations without the need of using the LSD interface, a shell based program called "Purpurea" was built especially for this dissertation. It runs on *nix systems and is publicly available at https://github.com/lirolim/purpurea under GNU General Public License. The main features of the program are:

- Query and change specific parameter values in a simulation file (.lsd);
- Create a set of experiments based on a single simulation file (baseline) and easily alter their parameters with a single command;
- Automatically create a log file saving all parameter changes in the simulation file and main results for selected variables;
- Compile and run simulations using a no-window version of the model;
- Parallelize one (or more simulation files) when running Monte Carlo simulations in order to use all processing units available;
- Automatically run the R script to create plots for key variables.

While it is still required to have the LMM and LSD programs installed in order to compile the model and create the initial model structure (variables and agents), Purpurea helps to alter parameters more easily, optimize the simulations, and to automate the data visualization using R.

In this dissertation, Purpurea aided the calibration process, making it more efficient since the parameters could be changed with a single command and the graphs in R were automatically generated. It was also used to create the set of simulation files for the experiments and to execute the Monte Carlo runs for single or multiple .lsd files in parallel, thus using all processing units available (in some cases, this meant running the simulation about eight times faster). Purpurea was also required to run the simulations remotely, since part of the simulations undertaken during the research process were executed either in a server in the cloud or in a computer that could not be accessed physically.