Monetary Policy and Stabilization in a Multisectoral Micro-Macro Dynamic Simulation Model

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Supervisor Mario Luiz Possas

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Abstract: Instability and fluctuation are properties of any capitalist economy, and the Global Financial Crisis brought back to the debate conditions and factors that amplify the regular business cycles. The crisis forced a macroeconomic rethinking, and the three pillars of consensus view were put in check: (i) the theory, (ii) the models, and (iii) the policy recommendations. The goal of this work is to contribute to a new economic thinking capable to make the right questions and to guide adequate economic policies, not only but especially in face of deep economic recessions and crises. To tackle the first pillar, we discuss the theoretical foundations of the New Consensus, which lead to the implication that monetary policy is fully capable to provide both nominal and real economic stability. The five traditional transmission channels of monetary policy collaborate to a negative correlation between the basic interest rate and aggregate demand, and between prices, as inflation is always explained by excess demand. The validity of each transmission channel is put into questioning by empirical evidence and theoretical reasons, but more importantly, using Post-Keynesian and Kaleckian theories of price formation under oligopolistic competition, alternative transmission mechanisms appear, and the effects of monetary policy might not necessarily be what conventional theory expects. The methodological pillar is tackled as we recognize that micro and sectoral aspects, as well as heterogeneity, should be considered in policy analysis, which is incompatible with the notion of the representative agent in orthodox DSGE models. The last decade saw a growing number of alternative models, especially in two heterodox simulation modeling approaches, and more recently a research agenda emerged to integrate the Agent-Based and the Stock-Flow Consistency approaches, as they are theoretically and methodologically complementary. We take advantage of a formal literature review on recent AB-SFC models to build up and enhance a precursor model, the Multisectoral Micro-Macro (MMM) model proposed by Possas and Dweck (2004) and Dweck (2006), which not only anticipated this methodological integration but also combined Keynesian, Kaleckian and Schumpeterian theories. Thus, we present a new version of the MMM model, as we understand that it is a broader goal of this thesis to develop this tool and make it more widespread, robust, complete, and "user-friendly". Finally, we use this model to tackle the third pillar and investigate the role of monetary policy. Simulation experiments show that in an inflation target regime, the monetary authority cannot force inflation towards a target that is incompatible with the structural conditions of the economy, especially in an open economy. External inflation and the productive and competitive structures are determinants of the average inflation rate. Monetary policy can, however, mitigate inflation volatility mainly via the exchange rate channels, the traditional and the cost one, but it does so compromising real stabilization. As the relative effectiveness of monetary policy depends on its interaction with other policies, we test several policy combinations, and show that unconstrained fiscal policy performs better than monetary to provide real stability without worsening inflation. Not only alternative monetary policy rules should be implemented, but also new combinations, different from the NCM recommendation, should be used to improve real and nominal economic stability, mitigating the negative effects of shocks, and, more importantly, of crisis and recessions.
Keywords: Monetary Policy, Business Fluctuations, Simulation Models
JEL Codes: E52, E32, C63

Resumo: Instabilidade e flutuações são propriedades de qualquer economia capitalista e a Crise Financeira Global trouxe para o debate as condições e fatores que amplificam e aumentam os ciclos regulares. A crise forçou uma revisão da macroeconomia e os três pilares da visão convencional foram colocados em cheque: (i) a teoria, (ii) os modelos e (iii) as recomendações de política. O objetivo desse trabalho é contribuir para um novo pensamento econômico capaz de fazer as perguntas corretas e guiar políticas econômicas adequadas, não apenas, mas especialmente, frente a crises e recessões econômicas profundas. Para abordar o primeiro pilar, discutimos os fundamentos teóricos do Novo Consenso, que levam à implicação de que a política monetária é plenamente capaz de prover estabilidade econômica, tanto nominal quanto real. Os cinco canais de transmissão tradicionais da política monetária colaboram para uma correlação negativa entre a taxa básica de juros e a demanda agregada e também entre os preços, já que a inflação é sempre explicada por excesso de demanda. A validade de cada canal de transmissão é questionada por evidências empíricas e razões teóricas, porém, usando teorias Pós-Keynesiana e Kaleckiana de formação de preço em oligopólio, canais alternativos aparecem, e assim os efeitos da política monetária podem não ser necessariamente o que a teoria convencional espera. O pilar metodológico é questionado ao reconhecer que aspectos micro e setoriais, assim como as heterogeneidades, devem ser considerados na análise de política, o que é incompatível com a noção de agente representativo dos modelos ortodoxos DSGE. A última década presenciou um número crescente de modelos alternativos, especialmente em duas abordagens de modelagem heterodoxas de simulação, e, mais recentemente, uma agenda de pesquisa surgiu para integrar as abordagens Agent-Based e Stock-Flow Consistent, já que são teórica e metodologicamente complementares. Aproveita-se de uma revisão da literatura de modelos AB-SFC recentes para desenvolver e ampliar um modelo precursor, o modelo Micro-Macro Multissetorial (MMM) proposto por Possas e Dweck (2004) e Dweck (2006), que não só antecipa essa integração, mas também combina teorias de Keynes, Kalecki e Schumpeter. Então apresentamos uma nova versão do modelo MMM, uma vez que é um objetivo mais amplo desta tese desenvolver essa ferramenta, tornando-a mais disseminada, robusta, completa e "user-friendly". Finalmente, utiliza-se desse modelo para abordar o terceiro pilar e investigar o papel da política monetária. Experimentos de simulação mostram que o regime de metas de inflação não é capaz de trazer a inflação para uma meta que seja incompatível com as condições estruturais da economia, especialmente numa economia aberta. A inflação externa e as estruturas produtiva e de concorrência são os principais determinantes da taxa média de inflação. A política monetária pode, entretanto, reduzir a volatilidade da inflação pelos canais de transmissão da taxa de câmbio, tanto o tradicional como o do câmbio-custo, mas o faz comprometendo a estabildidade real. Como a relativa eficácia da política monetária depende da sua interação com a política cambial, testamos algumas combinações de políticas e percebe-se que a política fiscal irrestrita performa melhor que a monetária para prover estabilidade real sem comprometer a inflação. Não só regras alternativas de política monetária mas também novas combinações de políticas econômicas, diferentes da recomendação do Novo Consenso, devem ser implementadas para prover estabilidade econômica, mitigando os efeitos deletérios dos choques e principalmente das crises e das recessões.
Palavras-Chave: Política Monetária, Flutuação Econômica, Modelos de Simulação

List of Symbols

Symbol	Description
Greek Letters	
Λ	Annual frequency
Γ	Investment frequency
Π	Mark-up frequency
Ω	Price frequency
Δ	Variation
Θ	Share of GDP
Ξ	Share of Exports
Φ	Share of Government Expenses
Υ	Capital lifetime
α	Input technical coefficient
β	Capital-output ratio
γ	Expectational parameter
δ	Profits distribution rate/Dividends rate
φ	Sensitivity
ψ	Adjustment parameter
μ	Market share adjustment
ϵ	Elasticity
ξ	Passthrough
ε	Exports coefficient
ϑ	External competitiveness
ζ	Propensity to consume
ι	Propensity to import
θ	Price strategy/Degree of Monopoly
λ	R&D revenue proportion
σ	Desired inventories proportion
χ	Desired precautionary share
π	Profit appropriation
ω	Wage appropriation
ρ	Profit margin
τ	Term
ϕ	Labor productivity
υ	Capital flows proportion
η	External income proportion
ν	International reserves proportion

κ	Smoothing parameter

Small Letters

a	Assets
am	Amortization
b	Bonds
bp	Balance of Payments
c	Consumption
ca	Capital Adequacy
cf	Capital Flows
co	Competitiveness
cr	Credit Rationing
cpi	Consumer Price Index
d	Debt
dd	Delivery Delay
dr	Debt Rate
def	Default
dep	Deposits
dfr	Default Rate
e	Expenses
eq	Equities
er	Exchange Rate
exp	Exports
f	Funds
fo	Financial Obligations
g	Government Expenses
gr	Growth Rate
i	Investment
ir	Interest Rate
im	Imitation Proportion
inn	Innovation Proportion
imp	Imports
inp	Inputs
int	International reserves
inv	Inventories
k	Capital
l	Loans
lp	Liquidity Preference
lev	Leverage
m	Money
mk	Mark-up
ms	Market-Share
n	Employment
nw	Net Worth
o	Orders
opp	Technological Opportunities
p	Price

pb	Payback Period
pr	Profits
pcu	Productive Capacity Utilization
q	Quality
re	Revenue
ri	Replacement Investment
rp	Risk Premium
rs	Reserves
rd	Random Draw
rnd	R&D Expenses
s	Sales
sd	Standard Deviation
st	Surplus Target
sv	Savings
spr	Spread
tb	Trade Balance
tr	Tax Rate
tax	Taxes
ub	Unemployment Benefits
ubr	Unemployment Benefits Rate
uvc	Unit Variable Cost
uic	Unit Input Cost
uwc	Unit Wage Cost
ufc	Unit Financial Cost
x	Production
xi	Expansion Investment
w	Wage Bill
wr	Wage Rate
y	Income

Number of Objects

N	Number of sectors
H	Number of classes
F	Number of firms
B	Number of banks
L	Number of loans
C	Number of clients

Aggregate Variables

GDP	Gross Domestic Product
CON	Aggregate Consumption
INV	Aggregate Investment
INP	Aggregate Intermediate Production
GOV	Total Government Expenses
EXP	Aggregate Exports
IMP	Aggregate Imports

TAX	Aggregate Taxes
WG	Aggregate Wages
PR	Aggregate Profits

Subscripts: Usually indicate the agent and the time period

0	Initial Time period
t	General Time period
T	General Investment period
i	General Firm
j	General Sector
l	General Loan
h	General Income Class/Household
c	Consumption Goods Sector
k	Capital Goods Sector
in	Intermediate Goods Sector
fs	Financial Sector
b	General Bank
g	Government
cb	Central Bank
x	External Sector
w	Workers
s	Shareholders

Superscripts: Usually indicate additional attributes of the variable

e	Expected
d	Desired/Demanded
t	Target
p	Potential
$*$	Effective
r	Real
n	Nominal
i	Internal/Domestic
x	External
nt	Net
dp	Disposable
s	Stock
a	Autonomous
av	Available
def	Default
dis	Distributed
ret	Retained
dep	Deposits
st	Short-Term
lt	Long-Term
c	Consumption
k	Capital

in	Intermediate
g	Government
cb	Central Bank
$-$	Average
ref	Reference
max	Maximum
min	Minimum

List of Acronyms

AB	Agent-Based
AB-SFC	Agent-Based Stock-Flow Consistent
CPI	Consumer Price Index
DSGE	Dynamic Stochastic General Equilibrium
GDP	Gross Domestic Product
GFC	Global Financial Crisis
MMM	Multisectoral Micro-Macro
SFC	Stock-Flow Consistent
NOLH	Near-Orthogonal Latin Hypercube
RMSE	Root Mean Square Error

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Introduction

The Global Financial Crisis (GFC) of 2008 and the decade afterwards highlighted the relevance of instability and stabilization measures. Instability and fluctuations are properties of any capitalist economy, as explained by Keynes (1936) back in the 30's. That does not mean one should simply accept economic volatility, as it imposes several costs and problems, not only to the economic system, but also to other social and political aspects of the world we live in. Many economists tried to estimate the welfare costs of fluctuations to justify stabilization policies. While Lucas (1987) argues that the gains of reducing economic fluctuation are small, even other mainstream economists put doubt on his conclusions (Otrok 2001; Imrohoroglu 2008; Gali, Gertler, and Lopez-Salido 2007). The way cycles are considered by Lucas, as regular gravitation around a stable equilibrium, obscures the real impacts and costs of long fluctuations, such as big recessions. Imrohoroglu (2008) argues that if recessions were understood as inefficient declines in GDP, as in a more Keynesian view, then the welfare cost could be higher, such as in the study performed by De Long et al. (1988). Under some labor market and mark-ups cyclicality assumptions, Gali, Gertler, and Lopez-Salido (2007) show that business cycles might generate significant efficiency losses. Their results suggest that these efficiency losses are modest because significant recessions have not often occurred in the post-war period in the analysis. Their work was developed just before the GFC.

Moreover, the GFC brought back to the debate conditions and factors that amplify the regular business cycles, especially the financial factors. Economists started to recognize that the financial side does matter, that real losses caused by the financial issues in the crisis were significant and did not seem to be temporary, as stated by Mishkin et al. (2012). In modern financial capitalism, as we live in, the financial conditions, the balance sheet structures, and the real-financial relations are extremely relevant, as they can mitigate or exacerbate business cycles. We had at least a decade of financial deregulation and credit boom which built endogenous financial fragility to the economic system, leading to a turnover possibly only comparable to the 1929 crisis.

The GFC forced economists to rethink macroeconomics and economic thinking as a whole. The consensus that prevailed before, namely the New Consensus in

Macroeconomics (NCM), was neither able to predict and fully explain the crisis, nor to guide an adequate response from macro policies. Relevant aspects of the real world were not considered in the theory behind the NCM, as well as the models derived from the theoretical assumptions. Consequently, its proponents and supporters started to admit limits to their policy recommendations, as the crisis debunked many things considered as absolute truth in the mainstream economic perspective, and it gave us some important lessons. Three pillars of consensus economic thinking were put in check: (i) the theory; (ii) the models; and (iii) the policy recommendations.

The Neo-Keynesian (or Neo-Classical) theory behind the mainstream view relies on exogenous shocks to explain economic fluctuations and crises. It is based on the idea that the economic system is powerful enough to self-stabilize via market forces. Alternative theories should be considered if one wants to understand and to explain the real economic phenomena, theories which take into account the uncertainty of the real world, and do not abstract the role of effective demand. It is also necessary to consider how markets operate under oligopolistic conditions; understand technological progress as an economic phenomenon; identify the economic system as a complex evolutionary system where agents are interconnected and have bounded rationality, and to take into account the real-financial relationships and endogenous financial fragilities. Many elements of heterodox theories were already developed long before, and were simply relegated from the mainstream circuit. The necessary review of economic theory should bring those elements back, shedding some light on powerful theoretical insights from authors of Keynesian, Kaleckian, Schumpeterian, and Minskyan approaches. Theoretical combination of different streams of heterodox approaches might also be more powerful than isolated ones, mainly if we search to understand and to explain economic dynamics and its properties. This idea is the base of the theoretical propositions of Possas (1983) and Possas (1987).

While the theories behind the mainstream view were put in check by the GFC, their models used to predict and to explain economic phenomena also lost credibility. The Dynamic General Stochastic Equilibrium (DSGE) models, in particular, could not explain disequilibrium. As alternative theories are required, so are alternative models and methodologies, and the crisis opened space for the appearance of alternative modeling methodologies. The last years saw a growing number of alternative models, especially those using simulation solutions, taking advantage of the exponential growth in computational power of the last decades. If the complexity and the non-linearities of a dynamic financial economy are considered, analytical models and solutions usually adopt simplifications which distort the object of analysis. Particularly, two heterodox modeling approaches started using simulation solutions before the GFC, but gained more influence thereafter, as DSGE validity started to become more questioned (Fagiolo and Roventini 2016).

In Agent-Based (AB) models each basic unit, the agent, has its problem defined and its own behavior rules heterogeneously, unlike the representative utility-maximizing agent characteristic of DSGE models. Such a tool allows us to analyze complex systems, characterized by micro-macro interactions, that is, which macro results depend on the interaction of microeconomic agents. Stock-Flow Consistent (SFC) models are macro models that attempt to coherently integrate the stocks and flows of an economy. Consistency between flows and stocks is generated by a series of accounting identities derived from the transaction matrices and balance sheets of each sector. More recently, an open research agenda tries to integrate those two methodologies to propose a strong and robust heterodox modeling approach as an alternative to the DSGE literature. The AB-SFC agenda (Caverzasi and Godin 2015; Caiani et al. 2016) integrates the advances of Agent-Based models on considering the complexity, interactions, and heterogeneity with the Stock-Flow Consistency approach that makes an effort to coherently integrate and organize flows and stocks generated from real and financial relations. Both approaches benefit from each other, as they are theoretically and methodologically complementary.

While there was some space for alternative theories and models, at least outside the mainstream circuit, the third pillar, the economic policies were still very limited in practice, except in some specific countries. Chen, Mrkaic, and Nabar (2019), Hall et al. (2017), and Antoshin et al. (2017) identify some real and long-term explanations for the world slow recovery after 2009, but they also highlight that those policy choices, before and immediately after the crisis, effectively influenced the economic performance of the past ten years. Their estimations suggest that unusually slow growth in government expenditures contributed to the slow growth of demand. Even if policy responses are not the main cause of the economic results of the last decade, economists recognize that policies during and after the crisis itself can partially explain country-specific performances.

The rethinking diminished, especially in the economic policy spectrum, when the world saw a big political turn to the right in the middle of the decade, perceived in many countries such as the United States, the United Kingdom, Italy, and Brazil. The inability of governments and policymakers to implement efficient policies after the crisis contributed to the slow recovery and the bad economic consequences thereof, creating even more social and political shocks and disturbances, and creating the environment for this new (old) right-wing to emerge, simply blaming the first easy enemy as responsible for the current economic problem. When the rethinking started to diminish, some ideas from the decades before returned, as the idea of necessary government primary surplus budget to stimulate confidence of the private sector, and to move the economy to a positive growth trajectory again. The Brazilian experience has particularly shown, time after time, that this idea is probably untrue. To end up, very recently the world saw another crisis. It was not caused by any economic reason or financial imbalance, but the Covid-19 crisis hit us when we were not prepared, nor fully recovered yet. It showed us how our economic system was and still is vulnerable and fragile, and how an exogenous shock might lead to economic consequences if we fail to coordinate efficient economic policies to mitigate the endogenous fragility of the system (Burlamaqui and Torres Filho 2020).

It is the role of policymakers and of economic policies in general to stabilize an unstable economy, as Minsky (1986) famously said. No one wants to live ten years or more in an economic recession, with rising unemployment, poverty, and social and political conflicts. It is true that economic downturns are normal and expected when one considers the business cycle theories, but the duration and amplitude of those bursts can or should be mitigated by correct economic policies, whereas myopic policies might instead worsen the economic scenario and amplify the cycles. If the current mainstream view failed to predict, explain, and guide recovery from the GFC, it is highly likely that it will fail again in response to the Covid-19 crisis. While we had an opportunity to really rethink macroeconomics and economic policies after the GFC and did not take the chance, history gives us a second chance to do it now. It is better not to waste it again. More than ever, the world needs an adequate theoretical and methodological framework that can understand and identify the best economic policies to guide policymakers and politicians. Otherwise, societies will suffer not only from a public health problem, but also from the economic consequences thereof.

The goal of this work is to contribute to a new economic thinking capable of making the right questions, trying to explain relevant economic phenomena and aiming at guiding adequate economic policies, not only but especially in face of deep economic recessions and crises. We tackle therefore the three pillars of consensus economic thinking: (i) the theory, (ii) the models and, (iii) the policy recommendations.

To the theoretical pillar, we bring back some relevant heterodox theories developed in the last century, in an integrated combination to effectively explain the main properties of economic dynamics in general. We are particularly interested in how those unconventional approaches see the relationship between the basic interest rate and economic stability, both output and price stabilities. In contrast with the mainstream view that monetary policy alone can provide real and nominal stability via the traditional transmission channels, we bring some untraditional transmission mechanisms from interest to demand and prices, highlighted by Post-Keynesian and Kaleckian perspectives. By relaxing a simple yet important theoretical assumption of the NCM, the perfect competition hypothesis, implying that prices are determined by supply and demand, those alternative channels became clear, and the final result of monetary policy might not always be what the Consensus expects. Especially, if some degree of oligopolistic competition is considered, as the Kaleckian approach emphasizes, the cost structure gains more importance to price setting, and other factors unrelated to the basic interest rate might affect prices, whereas the basic rate might affect demand and prices via different channels, making the final result ambiguous. When one takes into account these ambiguities and recognizes that each single transmission channel of monetary policy, traditional or not, might affect sectors differently, or even firms in the same sector differently too, the theoretical critique leads to a methodological critique as well.

A methodological pillar is proposed as we recognize that micro and sectoral aspects, as well as heterogeneity, should be considered to policy analysis, which is incompatible with the notion of representative agent in DSGE models. Moreover, as the relationships of the economy, especially the financial ones, characterize a complex system, an analytical model might distort the object and be uncapable of solving the ambiguity in the final effects. Therefore, computer simulation models in line with the two methodologies briefly presented, and the AB-SFC integration agenda consist of a powerful alternative tool to conventional models. In special, we try to build up and enhance a methodological and analytical framework, which combines several heterodox theoretical foundations. The Multisectoral Micro-Macro (MMM) model proposed by Possas and Dweck (2004) and Dweck (2006) in the consolidated version already included elements of both types of models mentioned above, and it is a robust, integrated theoretical and methodological framework, which combines foundations from Keynesian, Kaleckian and Schumpeterian theories, useful to investigate general dynamic properties of capitalist economies. We understand that enhancing and developing the MMM model is a broader goal of this thesis, as it is a continuous work, an attempt to turn the model more user-friendly and modular, so future developments could be more easily implemented. Sometimes, a good part of the hard work done to achieve this goal is not seen in the text presented here, but it can certainly be found by old and new users in the code, for instance. We hope to have facilitated the use of the model for future research. Some methodological advances and developments are pointed out in this work.

Finally, this work also tries to tackle the third pillar with some possible insights on alternative economic policy combinations to mitigate recessions, crises, and to stimulate economic recovery. Using the MMM model we try to answer the question whether monetary policy, by interest rate rules or Central Bank reaction functions, is the best macroeconomic policy to stabilize economic fluctuations, especially in a financial complex system. Is there any better option? Or maybe we should try to combine and coordinate different macro policies. Many possible answers were already anticipated by Minsky (1986), when he highlights the need of a *Big Government*, a *Big Bank* and a Dynamic Financial Regulation, but our modeling framework allows us to give some robust insights, and perhaps it contributes to the discussion of the best policy recommendations to stabilize the economy, which is crucial now.

To fulfil these goals, the rest of this work is structured as follows: a first chapter reviews the theoretical debate on monetary policy and economic stabilization. We first discuss the theoretical foundations of the NCM, which lead to the implication that monetary policy is the best tool to provide both real and nominal stabilization. We discuss the five traditional transmission mechanisms of monetary policy presented in the literature, but in a critical perspective, showing theoretical and empirical arguments which might question the validity of every specific step, and therefore the validity of the channel as a whole. Then we relax the assumption which mainly explains the inflationary process in the mainstream view, and we bring alternative theories, such as Post-Keynesian and Kaleckian to replace it. Under these approaches, not only other factors might be relevant to explain inflation, but also the basic rate might affect both demand and prices through other channels, apart from the traditional ones. We present some alternative transmission mechanisms and separate the effects on demand and prices. We then go back to discussing the link from demand to prices, but on a totally different perspective. It becomes clear that by simply considering this alternative, the final effects of the basic interest rate on demand and prices are ambiguous, and so monetary policy might not provide the economic stability as expected. This chapter ends with a methodological critique to monetary policy analysis in special, but to economic policies and stability analysis in general, which lead us to search for alternative methodological frameworks to be reviewed subsequently.

The second chapter thus reviews two recent heterodox simulation modeling approaches, the Agent-Based Models and the Stock-Flow Consistent Models, as well as the open agenda of integration between them, highlighting main features and elements of each group, the limits and problems of each family, and we also provide some literature examples. By doing that, we can see how both methodologies are complementary, and how integration would be desirable. A combination of those methodologies might present a strong alternative to DSGE models. We argue that a family of models already presented preliminary integrations between the two approaches. But as we identify that new developments should be implemented in the consolidated version of the model, especially regarding the financial sector, we take advantage of the literature review to investigate how the financial system is modeled, so we can extract some possible insights to enhance the core version of the MMM model in a finance-augmented version. We try to identify a minimal financial structure in the recent AB-SFC literature, focusing on four financial elements: (i) agents' demand for credit; (ii) credit rationing and individual credit supply; (iii) the banking sector and overall credit rationing; and (iv) interest rates setting.

A third chapter presents the new Financial-Augmented MMM model. We present the origin, theoretical roots and main features of the original MMM model. As the model is moderately complex, its description is presented in detail, in several ways, and consequently it takes the largest part of this thesis. To provide the best possible description to the reader, the model is described in several ways, including a typical SFC representation using the Flow of Funds and Balance Sheet Matrices, a simplified descriptive explanation, a stylized graphical representation of the flows and structure of the model, a detailed timeline of events that goes step by step through the order of variables calculated in each time step, a formalized exposition of the main equations using the notation presented in the List of Symbols, and a comparison with the literature presented in the Appendix. This chapter also contributes to a broader goal of this thesis to turn the model more user-friendly and modular, so future developments could be easily implemented.

The fourth and final chapter of the thesis is where we present the baseline results of the model, including a detailed calibration procedure and some empirical validation, and where we perform the policy experiments. Using the finance-augmented version presented in the third chapter, we test if the Taylor Rule in a NCM policy framework can provide both price and output stability. We experiment different inflation targets, and by employing a sensitivity analysis on several structural parameters, we study the relevance of those conditions on the average inflation rate. We also perform some experiments on transmission mechanisms to identify which channels contributes to or are against monetary policy effectiveness. As the exchange rate channels appear to be the strongest ones in favor of the stabilization role of monetary policy, its efficacy depends on its interaction with the other macroeconomic policy, and so other combinations, with fiscal and exchange rate policies, are tested. Finally, as unconventional policy mixes produce better economic results, we substitute the traditional Taylor Rule with some heterodox monetary policy rules and study their results. Not only alternative monetary rules should be implemented, but also new policy strategies, different from the NCM recommendation, should be used to improve real and nominal economic stability, mitigating the negative effects of shocks, and more importantly, of crises and recessions.

Chapter 1

Monetary Policy and Stabilization

The GFC and the decade afterwards debunked the twenty years of the so-called Great Moderation, a long period of low and stable inflation combined with positive (but relatively low) growth, especially in the United States of America. During that time, economists believed they had found all the answers to the problem of economic instability, that economic policy had achieved the most efficient standard, and that all that was there to be known was known. Some principles and policy recommendations solidified during those years becoming almost unquestioned truths. Those ideas, especially the ones more related to practical issues, became a consensus, a shared understanding among academics, policymakers and the public in general, also known as the New Consensus in Macroeconomics.

As pointed out by Blanchard, Dell'Ariccia, and Mauro (2010), the consensus was that monetary policy had only one goal (price stability) and one instrument (the basic interest rate). Fiscal policy, on its turn, had a secondary role, limited to budget control and to sustainability of the public debt. Exchange rates should be flexible, and it was believed that financial regulation was out of the scope of macroeconomic policy. Arestis and Sawyer (2002) define the consensus on a set of five principles and ideas, which can be summarized in a simple three equations model composed by an aggregate demand curve, a Phillips curve, and a policy reaction function such as the Taylor Rule. Mishkin (2007) argues that the result of the Great Moderation was due to the acceptance and understanding of those consensus ideas and principles. To be brief, economists believed they knew how to provide economic stability, and it was all in the power of monetary policy.

The crisis highlighted the relevance of instability and stabilization measures. Instability and fluctuations are properties of any capitalist economy, as showed by Keynes (1936) back in the 30's, in contrast with the underlying principle of the NCM, which states that the economy is stable around its natural rates. But recognizing the inherent existence of instability does not mean we should simply accept it, as it imposes several costs and problems not only to the economic system, but also to other social and political aspects of the world we live in. Many economists tried to estimate the welfare costs of fluctuations to justify stabilization policies.

While Lucas (1987) argues that the gains of reducing economic fluctuation are small, even other mainstream economists put doubt on his conclusions (Otrok 2001; Imrohoroglu 2008; Gali, Gertler, and Lopez-Salido 2007). The way cycles are considered by Lucas, as regular gravitation around a stable equilibrium obscures the real impacts and costs of long fluctuations, such as big recessions. Imrohoroglu (2008) argues that if recessions were understood as inefficient declines in GDP, as in a more Keynesian view, then the welfare cost could be higher, as in the study performed by De Long et al. (1988). Under some labor market and mark-ups cyclicality assumptions, Gali, Gertler, and Lopez-Salido (2007) show that business cycles might generate significant efficiency losses. Their results suggest that these efficiency losses are modest because significant recessions have not often occurred in the post-war period in the analysis. Their work was developed just before the GFC, which confirms the importance of cycles and stabilization policies.

Moreover, the GFC brought back to the debate about conditions and factors that amplify and increase the regular business cycles, especially the financial ones. Economists started to recognize that the financial side does matter, that real losses caused by the financial issues in the crisis were significant and did not seem to be temporary, as stated by Mishkin et al. (2012). In modern financial capitalism, as we live in, the financial conditions, the balance sheet structures, and the real-financial relations are extremely relevant, as they can mitigate or exacerbate business cycles. We had at least a decade of financial deregulation and credit boom that built endogenous financial fragility to the economic system, leading to a turnover maybe only comparable with the 1929 crisis.

But since then, the World Economy has not been the same. Several economists and scholars have pointed out that the GFC presented the slowest recovery among similar crises in the past. Chen, Mrkaic, and Nabar (2019), while analyzing a sample of 180 countries, argue that output, employment, and equality losses of the post-crisis are persistent. GDP remained below the pre-crisis level in more than 60% of countries, regardless of whether the country effectively suffered an internal banking crisis. Hall et al. (2017) focus on the US performance and recovery instead. They show that despite unemployment rates had already returned to pre-crisis level in 2016, GDP per capita grew around only one percent annually from 2009 to 2016, the slowest expansionary pace in the past 70 years of the North American economy. Using a supply-side growth decomposition, they point out that structural non-cyclical reduction of productivity and labor force engagement might be explanatory factors for the slow recovery. However, the authors do not exclude demand-side factors and cyclical components to help explain the whole phenomenon. Antoshin et al. (2017)

give proper attention to the case of European countries. Unanimously, they show how European performance after the crisis was worse than expected or predicted by historical patterns. and financial variables, especially the credit supply, played an important role in amplifying the business cycle in Europe. Some authors even look at the slow performance of the last decade as an indicative of a possible secular stagnation, but while this possibility is not accepted by everyone, all mentioned authors point out the inability of monetary policy, in a context of zero lower bounds, to stimulate economic performance and reduce the sluggish recovery.

Chen, Mrkaic, and Nabar (2019), Hall et al. (2017), and Antoshin et al. (2017) identify some real and long-term explanations for the world's slow recovery after 2009, but they also highlight that those policy choices, before and immediately after the crisis, effectively influenced the economic performance of the past ten years. In special, their estimations suggest that unusually slow growth in government expenditures contributed to the slow growth in demand. Even if policy responses are not the main cause of the economic results of the last decade, economists recognize that policies, during and after the crisis itself, can partially explain country-specific performances. Therefore, in some economies a combination of misconceived policies, before, during, and after the crisis, contributed to years of slow recovery. Those policies were still stuck on the consensus ideas before the crisis. If the current mainstream view failed to predict, explain, and guide recovery from the GFC, it is highly likely that it will fail again in response to the Covid-19 crisis or the next one.

It is the role of policymakers and of economic policies in general to stabilize an unstable economy, as Minsky (1986) famous quote says. No one wants to live ten years or more in an economic recession, with rising unemployment, poverty, and social and political conflicts. It is true that economic downturns are normal and expected when one considers the business cycle theories, but the duration and amplitude of those bursts can or should be mitigated by correct economic policies, whereas myopic policies might instead worsen the economic scenario and amplify the cycles.

In this chapter we will discuss monetary policy and its role as a stabilization policy, understanding the theoretical roots which supported the consensus ideas before the GFC, stressing the mechanisms that were supposed to guarantee the efficacy of a Taylor Rule as the monetary authority reaction function, the conventional transmission mechanisms in the literature. We then present alternative views, especially a Post-Keynesian framework, which brings other channels through which the basic interest rate affects not only aggregate demand, but also prices, showing that the final effect of monetary policy is extremely ambiguous and not necessarily the one expected by the conventional channels.

1.1 The Taylor Rule and the NCM

Before the 2008 crisis, the conduct of monetary policy and, in general, the role of macroeconomic policy, was based on a shared consensus between academics, policymakers, and the general public. This consensus became known as the NCM. The NCM, which synthesized more practical issues, was originated from a very defined theoretical framework, the New-Keynesian approach. The consensus was established during two decades of empirical evidence and policy results in developed countries, combined with 30 or more years of evolving economic theory, from the Monetarists to the Real Business Cycles schools of thoughts.

1.1.1 Theoretical Roots and Principles of the NCM

Arestis and Sawyer (2002) list some elements which describe the world-view of the New-Keynesian approach, that is, the basic principles that justify the theoretical construction. Such principles, according to the authors, are:

1. The view that the market economy is essentially stable, and that macroeconomic policy, in particular fiscal policy, can destabilize the economy.

2. Low inflation is an objective that must be pursued, it is desirable. Monetary policy, in particular, can and should be used to achieve this goal.

3. The level of economic activity fluctuates around a Natural Rate of Unemployment. Unemployment below the Natural Rate would lead to an increase in inflation and vice versa. The Natural Rate is a real phenomenon, determined by the supply side in the labor market.

4. The essence of Say's Law is valid. In other words, the level of effective demand has no role in determining production in the long run.

5. The market system involves market failures, as there are externalities, public goods and market power. The role of macroeconomic policy and government, in general, is to correct these shortcomings.

This view was built over a few decades, based on theoretical advances in the mainstream of macroeconomics and empirical findings about the state of advanced economies in that period. Principles 1 and 2, for example, derive from these findings, as highlighted by Goodfriend (2007). According to the author, the 1970's were a decade of many disturbances in the U.S. economy, such as the collapse of Bretton-Woods arrangements, oil shocks, growth with high inflation in a stop-and-go regime with high volatility. The world has learned a few lessons, however, from the tighter policies of the Volker Era at the end of the decade: (i) inflation is a monetary phenomenon, generated by the financing of fiscal deficits, (ii) interest rates can be used as an instrument to combat inflationary expectations, and (iii) credibility can be achieved by an independent Central Bank. But the period that really consolidated those hypotheses was the so-called Great Moderation, which followed from the end of the 1980's until the eve of the 2008 financial crisis.

While the first two principles have strong support on the empirical evidence, the other three derive from the theoretical development of macroeconomics in recent decades. The existence of a Natural Rate of Unemployment is the main theoretical pillar that structures this view. This notion was first elaborated by Friedman, incorporated into the New-Classic models, into Real Business Cycle models, and finally into the New-Keynesian models, which replicate the theoretical structure of the Real Cycle models, incorporating market power and price rigidities. All these schools of thought assume that there is a natural or potential long-term trend, defined by real economic factors, and that the current state of the economy fluctuates around this trend due to external shocks. This hypothesis directly derives from principle 4, as in the long run the growth of the product is determined by its natural or potential trend. Temporary frictions, such as variations in demand, do not affect this trend. Principle 5 is more general and conceptual, but it implies that monetary policy, in special, should then be used to mitigate fluctuations around the long-term trend caused by market failures or external shocks. Monetary policy, always preferable to fiscal policy, should be used for the purpose of stabilizing activity, and this does not affect real variables in the long run.

Arestis and Sawyer (2002) also claim that the NCM can be synthesized by a world described by three equations: The first equation describes an IS curve, which corresponds to the equilibrium in the goods market, where the current output gap depends on the past and expected gap, as well as the expected real interest rate, where the output gap is the difference between the current output and the potential one. External demand shocks positively affect the output gap in the period. This equation is derived from the intertemporal optimization of the agents' utility function. The second equation describes a Phillips curve, which corresponds to the trade-off between unemployment and inflation, where current inflation depends on the current output gap, as well as the past inflation and the expectation of future inflation. This equation can also be understood as a supply function. External supply shocks positively affect inflation via costs. This equation represents the decision of the firms, which can increase the price level according to the quantity produced with the correction memory (price rigidity), and with the expectation of increased costs. Finally, the third equation describes a monetary policy rule, or a Central Bank reaction function, where the nominal interest rate is explained by the current output gap and the deviation of current inflation from the target. This equation assumes that the policy instrument used by the Central Bank is the nominal interest rate. The Central Bank changes this rate if the GDP deviates from the potential, and/or the current inflation deviates from the target. It is worth noting that if the GDP is at the potential level, and inflation is in line with the target, the current nominal interest rate will be exactly equal to the equilibrium real interest rate, plus the current inflation rate (equal to the target).

As described by the third equation, the basic nominal interest rate is the core policy instrument, defined by the monetary authority. In the NCM model the Central Bank is a rational maximizing agent, like households and firms. It seeks to maximize a function of social welfare, or to minimize a function of social loss, where the social loss results from the deviations of the product in relation to the potential and of inflation in relation to its goal, weighted by the Central Bank's preferences. From this maximization, the Central Bank finds its optimal nominal interest rate. If the monetary authority is credible, the establishment of the nominal interest rate at the optimum level guides inflation expectations, so that it converges to the inflation target. Credibility and commitment to a nominal anchor promote price stability in this theoretical and practical framework called the Inflation Target Regime. The Regime appears as a solution to the theoretical propositions of Sargent, Wallace, et al. (1981) and Kydland and Prescott (1977): the ineffectiveness of monetary policy and the temporal inconsistency of the monetary policy, which causes the inflationary bias.

Sargent and Wallace (1976) develop the proposition that monetary policy is ineffective. According to the authors, any monetary policy rule would be incorporated by the agents' rational expectations, thus not being able to affect the real variables. Only policy surprises, which were not incorporated into the agents' expectations, would be effective in affecting the real variables. The so-called problem of temporal inconsistency was developed by Kydland and Prescott (1977), and further developed by Barro and Gordon (1983). A policy is said to be temporarily inconsistent if the optimal policy in one period ceases to be optimal in the next period, even if nothing new has happened. The authors show that discretionary policies suffer from temporal inconsistency, which generates an inflationary bias to achieve greater social welfare. The inflationary bias of discretionary policies generates a loss of credibility for the monetary authority, reinforcing even more the inflationary bias.

The Inflation Target Regime is then a development, a formalization of Walsh's independent Central Bank model, proposed as a solution to the problem of temporal inconsistency, and to the inflationary bias of discretionary monetary policies. It was adopted in different ways by different countries since the 1990's, and it was incorporated as an analytical-theoretical framework into the New-Keynesian models. As such, it constitutes a fundamental element of the Consensus. In practice, the

Regime consists of the adoption of an inflation target for a given period, and the commitment of the monetary authority to pursue that goal. The monetary authority generally uses the basic interest rate, or interest rate on the interbank market, as a policy instrument. It is gradually adjusted according to a policy reaction rule that observes the current state of the economy, that is, the deviation of the current product in relation to the potential, and the deviation of the current inflation in relation to the target.

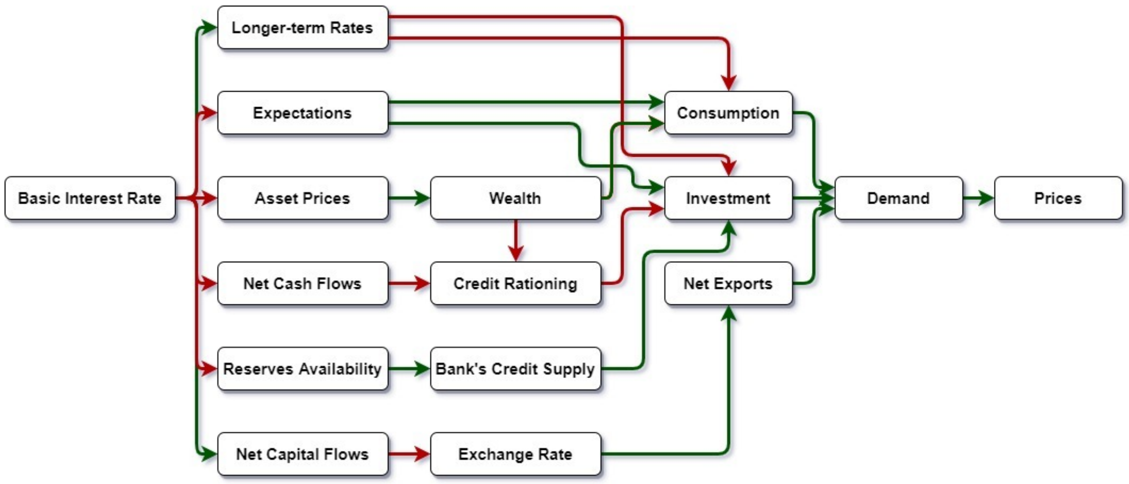
The policy rules used by most monetary authorities follow some form or adaptation around Taylor (1993) famous proposition. The Taylor Rule, as it is known, adjusts the nominal interest rate as an instrument to change the real interest rate, the main decision variable. The idea is that a higher real interest rate, higher than the natural rate in a Wicksellian sense, induces a lower level of investment and a higher level of savings, which reduces aggregate demand, and given the level of output, price inflation is reduced. On the opposite, a lower interest rate stimulates investment and aggregate demand over the potential level, reducing the output gap, but increasing inflation. While this is the general framework that explains the effectiveness of monetary policy, interest rates affect the level of aggregate demand via several channels. Although they are already well established and documented in the literature, we will discuss them here breifly, especially to present some questionings to their steps and internal logic.

1.1.2 Conventional Transmission Mechanisms

The mechanisms through which the basic interest rate affects other intermediate variables and the final objective variables of monetary policy are called transmission channels or mechanisms. Mishkin (1995) and Mishkin (1996) describe the main channels in the New Consensus view: the interest rate channel, the asset price channel, the exchange rate channel, the expectations channel and the credit channel, which is usually divided in two sub-channels, the bank lending channel and the balance-sheet channel. The traditional channels can be represented as in Figure 1.1, for instance.

But before detailing each channel, a first more general assessment is necessary. The transmission mechanisms intend to explain in more detail the link between the basic interest rate and the objective variables, a link synthesized by the already put intuition in a broader way. While some authors argue that one specific channel is the main responsible for the effectiveness of monetary policy, it is clear that the channels might co-exist. In fact, the literature around the transmission mechanisms usually investigates which the strongest or the main channel is, theoretically or empirically, and while some individual channel may be criticized or obscured by another, the

Figure 1.1: Traditional Transmission Mechanisms of Monetary Policy



Source: Author's Elaboration. Green arrows represent a positive correlation from one variable to the other. Red arrows represent negative correlations.

effectiveness of monetary policy is not questioned. And is due to two causes.

The first one is the fact that all channels produce the same final effect on demand, in terms of direction. The intensity might be weaker or stronger, depending on the circumstances and on which channel is operating, or the timing of monetary policy might be affected by several intermediate variables through which the channels pass, but the resulting effect, the negative correlation between the basic interest rate and demand is always present. When the Central Bank increases the basic interest rate, the effect on aggregate demand might be more or less intensive, it might take more or less time, it might pass through one or more specific transmission mechanisms, but the expected result is always the same: reducing aggregate demand.

Moreover, if through all channels an increase in the basic interest rate reduces aggregate demand, the effectiveness of monetary policy in taming inflation is also guaranteed, as there is an implicit hypothesis: inflation is always a phenomenon of demand. In the words of Gordon (1997), "in the long run inflation is always and everywhere an excess nominal GDP phenomenon. Supply shocks will come and go. What remains to sustain long-run inflation is steady growth of nominal GDP in excess of the growth of natural or potential real output", which is another way to assert Friedman's conclusion that inflation is always and everywhere a monetary phenomenon. Other possible explanations for the inflationary phenomenon, as seen in the case of supply shocks, are usually abstracted. Thus, whenever the economy is operating at a level of demand above the potential output, the reaction of firms is to raise prices, and consequently, inflation arises too. The way to contain inflation is thus obviously to retract demand, bringing the economy back to the level of potential output. Another implication is the idea that a monetary authority reaction function, which strictly targets inflation is enough to stabilize both prices and the real output.

With that in mind, let us see how monetary policy provides stabilization in the NCM view. We will present the five traditional transmission mechanisms critically, bringing some empirical and theoretical questioning to their individual validity.

The Interest Rates Channel

This is the most "traditional" channel, being present in the economic literature for at least 70 years, as Mishkin (1995) points out. According to this mechanism, investment and consumption decisions, especially in durable goods, depend negatively on the interest rate which relevant to those decisions. The basic rate serves as a reference for all other interest rates in the economy, in the well-known interest rate term structure or yield curve. An increase in the basic rate raises all other rates for all possible maturity periods, thus decreasing investment decisions and consumption of durable goods, thereby reducing aggregate demand. By reducing aggregate demand this channel can control demand inflation. Some authors argue that this is the main transmission channel of monetary policy. For example, Angeloni et al. (2003) aims to identify which are the main transmission mechanisms in the Euro area. Under their assumptions, they cannot reject the hypothesis that the traditional interest rate channel is the most important mechanism for their cases.

Several studies try to identify what factors could affect the efficacy of this channel. The first questioning point is the transition from the basic rate to interest rates for other maturities. Depending on the structure of the financial system of each economy, especially the degree of banking concentration and financial innovations, an increase in the basic rate might not be passed onto medium and long-term rates. This problem can generate an asymmetry: depending on the market power of the banks, an increase in the basic rate might increase the medium and long-term rates, as the basic rate reflects the cost of banks' liquidity, and the other rates can be seen as added margins to the basic rate, but a reduction in the basic rate might not necessarily reduce medium and long-term rates, if banks with sufficient market power take advantage of such a reduction to increase their margins without reducing longer-term rates.

Borio and Fritz (1995) study the response of average loan rates to the basic interest rate across several countries. They find that, in general, the response is positive and symmetric, but there are some countries in which the response is relatively low, and in some cases, like in Japan and Germany, asymmetries appear. Following these ideas, Mojon (2000) examines country specific responses within the Euro area, emphasizing their different financial structures. He finds that bank competition is relevant to explain country asymmetries in the lend rates response, among other factors.

Even if medium and long-term rates are affected, this channel depends on the interest sensitivity of the agents' decisions. For an increase in the basic rate to affect agents' decisions, that increase must be large enough and/or the decisions must be sensitive enough for a firm to interrupt or to give up an investment project, or households decide not to buy a durable asset. Regarding investment decisions, this sensitivity depends fundamentally on the expected profitability. The increase should be large enough, so that the expected profitability, even with the increase in the financial cost, becomes zero.

The Asset Prices Channel

Asset prices mean all relevant prices for financial assets, other than the exchange rate and interest rates. According to this channel, an increase in the basic interest rate affects the price of shares and other fixed-rate assets. Following Tobin's "Q" theory, the fall in stock prices reduces the investment capacity of firms. This channel also affects consumption through the wealth effect. If the assets held by households are valued less, they feel less wealthy and reduce their consumption. Reductions in investment and consumption affect aggregate demand, and subsequently the price level (Dan 2013).

The asset price channel relies on Tobin's "Q" theory, which is widely questioned to explain firms' investment decisions. It is quite unreasonable to assume that the value of a firm's already issued shares affects its investment capacity immediately. The fall in the price of a firm's shares might affect the agents' view of that firm, as a flag, and this might secondly affect the firm's financial conditions, but the effect is not immediate. Still, the transition from the basic interest rate to the stock prices is unclear. The effect of this channel on consumption is even more questioned. Although the wealth effect has been described in the economic literature for almost 100 years, and it is present in several orthodox models to date, there is little empirical evidence between consumption and asset prices. Few household units can afford to own an asset portfolio and consume based on the nominal value of that portfolio. If most households do not have such assets, the effect of their prices on consumption will be negligible. The magnitude of this effect depends on the composition of wealth among heterogeneous household units, and the propensity to consume on wealth.

Empirical evidence on the importance of this channel is inconclusive. For example, Tang et al. (2006), while analyzing the role of each channel for Malaysia, found that the asset price channel is the less important for inflationary effects. Zhang and Huang (2017) study the asset price channel for China, and discover that the type of assets held by the general public and considered as permanent wealth for their consumption and investment decisions does matter. For Kenya, Misati and Nyamongo (2012) did not find any significant correlation from the basic interest rate to asset prices, but they found, on the other hand, an opposite relationship.

The Credit Channel

While the first channel discusses the impact of the basic rate on the price of credit, this channel highlights how the basic rate can affect the amount of credit. This channel, deeply discussed by Bernanke and Gertler (1995), gained more relevance than the first, as empirical evidence shows that banks operate with credit rationing, and not through price competition raising the interest on loans, for example (Stiglitz and Weiss 1981). Thus, the amount of credit, whether the firm or household will obtain the loan to finance its investment or consumption decision, is more relevant than the interest to be paid on the loan. This channel is described by two sub-channels: the banking lending channel and the balance sheet channel. Through the lending channel, an increase in the basic interest rate negatively affects the availability of bank reserves, and via a monetary multiplier it affects the amount of credit that banks can offer. Through the balance sheet channel, an increase in the interest rate decreases the net cash flows of firms, which affect their balance sheets and reduce their ability to pay the loans, which is a determining factor for banks to grant loans or not.

The credit channel can be criticized for how the credit decision of banks is described. Despite being found in any textbook, the bank multiplier is highly contested by theories of endogenous money. The view of the bank multiplier assumes that the banks' credit capacity is determined by the availability of previously accumulated reserves. Banks are, however, much less passive than this view supposes. Banks will not refuse lucrative loan demands because they are at the limit of their bank reserves. On the contrary, banks seek to maintain the legal and desired reserve requirements as a result of their loans. Thus, this view of endogenous money, in which banks offer credit by their expected profitability, and then seek the necessary reserves to maintain the level required for that new volume of loans, invalidates the passage of reserves to the volume of credit. Recent evidence shows inverse effects: unconventional monetary policy and long periods of low interest rates after the GFC showed a reduction of bank profitability[1].

The balance sheet channel is indeed relevant. However, it is necessary to consider the heterogeneities between firms and their portfolios. Some firms might have high net indebtedness levels, others might have a positive net indebtedness, but far from an acceptable limit, and some firms might also have negative net indebtedness levels. Firms with negative net indebtedness will be little affected by this channel, and, on the contrary, as they hold assets which pay interest in their portfolios, they might

[1] To be discussed in the next section.

have an increase in their net cash flows. Indebted firms might experience a reduction in their cash flow, but not all firms will have a level of indebtedness high enough to exceed an acceptable limit to the point that the bank does not grant the loan. The real effect of this channel depends on the composition of the heterogeneous firms and their balance sheets. If most firms are already at a high level of indebtedness, this channel can be significant. Otherwise, its effect might be null. Moreover, Mishkin (1995) points out that this channel can generate financial disturbances, which would not be desirable, but would not influence the final effect of the channel either. Let us suppose the case of firms being at an already high level of indebtedness. An increase in the interest rate reduces their cash flows, limiting not only their ability to repay new loans but also the loans already taken, which could lead to bankruptcies due to high indebtedness. In this case, bankruptcies would effectively decrease investment decisions, as firms can no longer operate.

The Expectations Channel

Through this transmission channel changes in the basic interest rate serve as signals for the agents' expectations. An increase in the basic interest rate represents an expectation of a worsening of the economic situation in the near future, leading agents to reduce their spending on consumption and investment as a precaution. A fall in the basic interest rate amidst a recessionary scenario, for example, might indicate a prospect of improvement, causing agents to readjust their expectations upwards, and resume their spending on consumption and investment. This channel gained a lot of importance in the most recent debate, highlighting the relevance of the credibility of the monetary authority for it to take effect. Still, this channel supposes that, if the authority is credible, the announcement of the change in the interest rate is enough for agents to readjust their expectations, which might come even before the effective increase in the rate and other transmission channels. As a result, the transparency and credibility of the monetary authority started to gain more importance than both the level and the effective adjustments of the basic interest rate themselves.

Although this channel has a strong theoretical argument, based on rational expectations, which justify institutional arrangements such as the Inflation Target Regime, seeking credibility, the literature and the empirical evidence around this channel is extremely scarce in comparison with the other traditional channels. Another strong theoretical but alternative argument might explain the lack of evidence. The expectations channel assumes rational expectations, but expectations are a much more subjective, and formed on a much more uncertain knowledge basis, if one considers a Keynesian point of view. Other factors outside the economic spectrum can positively or negatively influence the agents' perspectives, such as a political or institutional crisis, for example. The impact of the basic rate on expectations assumes that nothing else affects them. If this is not assumed and there are other subjective determinants for the prospects, the effectiveness of this channel can be mitigated.

Even relevant and robust studies under the mainstream view corroborate this critique. As an example, Williams (2005) investigate optimal monetary policy on a large-scale open-economy econometric model, which presents several advantages in comparison with common DSGE models. His results show that the optimal monetary policy should target inflation, unemployment, and the interest rate volatility itself, and as he puts: "these results are robust to variations in parameter values and the specifications of output dynamics and price dynamics, but the characteristics of efficient policy rules depend critically on the assumption regarding expectations formation." (Williams 2005, p.3). He argues, backed by other models which showed the same effect, that when agents do not anticipate policy movements into their expectations, the efficient monetary policy rule that relies on that anticipation in fact presents poor results.

The Exchange Rate Channel

The basic interest rate increases the profitability of government bonds and other derivative securities, which attracts short-term foreign capital, thus affecting the exchange rate. In general, an increase in the basic interest rate leads to an exchange rate appreciation, and a fall leads to an exchange rate depreciation. The exchange rate is a key variable, determining exports and imports. An appreciated exchange rate tends to reduce exports and increase imports, whereas a depreciated rate increases exports and decreases imports. Net exports, a component of aggregate demand, follow the direction of the exchange rate. Thus, through the exchange rate channel, an increase in the basic rate appreciates the exchange rate, which reduces net exports, aggregate demand, and prices. A reduction in the basic interest rate depreciates the exchange rate, increases net exports, and increases aggregate demand.

This channel has little prominence in the monetary policy debate in developed economies, especially in the United States. However, it gains more relevance the greater the degree of economy's openness. The impact of the basic rate on the exchange rate in special depends on the relevance of the capital account in relation to the trade balance. The higher the capital account to GDP ratio, the greater the exchange rate volatility in face of changes in interest rates. This channel also assumes that the exchange rate is flexible and it is not subject to policy control. If the exchange rate is fixed, its impact is canceled. Still, even if the exchange rate is flexible, an increase in interest rates can generate an immediate short-term impact on capital flows and on the exchange rate, but the most persistent and lasting impact depends on the balance of payments result. Thus, if a negative trade balance, for example, counterbalances the effect of increased capital flows, the final effect on the exchange rate might be contrary to expectations.

1.2 A Heterodox Approach to Monetary Policy

Each channel discussed above requires a sequence of events passing through several intermediate variables, until the effect of the basic interest rate reaches the price inflation. In order to fully understand each channel, one should analyze each step of this sequence, and question its validity by asking what are the factors that mitigate, intensify, or cancel each step. We have already presented some common critiques to individual channels and specific transmission points. Despite all possible critique already highlighted, let us assume that all (or at least some) of the traditional channels are valid, and ask a different question: are there alternative channels besides the five conventional ones?

In order to discover possible alternative channels, one should release itself from the limitations imposed by the NCM principles. It is necessary, from now on, to try to see the world from a different perspective, adopting a heterodox approach. One fundamental difference between the mainstream view of the NCM and most of the heterodox economic approaches is how prices are defined and formed. Note that the idea that prices depend on the level of demand, while supply is determined by real natural forces, is implicit in the orthodox view and in the conventional transmission mechanisms. A perfect competition model is in play. In contrast, some heterodox approaches, such as the Post-Keynesian and Kaleckian for example, assume that firms have some market power in general, so they usually form prices by adding a mark-up over some measurement of unit cost, in a more oligopolistic scenario. When market power is considered, the final link between demand and prices in all five channels might be compromised.

Moreover, inflation can have multiple sources, not only demand. For example, if there is an exogenous shock in the price of inputs, which represents a cost to most firms, and they have some market power to form their prices by mark-up, they will increase prices to maintain their desired level of profitability. This is one example of the several cost-push inflation theories or, as Lavoie (2014) defines, the cost-plus pricing approach. While almost all Post-Keynesian authors, in a broad sense, accept and adopt this approach, there is no consensus on the exact determinants of price setting. Lima and Setterfield (2010) extensively discuss the growing recent empirical evidence, but also the long history of discussion around this topic, that can be traced back even to the 19th Century, especially considering the positive relationship between interest rates and prices. In addition, the authors discuss how this channel is present in several heterodox approaches and how there are several possible ways to model this broad channel. For example, if prices are determined as a mark-up over unit labor cost (following Weintraub et al. (1958)), inflation could be explained by the evolution of mark-ups, related to the sectoral competition, by the behavior of wages, and by the labor productivity movement, or any combination of these factors.

Post-Keynesian theory of inflation usually points to several cost factors such as (i) wages, (ii) mark-ups (iii) diminishing returns, (iv) imported costs, (v) supply shocks, (vi) taxes, and even (vii) demand (Davidson 2011; Sicsú 2003). Again, note that this approach does not deny the existence of the five traditional transmission mechanisms, despite all possible critiques already discussed to each of them individually. Those mechanisms explain how the basic rate affects demand, which in its turn affects inflation since it is implicit that excess demand is the main (and only) cause of inflation. Heterodox theories, such as Post-Keynesian and Kaleckian, assume oligopolistic markets in general, in contrast to the implicit perfect competition of the NCM, and therefore changes in prices can happen due to several other causes other than demand. If that is the case, all five traditional channels could be effective, could affect demand and output, but could have no impact on inflation. In parallel, other factors which affect the cost structure and the market competition structure could affect inflation without affecting demand and output. The NCM corollary that pursuing stable inflation is enough to generate both price and output stability is not necessarily true under heterodox price theories.

Once that possibility is considered, we should investigate the channels through which the basic interest rate affects the cost structure, and therefore prices. For the sake of clarity, if there is a channel through which the basic rate affects prices via the cost structure and not via demand, we will call it a cost channel or a direct channel, whereas if a channel affects prices via aggregate demand, we will call it an indirect channel. Under this definition, all five traditional channels are indirect. However, the final link from demand to prices should also be investigated under a different lens, if we relax the perfect competition hypothesis of the NCM, so we can study transmission channels from the basic interest rate to prices, transmission channels from the basic rate to demand, and finally examine if there is a link from demand to prices turning the demand channels into indirect price channels.

1.2.1 Alternative Transmission Mechanisms

The Exchange Rate Cost Channel

The traditional exchange rate channel only highlights the indirect effect of the exchange rate on prices, passing through aggregate demand, but even BCB (1999) recognizes that the exchange rate has direct effects on prices. Usually, two sub-channels explain the direct effects of the exchange rate to prices.

First, an appreciation of the exchange rate decreases the cost of foreign products in domestic currency, and so, if consumers have access to the international market, and domestic products compete with foreign products, this might force domestic firms to reduce prices in an attempt to retain their demand. Clearly this sub-channel depends on sectoral characteristics, the price-elasticity of exports [2]and the degree of internationalization of the domestic economy.

Second, an appreciation of the exchange rate decreases the cost of imported inputs and the cost of domestic production. If the unit cost of production is determinant to prices, then it will lead to changes in prices. However, this channel, as any cost channel, is highly subjected to asymmetries. If firms have enough market power, whenever there is a cost increase, they will try to pass most of the increase to prices to keep profitability at least constant. But when costs decrease and firms have enough market power, they might attempt to increase profitability leaving the price constant. Pimentel et al. (2020), for example, investigate the asymmetries in the exchange rate cost channel for the Brazilian economy. Both sub-channels might operate simultaneously.

Note that the exchange rate cost channel also depends on the first steps of the traditional exchange rate channel, the link from the basic interest rate to the exchange rate. Therefore, the trade balance result, the exchange rate policy and the degree of openness of the capital account also influence the final effect of this channel. It is also important to highlight that this channel, although heterodox and direct, has the same final effect on prices, even if not via aggregate demand: an increase in the basic interest rate will lead to a decrease in inflation. Summa and Serrano (2018) and Modenesi and Araújo (2013), for example, argue that this is the main channel through which the Inflation Targeting Regime was able to keep inflation under control during the past decades in the Brazilian economy.

The Interest Rate Cost Channel

This is the most direct channel of monetary policy, the direct effect of interest rates on costs, and therefore on prices. Differently from the exchange rate-cost

[2]For instance, Padrón et al. (2015) investigate why the price elasticity of Brazilian exports is low, which affects this sub-channel.

channel, the interest rate-cost channel has an adverse impact on monetary policy effectiveness, as it explains the largely documented positive correlation between interest and prices. This correlation, as presented by Lima and Setterfield (2010) has several names: Gibson's Paradox (Keynes 1930), Price Puzzle (Eichenbaum 1992), or Cavallo's Effect (Taylor 2009).

Hannsgen (2004) and Hannsgen (2006) study in detail this effect. It is very clear and direct: if interest rates are a cost of production and prices are based on costs, then increases in the interest rates will increase prices, corroborating this proposition with empirical evidence and an analytical model. Besides, recent studies performed by Sicsú, Modenesi, and Pimentel (2020) and Passos and Modenesi (2021) identify that this interest-cost channel to prices and inflation is even more pronounced in highly indebted economies. If firms, in general, can accumulate own resources and do not strongly depend on external finance to produce, the interest rate on loans will have almost no impact on the cost structure, and therefore on prices. However, the more firms depend on the external finance, the stronger this channel can be. It is clear that this channel affects firms heterogeneously, since different firms in the same sector or market will be affected differently, depending on their financial capacity, which might be correlated with the market-share. Smaller firms are more likely to be affected by this channel.

An Inverse Bank Lending Channel

As pointed out when the bank lending channel was discussed, for theories which accept endogenous money, a horizontalist approach to money, which is common ground for most Post-Keynesian economists nowadays, bank reserves have no causal relationship with the ability of banks to provide credit (Rochon and Setterfield 2008). Therefore, the traditional bank lending channel makes no sense. Another variable should be related to the banks' ability to lend, for instance, profitability.

Several recent empirical studies show some evidence of a possible inverse credit channel, but the effect of interest rates on bank profits was first investigated by Samuelson (1945). He argues that an increase in the interest rate, which increases the whole interest system, improves the condition of an individual bank and the banking system as a whole. More recently, especially in the light of the effects of monetary policy easing and lowering interest rates after the GFC, several empirical studies search for evidence of this correlation.

Borio, Gambacorta, and Hofmann (2017) perform a statistical study which shows a positive correlation between interest rates and bank profitability. Interest rates affect bank profitability by the impact on net interest income, non-interest income, such as fees, and loan loss provisions. The positive effect on net interest income seems to overcome the negative effect due to loan losses. They also find some non-linearity, especially related to the deposits rate. However, they leave the important question of the relationship between bank profitability and macroeconomic result for further research. Altavilla, Boucinha, and Peydró (2018) find similar results for banks in the Euro area, in which accommodative monetary policy has a negative effect on bank profits, although they argue that this effect is counterbalanced by the improvement in macroeconomic conditions by other channels. They argue that low profitability affects the bank's capacity to accumulate retained earnings and the ability to provide credit. In addition, bank profitability signals the bank's financial health, and contributes to the financial stability of the economy. The different characteristics of bank assets and liabilities are relevant to the link between the balance sheet structure and the bank profitability. Kumar, Acharya, and Ho (2020) find the same positive correlation for banks in New Zealand.

1.2.2 The Link from Demand to Prices

For the NCM, the basic rate will always negatively affect demand, which will always positively affect inflation. Therefore, the basic interest rate can always affect both output and price stability in the same direction. The main discussion is: what is the relatively most important transmission channel? What are the factors that affect its intensity? But the general result is always the same. If one considers the possible critiques and alternatives discussed here, it becomes clear that basic interest rates can have negative (by the five traditional channels) and positive effects on demand (by the inverse credit channel), and it could also have positive (Gibson's paradox) and negative (exchange rate-cost channel), without considering the transmission from demand to prices as always valid.

This last link is not always true, but it is possible, and in a heterodox point of view it is usually explained by another theory, but not by the perfect competition scenario. This, however, is the effective case in some sectors, some markets, using Hicks's definition, *flexprice* markets. Some commodities markets, agricultural products and perhaps services sectors have less room to adjust production to meet demand, especially if they cannot retain a level of inventories, or if production is limited by some constraints. In these cases, it is possible that prices are more volatile and represent the mechanism which tries to adjust production to demand, so when demand increases, for a given limited supply, prices will increase as well.

Most of industrial production is, on the contrary to the above example, *fixprice*, meaning that prices are less volatile, and they operate with some level of inventories and idle capacity to meet unexpected increases of demand with more products, instead of rising prices. In those sectors, however, demand might still have some impact on prices, apart from this short-run adjustment process.

One type of inflation listed by Davidson (2011), apart from the typical demand inflation, is also related to the level of economic activity, and, as Sicsú (2003) argues, it is the main explanation for inflation when the economy is close to full employment for Keynes: the diminishing return inflation. It does not occur all the time, but under certain conditions the economic activity can influence prices by lowering average productivity. Even if firms have idle capacity to meet unexpected demand, this spare capacity is usually composed by less productive capital goods, reducing the average productivity of the firm. Note that, differently from the neoclassical labor market theory, that does not mean that the firm is employing less productive workers, but instead is employing less productive machines. The reduction of the average productivity increases the labor cost, and for given mark-ups and wage rates, the final price might increase if firms decide to pass the increase in labor cost onto prices. But since what is relevant for the price formation is the unit labor cost, the final effect of productivity on wage cost will depend on the wage rate adjustment, and it will depend on how productivity gains (and losses) are appropriated by firms or by workers, meaning that it will depend on how the change in productivity will be translated to a change in the wage rate. Nominal wage setting is usually explained by conflict inflation theory.

As pointed out by Lavoie (2014), the basics of conflict inflation theory can be seen in Kalecki (1971), it is summarized by Rowthorn (1977), and it is adopted by several Post-Keynesian or Neo-Kaleckian authors. On the contrary to neoclassical equilibrium in the labor market, this theory supposes that there is an inconsistency in the income claims of workers and capitalists (or firms), which is the result of the constant bargaining process of nominal wage setting. The nominal wage is a cost for the firms, but is the source of income for workers who constantly aspire higher nominal wages, at least to keep up with past inflation, keeping the real wage constant. Combining this idea with the recognition that firms set prices using some sort of mark-up rule, higher nominal wages are passed (perhaps not entirely) onto prices if firms tend to keep the mark-up constant, which causes inflation and generates more nominal wage claims in following periods. This creates a wage-price spiral. But more relevant to us is the fact that wage claims by the workers really depend on their bargaining power, which has some relation with the economic cycle. When the economy is on a boom, unemployment is low, and so the bargaining power of workers increases, whereas when the economy is on a burst, with high unemployment, bargaining power decreases. Economic activity has some relation with the wage claims and the wage inflation.

Using those theories, monetary policy still retains effects on both price and output. Besides the direct channels from the interest rate to costs, monetary policy might be able to affect demand, depending on the validity and relative importance of traditional and adverse channels, and indirectly affect prices, since we can identify some relation from demand to price. In addition, if interest rates can affect the economic activity, and the nominal wage setting depends on and is influenced by demand, therefore, monetary policy will also affect the distribution of income. Very few authors recognize and discuss the distributive implications of monetary policy.

1.2.3 Distributive Effects of Interest Rates

An important additional effect of interest rates, which is usually not considered in the conventional view, is the distributive effect. The interest rate is also a distributive variable which affects income flows, consequently affecting the income distribution of the economy. If someone pays interest, someone is on the other side getting paid. This implies that the interest rate affects the economic agents' income and expenditure flows. Surplus agents generally make resources available, and receive interest in return, whereas deficit agents generally depend on debt, and therefore pay interest. It becomes obvious that the interest rate has distributional effects, as it determines the cash flow of agents, both deficit and surplus.

High interest rate policies generate income redistribution in favor of surplus agents. Households and firms in already consolidated positions generally have surplus resources, and are the ones that benefit from high interest rates. Banks and financial institutions also benefit from the distributional effects of high interest rates, as these rates directly determine the profit from banking and financial activity. On the other hand, households and firms in less comfortable positions in general depend on loans and are borrowers of credit. These are the agents who pay the interest and do not benefit from high interest policies (Erber 2011; Erber 2012).

After all, as Smithin (2004) states, the product of labor must be divided into three parts: the profit share of the capitalist activity, the wage share of workers, and the interest payment. The author strongly criticizes the NCM policy recommendations and the theory which supports them, especially the apparent technocrat approach and notions, such as NAIRU, natural interest rate, and so on, which mask the distributional effects of those policies.

Not only the interest rate affects income distribution, but also the distribution has consequences on the rest of the economy. Surplus agents, the ones who usually receive the interest payments, rentiers, tend to have lower propensities to consume than industrial capitalists and workers, so a policy shift towards a higher interest rate which favors rentiers, tends to decrease the average propensity to consume. As pointed out by Rochon and Setterfield (2008), for those who understand that economic growth is related to demand, both in the short and in the long runs, the income distribution has an impact on the economic activity.

Argitis and Pitelis (2001) argue that restrictive monetary policy had increased interest rates in the 70's and 80's in the United Kingdom and in the United States, leading to a redistribution of income in favor of financial income. Using a simple but still powerful Post-Keynesian and Kaleckian theoretical framework and empirical evidence, they show that changes in the interest rates might affect what they call *intracapitalist* distribution, which means between non-financial or industrial capital and financial capital, in line with a Marxian point of view, but also the traditional functional income distribution between profits and wages, if interests are considered a cost to firms, and under oligopolistic competition they try to increase prices to compensate the cost increase, therefore considering the interest-cost channel. Moreover, they argue that the shift in income distribution, when reducing the profit share of firms, might disincentive industrial production, thus reducing the economic activity. In particular for the UK economy, Arestis and Howells (1994) show that during the 70's and 80's the share of floating rate assets increased vis-a-vis fixed rate assets, which increases agents' balance sheet sensitivity to changes in the basic interest rate. Moreover, the net balance of most income classes presented a negative trend during that period, with classes becoming net debtors by 1985.

The work of Argitis and Pitelis (2001) goes beyond the simple redistributive effect from savers to debtors, and relates the distributive effects of interest rates with the increasing complexity of the financial system and the financial relations. This point is synthesized here:

> "(...)the impact of interest changes on sectors and units depends upon their net holdings of floating rate assets. It is not enough to say that "savers win and debtors lose" when interest rates rise. Most units are simultaneous holders of assets and debts and the holdings of both may vary together substantially over time. What matters for the impact of interest rate changes is the net position in a subset of financial assets and liabilities and, more strictly still, what matters is the size of this surplus/deficit relative to income.(Arestis and Howells 1994, p.61)"

The role of interest rates, and consequently of monetary policy, in the income distribution has been the focus of an interesting debate within the Post-Keynesian literature, bringing back Keynes' notion of the "euthanasia of the rentier". The work of Smithin is part of this debate.

Parking-it Approach VS Activist Approach

Once it is understood that the interest rate has additional effects apart from the traditional transmission mechanisms, the question remains whether it should be used as a monetary policy instrument in the Post-Keynesian view. If so, how it should done, and if not, what should be done with the interest rate? Rochon and Setterfield (2007) and Rochon and Setterfield (2008) review the debate within the Post-Keynesian view.

The first question that is up for debate is: should the interest rate be used as an instrument of monetary policy to generate real stabilization, as proposed by the NCM and the Taylor Rule? Some Post-Keynesian authors defend this position, called *Activist approach*. This approach within the Post-Keynesian view was originally proposed by Moore (1988) and is also advocated by Palley (2007). Although the authors do not prioritize inflationary control as the orthodox authors do, they argue that the Central Bank should adjust the interest rate up or down whenever the economy deviates from the Central Bank's objectives in the short term. Palley, for example, argues that one of these objectives should be a minimum unemployment rate.

In contrast to the Activist approach, many Post-Keynesian authors defend the *Parking-it approach* or stationary approach, recognizing that the Central Bank should not finetune the current state of the economy with the interest rate as an instrument. What these authors argue is that the interest rate should be kept at the same level, as interest rate variations are not so effective in affecting aggregate demand. If interest rate changes might have erratic effects on both price and output stability, including the distributive effects, then it is preferable to use another policy instrument and keep the interest rate at a defined level.

Within the stationary approach, however, there is another debate. What should be the level of interest rates to be kept fixed? Note that Post-Keynesian authors reject the notion of natural interest rate, in the Wicksellian sense of the NCM, and in fact, the interest rate is a policy-variable, which the Central Bank can arbitrarily choose. Still, are we talking about the level of real interest rate or nominal interest rate? Rochon and Setterfield (2007) and Rochon and Setterfield (2008) recognize three different proposals for alternative interest rates rules, namely: the Smithin Rule, the Kansas City Rule and the Pasinetti Rule.

It is worth noting that the central issue in this debate is the distributional effects of the interest rate. In particular, it highlights what should be done with rentiers, a surplus class that receives interest as cash flow. Keynes had already proposed the euthanasia of rentiers, saying that the interest rate should be low or zero for that class to stop relying on rentism, and invest capital in productive investment.

The **Smithin Rule**, proposed by Smithin (2004) and Smithin (2007), states that the monetary authority should pursue a low but positive real interest rate in the medium term. The existence of a positive real interest rate allows rentiers to survive, but keeping this rate low reduces the income distribution for this class. Some authors who work with this rule, such as Rochon and Setterfield (2007), make an approximation to zero real interest rate, according to what Smithin stated, as the optimal theoretical value for the real interest rate would be probably zero.

The second rule to stand out is the **Kansas City rule**, defended by Wray (2007). Contrary to the Smithin Rule, Wray argues that the monetary authority should set zero nominal interest rate. The real interest rate can be negative, if inflation is positive. This rule is more radical in the sense of rentier euthanasia, since the negative real interest rate completely inhibits rentism. Rochon and Setterfield (2008) however emphasize that the complete euthanasia of rentism depends on the term structure of the interest rate. The central bank controls the basic interest rate of the interbank market. All other interest rates in the economy, for different terms, are a positive spread on that rate. A long-term asset, for example, might have a positive real interest rate, if the nominal rate is a positive spread of the basic rate, even if the latter is zero.

The third rule is the fair interest rate rule, or the **Pasinetti Rule**. This rule is defended by Lavoie and Seccareccia (1999) and it is based on the proposal by Pasinetti (1981). The fair interest rate would be the interest rate which keeps the income distribution unchanged. However, this income distribution does not take financial activities into account. For example, the interest rate X is said to be fair if the purchasing power which is being temporarily exchanged between lenders and borrowers remains the same in terms of hours of commanded labor. For this, the real interest rate should be equal to the growth rate of labor productivity. Even if this is positive, which means that, in absolute and nominal terms, lenders are receiving income and borrowers are incurring expenses, the purchasing power of controlled labor intertemporally remains unchanged, and that rate is said to be fair. It is worth noting that Pasinetti's proposal is to keep the position of rentiers in society unchanged, whatever it might be at the beginning.

We can identify some approximations and divergences between the three rules. To begin with, the Smithin Rule and the Pasinetti Rule seek to control real interest rates. Both rules seek to park the real interest rate at some level: the first at zero, or close to zero, and the second at the same value as the rate of productivity growth. The difference in the level lies in what each rule seeks to keep unchanged. The first seeks to keep renters' purchasing power in terms of goods and services unchanged, whereas the second seeks to maintain renters' purchasing power in terms of hours worked. In contrast, the Kansas City Rule is the only one of the three which argues that the monetary authority should pursue nominal rates and not real interest rates. The real interest rate adjusts endogenously in this case. This implies that, in terms of the nominal interest rate, only the Kansas City Rule is in fact a stationary rule. In the case of the other two rules, the nominal interest rate should be adjusted according to inflation, to keep the real interest rate unchanged. This implies that these two rules are stationary in terms of the real interest rate but activist in terms of the nominal interest rate. The monetary authority should constantly monitor the current state of the economy, especially inflation, to adjust the nominal interest rate.

This entire debate, the recognition of distributive effects, and even the distributive conflict theory of inflation can only occur if heterogeneities come into play, if we recognize some level of disaggregation among agents, firms and households, and if we recognize that distinct agents have distinct goals, which might be conflicting most of the time. If all agents are the same, such as in models with representative agents, distributional effects cannot occur, which leads us to a methodological critique.

1.2.4 Microeconomic Aspects

Even if one considers the validity (or not) of the traditional channels, the existence of alternative channels, different relations between demand and prices, and even new propositions for monetary policy rules in line with the Post-Keynesian framework, there is still something missing: the analysis is done in a macro, aggregated level, without considering microeconomic aspects, sectoral and firms' heterogeneities. Some critiques to the traditional channels presented here already hinted at this, as some channels, especially the balance-sheet channel, have heterogeneous effects on different firms regarding their size, market-share and other heterogeneities. The same can be extended to sectors, as some sectors might heavily depend on imported inputs being strongly affected by the exchange rate cost channel.

This strong methodological critique is presented by Martins et al. (2017), and it is a critique not only to NCM theorists and transmission channels, but also to most Post-Keynesian monetary policy analysis which also fails to consider microeconomic aspects. Their motivation is based on a few but relevant empirical studies (Dedola and Lippi 2005; Dios Tena and Tremayne 2009; Bouakez, Cardia, and Ruge-Murcia 2009; Vespignani 2013) which identify heterogeneous effects of monetary policy when analyzed in a more disaggregated way. In general, they find that both firm-level heterogeneities, such as leverage and market-share, and sectoral heterogeneities, such as market concentration and structure, generate different responses to the same monetary policy shock, and this could even be one possible explanation for some cases of inefficacy of monetary policy since some sectors might react oppositely than the expected by a macro analysis, or even not react at all to monetary shocks. Inspired by the critique and the empirical evidence, Silva, Feijó, and Modenesi (2018) perform similar study for the Brazilian economy, considering 21 industrial sectors, and their results show that intermediate costs are the main source of price inflation among the sectors, with strong heterogeneity, rather than demand shocks.

From a theoretical point of view, Martins et al. (2017) base their analysis on Post-Keynesian approach to prices, as already presented, but also on a fundamental principle stated by Lee (2014) that "the economy is an interdependent disaggregated whole where the distinction between micro and macro makes no sense". Based on the empirical evidence and on the theoretical and methodological grounds, the conclusion is that in a monetary economy, the transmission mechanisms of monetary policy operate with ambiguous effects of interest rate changes on aggregate demand, prices, and inflation, so an alternative framework should be used to offer a more complete description of pricing and inflation. Microeconomic and macroeconomic aspects should be integrated.

1.3 Discussion

To sum up, for the NCM, a monetary authority that pursues inflation target using a reaction function as the Taylor Rule will succeed to provide both price and output stability, because implicitly there is the assumption of perfect competition, and inflation is always explained by excess demand, whereas supply shocks are considered temporary. Therefore, raising the basic interest rate will reduce aggregate demand and then prices. The basic interest rate will certainly have a negative effect on aggregate demand through at least five traditional transmission mechanisms. While there are some debates on the validity of specific channels, or which one is the most important, all channels will have the same final effect on demand in terms of direction, so the final result is unquestioned.

However, the simple recognition that firms do not operate under perfect competition, not even in the long run, where oligopolistic markets are much more common and plausible, and so prices are usually defined as a mark-up over some measurement of the cost structure, changes completely the implications for monetary policy as the last link from demand to prices is not necessarily true. To go further, once recognized that several factors can affect the cost structure, an eclecticism of explanations for inflation arises, including an increase of interest rates. The phenomenon of Gibson's paradox, or the price puzzle, is well known and easily explained by that approach. The basic interest rates can affect prices directly, not necessarily via demand, but via the interest-cost channel as an example, which is relevant for highly indebted economies, and the exchange rate-cost channel, even more important in small open economies. The first cost channel results in a positive correlation from interest to prices, but the latter results in a negative correlation, via exchange rates fluctuation. By simply considering these two direct cost channels, the final result on prices will depend on the circumstances and on the conditions of each specific economy and cannot be known *a priori*.

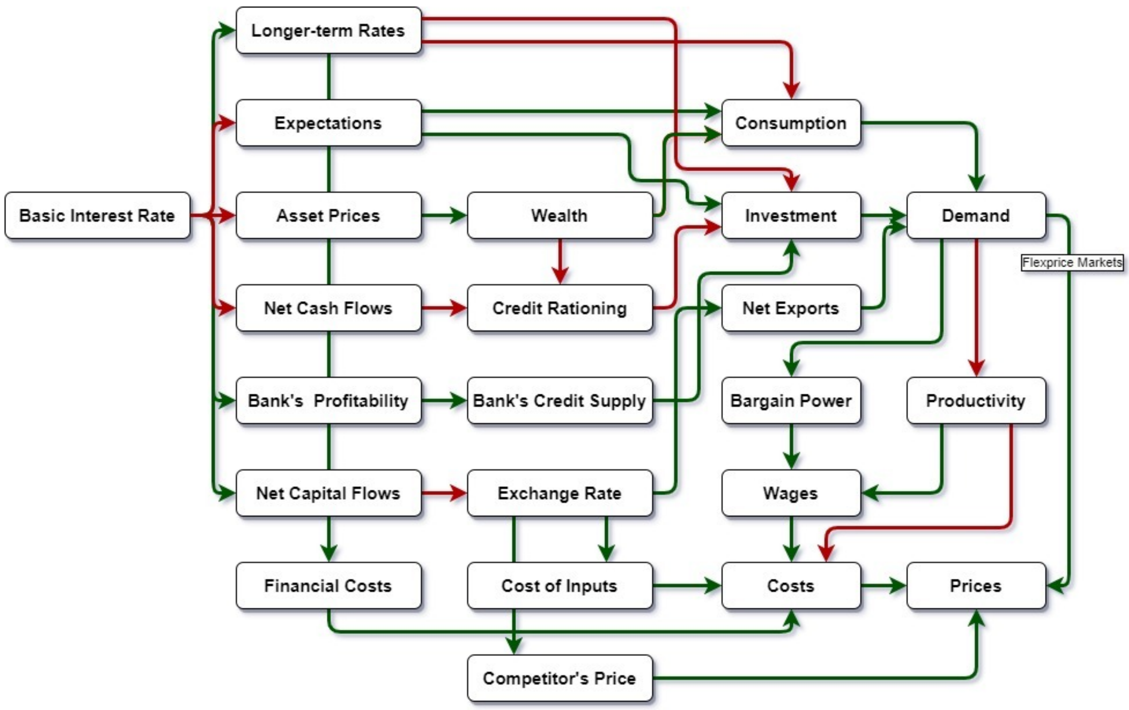
Moreover, several empirical studies and alternative theories might put in check the validity of each traditional channels individually. For example, while the traditional bank lending channel supposes that an increase in the basic interest rate will reduce bank reserves availability, and by the monetary multiplier reduce the credit supply, recent evidence shows that an increase in the basic interest rate is positively correlated to bank profitability and soundness, which can improve the bank's capacity to supply credit. With alternative channels, the final result on demand is also now ambiguous, as some channels might have a positive impact, whereas others can have negative effects.

Finally, the link from demand to prices could be as assumed by the NCM in some *flexprice* markets, but in general if there is a positive correlation then other explanations might arise, such as diminishing returns, but more importantly, the distributive conflict and the bargaining process on nominal wage rates, which often contribute to indexation and propagation of the initial effects. All these implications appear even in a macro aggregated analysis of the transmission mechanisms of monetary policy, but if sectoral and micro aspects are taken into account, when heterogeneities are considered, the same channel might have different impacts on different firms or sectors, leading to an even more unpredictable result at the macro level.

A simple but important change in the hypothesis completely alters the results and the implications for economic policy. With ambiguous effects on both prices and demand, monetary policy might not be effective to provide price stability nor output stability. In fact, the result can be completely opposite from the expected, increasing instability. As Hannsgen (2006) states, monetary policy is an extremely imprecise gun, which might be best not to be fired at all. With that in mind, a more precise representation than Figure 1.1 would be Figure 1.2.

Considering the complexity of the topic, possible alternative channels, the existence of a price puzzle, individual critiques to each of the traditional transmission mechanisms, distributive aspects, the relevance of the financial conditions on the effectiveness of monetary policy, and finally, the methodological and theoretical critique highlighted above, we seek an alternative framework, as Martins et al. (2017) propose. Instead of an aggregate DGSE model based on representative agents, we need a model which integrates micro and macro aspects and accounts for firm-level and sectoral-level heterogeneities, to gain some insights on the stabilizing role of monetary policy and the effectiveness of a Taylor Rule on a complex, financial and evolving economy, considering all the possibilities discussed in this chapter, without pre-defined results. A robust alternative methodology seems to emerge in the last decades within the non-conventional literatures: simulation models.

Figure 1.2: Traditional and Alternative Transmission Mechanisms of Monetary Policy



Source: Author's Elaboration. Green arrows represent a positive correlation from one variable to the other. Red arrows represent negative correlations.

Chapter 2

Heterodox Simulation Models: A Review

There is a debate on the methodology of economic models' resolution: there are those who support analytical solution, and there are those who advocate solution by computer simulation. As exposed by Dweck (2006), there is no contrast between analytical results and simulation results. It is possible that in certain situations analytical results are preferable, whereas in some other cases simulation results are more desirable. In many cases, however, analytical results depend on strong simplifications, which might distort the object of analysis and compromise the results, especially when dynamic effects, structural change, interactions between agents, and non-linearities occur. If one recognizes the dynamics and the complexity surrounding the object of economic analysis, largely characterized by those elements mentioned above, simulation method represents a strong option, what has led to a growing preference for this method in recent years. It should also be noted that such method benefits from the increasing computational processing capacity of recent technological developments.

From the mid-2000's onwards, two approaches gained strength and notoriety by using the simulation method: the Agent-Based approach and the Stock-Flow Consistent approach. Both gained even more prominence after the 2008 Crisis, with increasing criticism on orthodox models and their methodology, and with great search for alternative approaches. The Dynamic Stochastic General Equilibrium models used by orthodoxy were not able to predict or to fully explain the crisis, nor were they able to guide an adequate response of economic policy, and thus their validity was further questioned. Alternative approaches and models dealing with the complexity and dynamics of the economy gained much more space.

In a nutshell, AB models follow similar mathematical instrumental framework, although theoretical assumptions vary greatly from model to model. In this framework, each basic unit, the agent, has its problem defined and its own behavior rules heterogeneously, unlike the representative utility maximizing agent characteristic of DSGE models. This approach is widely used by Neo-Shumpeterian authors who focus more on micro themes, trying to somehow make a micro-macro integration. Such tool allows us to analyze complex systems characterized by micro-macro interactions, that is, macro results depending on the interaction of microeconomic agents.

SFC models are macro models which attempt to coherently integrate the stocks and flows of an economy. Consistency between flows and stocks is generated by a series of accounting identities derived from the transaction matrices and balance sheets of each sector. It is noteworthy that the consistency between stocks and flows is nothing more than a condition that should necessarily be met in all models to be consistent and robust. Moreover, the matrices and the accounting statements which generate this consistency are also an instrumental tool. Theory and hypotheses arise in another feature of models: behavioral equations.

Both approaches are methodologically heterodox, in contrast to the modelling methodology employed by orthodoxy, the DSGE models. But it is worth noting that they are both instrumental, methodological approaches. The theory arises in the equations described by the model itself. Nevertheless, they are mostly employed by heterodox authors, in conjunction with heterodox theoretical questions. That is, they can be a good alternative to orthodoxy as a whole, theoretically and methodologically.

Despite that, each of those approaches is more restricted to distinct heterodox groups. AB models, although dealing with micro-macro interaction, focus more on micro aspects, so they are more employed by Neo-Schumpeterian authors. Whereas the SFC models, despite having micro-foundations and behavioral equations for each sector, focus more on the macro and accounting aspects of flows and stocks of the economy, so they are widely used by Post-Keynesian authors.

There is a recent open research agenda that proposes the integration of those two approaches, because they are methodologically heterodox, powerful for unconventional theoretical issues, and somewhat complementary to each other. Caverzasi and Godin (2015) highlight that an AB-SFC integration would be a strong alternative to DSGE models, deepening the micro-foundations in relation to SFC models. Caiani et al. (2016) in turn build a reference model for future works seeking to integrate the two approaches. Several other recent works try to combine the two frameworks somehow.

This chapter reviews the origin, essential elements, basic structure and the main literature models of those two approaches individually. In sequence, we try to identify the complementarities between them as the integration literature proposes, and finally as this combined approach is growing, we perform a review on how recent

AB-SFC models formalized the financial sector, especially regarding four main aspects: (i) firms' demand for credit; (ii) individual credit supply and credit rationing by the banks; (iii) banks' liquidity preference, regulatory rules and total supply of credit, and (iv) interest rate setting. We also analyze the balance sheet structure of each model. The idea is to examine the most prominent models in this literature. and see how they treat financial variables, what their limits and possible expansions are. We also aim at identifying a minimal financial structure in this integration literature. Finally, this effort is justified as it is also an attempt to bring most models to a common ground, using the same symbols and notations to facilitate comparative exposition.

2.1 Agent-Based Models

2.1.1 Origin and Contextualization

The exact origin of the AB approach cannot be credited to a single work or author. The emergence of this approach benefited from various developments in science (Turrell 2016) and several other theoretical views which share the same methodological or theoretical issues. In general, all these views which contributed to the current establishment of the AB approach shared some methodological discontent with the ideas of representative agent and hyperrationality, common in the orthodox view and in DSGE models. The original starting point of AB modelling is the recognition that the economic system is a complex and dynamic system composed of "individuals" or independent and uncoordinated agents who interact locally and repeatedly, generating some regularities (Tesfatsion 2006).

Such recognition can be identified in the attempt to formulate a general Walrasian equilibrium and the various attempts to broaden or to develop it during the 20th Century. One of the views that contributed to the establishment of the AB approach was the attempt to heterogenize agents in Walrasian general equilibrium models by orthodox authors (Tesfatsion 2006). In parallel, authors who contributed to the emergence of the so-called Neo-Schumpeterian/evolutionary approach, such as Richard Nelson and Sidney Winter, for example, in their seminal work (Nelson and Winter 1982), also questioned rationality and the representative agent, implementing heterogeneity between agents, but based on a completely different theoretical framework from the orthodox one.

That shows how different theoretical views contributed to the establishment of an economic model approach. However, it also shows that the AB approach is a methodological approach, it is a mathematical instrument that allows modelling the economy in a certain way. In this instrumental framework each agent has its problem well defined, and its own rules of behavior heterogeneously, unlike the representative utility maximizing agent characteristic of DSGE models. The way in which the problem and the behavior rules are defined depends heavily on theoretical hypotheses, which allow different theoretical views to rise within the same methodological approach.

Despite the possibility of distinct theoretical views within the AB approach, the attempt to implement it for orthodox general equilibrium models has not been widely accepted: few researchers have devoted themselves to it, thus being relegated to a small niche in the orthodoxy. On the other hand, within the Neo-Schumpeterian/evolutionary view, the AB approach has been widely accepted and used, as this approach focus more on microeconomic themes, interactions between agents, and micro-macro relations which emerge from the micro spectrum. Thus, the AB approach, by emphasizing agents at the micro level, allows us to analyze relevant issues to the neo-Schumpeterian view, such as the process of innovation, competition and market selection mechanisms.

However, it was not possible to emphasize on the agents themselves until the 1990's, due to the lack of sophisticated tools to model the economy in such a way. Those tools involve both advances in logic and computational capacity, as highlighted by Tesfatsion (2006). But when some initial tools were available (Hanappi 2017), some initial attempts were made to model the economic system based on the complexity and on the interactions between agents, albeit in isolation, such as Tesfatsion et al. (2001) and Tesfatsion (2002), Valente (2005) and Fagiolo, Dosi, and Gabriele (2004), as an example.

The first two attempts to standardize and to define AB approach are quite similar and almost simultaneous. Tesfatsion (2006) tries to define general characteristics and procedures for the methodological approach, which the author defines and names as Agent-based Computational Economies (ACE). Pyka and Fagiolo (2007) also list general elements and characteristics for a methodological approach, in particular for the Neo-Schumpeterian models, which the authors define as Agent-Based Modelling (ABM). Despite some punctual differences, including the difference in name, the two views share much more in common than they diverge, to the point that we can group them into one, referred herein as AB models.

2.1.2 Essential Elements and Basic Structure

We can outline the AB approach following the definition of Tesfatsion (2006): The AB approach would be the computational study of economies through complex dynamic systems. Each complex system exhibits two fundamental characteristics: (i) it is a system composed of interacting agents, and (ii) it is a system which exhibits emergent properties derived from interactions between agents. Agents can be individuals, social groups, institutions, physical and even biological entities. Additionally, an agent might be composed of several other agents in hierarchical constructs. What defines the agents are the common behavioral methods, ranging from very sophisticated and learned behaviors to simple adaptive responses.

Pyka and Fagiolo (2007) define ten fundamental elements or characteristics[1] of the AB approach, reinforced by Fagiolo and Roventini (2016). It is worth noting that not every AB model incorporates the exact ten elements, but generally they incorporates a subset of them. They are:

1. Bottom-up perspective: Aggregate properties must be obtained as the macro outcome of a possibly unconstrained micro dynamics going on at the level basic entities, agents.

2. Heterogeneity: Agents are heterogeneous in some of their characteristics.

3. The evolving complex system approach: Agents live in complex systems that evolve through time. Therefore, aggregate properties are thought to emerge out of repeated interactions among simple entities.

4. Non-linearity: Interactions are inherently non-linear. Additionally, non-linear feedback loops exist between micro and macro levels.

5. Direct or endogenous interactions: Agents interact directly, so decisions undertaken today directly depend on the past choices made by other agents, through feedback mechanisms.

6. Bounded rationality: The environment is too complex for hyperrationality to be a viable simplifying assumption. More generally, agents are assumed to behave as boundedly rational entities.

7. Learning: Agents engage in the open-ended search of dynamically changing environments.

8. "True" dynamics: AB models are characterized by true non-reversible dynamics, so the state of the system evolves in a path-dependent manner.

9. Endogenous and persistent novelty: Socio-economic systems are inherently non-stationary due to ongoing introduction of novelty and new patterns of behavior.

10. Selection-based market mechanisms: Agents typically undergo a selection mechanism.

[1]Those elements are more specific to AB models applied to the evolutionary approach.

Additionally, Pyka and Fagiolo (2007) and Fagiolo and Roventini (2016) establish a basic structure for AB models. Initially, one should define a population of agents (individuals, consumers, firms, etc.) or a set of populations, which might be constant over time or not. Time is considered in discrete periods (it can be days, weeks, months, quarters, years, etc.). Each agent is characterized by micro decisions (micro variables) and micro parameters. Initial values should be set for all variables and parameters. At each time period, one or more agents should formulate micro decisions by collecting available information based on previous periods, and/or the agents they are interacting with, thus defining a routine or behavior rule. After that decision, a new set of values for the micro variables is introduced to the system for new interaction rounds. Macro variables are then computed. New rounds of decisions and interactions take place in subsequent time periods. Usually, there is a stochastic component in the decision rules, making the trajectory of the model a stochastic process. A major feature of AB models is that those steps are usually described by a timeline of events, where the order of events and decision making at each time period is specified.

Pyka and Fagiolo (2007) reinforce that the above description, although simple, has a diversity of applications. For example, a variety of decision rules, behaviors, routines can be tested, from simple deterministic rules to complicated algorithms with stochastic and nonlinear components with feedback rules. Similarly, different expectation formation rules can be modelled, for example. The AB approach is quite flexible, so that several lines of models emerge, seeking to analyze the most diverse topics, as we will see below.

2.1.3 Main Literature Models

In this subsection we briefly present the main AB models developed in recent years. Our goal is not to make a wide review of the literature, but only to contextualize the main models and authors. For detailed reviews, Fagiolo and Roventini (2016) analyze recent works on at least five major topics within macroeconomic policy analysis, such as fiscal policy, monetary policy, financial instability and macroprudential policy, labor policies, and even climate policies. Turrell (2016) and Hanappi (2017) contextualize the AB models in a broader and historical perspective. Finally, Dawid and Gatti (2018) present an extensive comparative analysis of eight different macroeconomic AB families of models.

First, as already explained above, there are both orthodox and heterodox AB models, depending on the theoretical choice behind the behavioral equations and the description of the system. Among the orthodox models, in general, we find models which seek to incorporate heterogeneous agents in a Walrasian general dynamic equilibrium, as models that seek to deepen the decision of heterogeneous agents in a context of general equilibrium. Among the heterodox models we can distinguish three types of models: (i) topic-specific models, which model only specific issues or sectors, (ii) models of simple artificial economies, and (iii) models of large-scale artificial economies. These last two types describe a complete artificial economic system, either in a simplified form or in a more detailed and large scale. Simple artificial economy models are theoretical models, whereas large-scale models are more applied to real cases and particularities. This differentiation between theoretical models and large-scale models is highlighted by Lengnick (2013).

Stand out as topic-specific models those developed by the Bank of England, such as Galbiati and Soramaki (2008), modeling the payment system, Baptista et al. (2016), which models the real estate market in the United Kingdom, and Braun-Munzinger, Liu, and Turrell (2016), a model of the corporate bond market. There are also models by the Brazilian Central Bank, such as Da Silva, Lima, et al. (2015) and Santos (2005). The former models a banking system to analyze effects of monetary policy and prudential regulation, whereas the latter models a dynamic game of bank runs.

The large-scale artificial economy model that mostly stands out in the literature is the Eurace@Unibi model, the result of an European Union-funded research project for the construction of an AB macroeconomic model simulation platform. The original project was finished in 2009 and resulted in a first version of the Eurace model, but this first version was continuously developed later, so the most developed and complete version is described in Dawid et al. (2012) and Dawid et al. (2016). Other works addressing specific themes using the Eurace@Unibi model were developed by Cincotti, Raberto, and Teglio (2010) and Cincotti, Raberto, and Teglio (2012), Dawid et al. (2013) and Dawid, Harting, and Neugart (2018), Raberto, Teglio, and Cincotti (2011) and Teglio et al. (2017). The model provides representation of a closed economy with spatial structure. In fact, this can be considered the most particular feature of this model: agents are located in regions, where heterogeneity is generates, not only between agents within the same region, but also between different regions.

Among the models of simple artificial economies there is greater diversity. As much as these models describe a complete and still stylized economy, each paper proposes to analyze specific issues within that model, so that different specifications are made to facilitate the analysis at hand, simplifying some aspects and/or better developing others. For example, Lengnick (2013) proposes to build a basic reference model. Chiarella and Di Guilmi (2012) build a model and analyze results of different fiscal policies in a financially fragile economy. Salle, Yıldızoğlu, and Sénégas (2013) create a model to analyze the inflation targeting regime.

One of the simple artificial economy model family is based on the seminal model by Howitt and Clower (2000), in which a network of expert agents is capable of self-organization and self-regulation. Based on this model, Ashraf, Gershman, and Howitt (2016) and Ashraf, Gershman, and Howitt (2017) analyze, respectively, how banks can affect macro variables, and how inflation impacts them. Napoletano, Roventini, and Gaffard (2017) use a similar basis to analyze the impact of credit rationing on macroeconomic variables, in particular on the fiscal multiplier. Finally, Popoyan, Napoletano, and Roventini (2017) use a larger version of the model to study the impact of alternative macro prudential regulations and their interactions with different monetary policy rules on macroeconomic variables.

Gatti et al. (2005) build a base model to explain economic fluctuations, based on an interconnected credit network and financial fragility. Later, the same model was used by Gatti et al. (2009) and Gatti et al. (2010) to analyze a banking crisis and to discuss a financial accelerator in the economic cycle. While Delle Gatti's model discusses the business cycle and highlights credit interrelationships, Ciarli et al. (2010) and Ciarli et al. (2012) model discusses economic growth within the Neo-Schumpeterian view, with emphasis on structural change. The model is based on early works in the Neo-Schumpeterian line, and it is also used by Lorentz et al. (2016) and Ciarli and Valente (2016).

However, among the simple artificial economy models, the most developed is what is known in the literature as the K+S (Keynes + Schumpeter) model established by Dosi, Fagiolo, and Roventini (2010) and later developed and used for specific analysis in Dosi et al. (2013), Dosi et al. (2015), Dosi et al. (2016), Dosi et al. (2017b), Dosi et al. (2017a), and Dosi, Roventini, and Russo (2019). As it is the most developed stylized model (in terms of number of papers), it is used as a reference for many others, and it is the one that mostly dialogues with the diversity of models. So, let us briefly describe the structure of the model.

The model is composed of two sectors, one of capital goods and the other one of consumption goods, both with a population of firms. There is also a population of households/workers and a public sector. Capital firms produce heterogeneous machines as a result of heterogeneity in R&D: they can innovate or imitate other innovative firms. The chance of success in implementing a technology (imitation or innovation) that increases productivity depends on a random seed. After successfully or unsuccessfully implementing the new technology, capital goods firms offer machines with different productivity. These machines are demanded by consumer goods firms, which now have different productivity, competitiveness and mark-ups (and prices), affecting their revenues, profits and ultimately the entry and exit of firms in the market. Workers who are not employed by firms receive government unemployment benefits equivalent to a fraction of the average wage. The government raises funds by charging taxes on wages and profits. The model is able to replicate stylized facts such as long-term growth and regular fluctuations. The authors conclude that only the "Schumpeterian engine" of technological change is not sufficient to sustain long-term growth without a Keynesian autonomous demand-generating process, in the model represented by government unemployment benefits. Other papers develop specific parts of the model, such as the financial system, or the labor market.

2.2 Stock-Flow Consistent Models

2.2.1 Origin and Contextualization

The origin of SFC models comes from the recognition that every flow in an economy comes from somewhere and goes somewhere, so nothing is lost. The first author to recognize such feature and who tried to account for all flows of the economy was Copeland (1949), who studied cash flows for the US case, creating the flow of funds. Subsequently, two parallel authors resumed their attempt to account for the cash flows of the whole economy (Caverzasi and Godin 2015).

Nobel laureate James Tobin, along with other co-authors, developed what became known as the "pitfalls" approach, by recognizing that prices and quantities determined in the financial and monetary markets are influenced by and also affect the real side of the economy, while criticizing the purely financial models of that time (Nikiforos and Zezza 2017). This recognition was taken into account when Tobin was trying to create an empirical model for the US, which described both the financial side and the real side. This model (Backus et al. 1980) combined behavioral theoretical assumptions, with a rigorous accounting apparatus based on Copeland's cash flow, resulting in a possible first SFC model (Caverzasi and Godin 2015).

In parallel, Wynne Godley, in the 1970s and 1980s, began to develop the principles which characterize SFC models in an attempt to create a rigorous model to describe both the real and the financial sides, combining theory with empirical work (combining his academic work, as Director of the Cambridge Department of Applied Economics, and practical life, with 14 years of experience working at the English Treasury), a very similar motivation to Tobin's. His work became stronger in the 1990's after joining the Levy Institute of Bard College in New York. During that period the model began to be formalized in a series of publications (Caverzasi and Godin 2015).

The work of Godley and other authors at the Levy Institute gained strength and greatly contributed to the current establishment of SFC models. His work gave birth to the Levy Macroeconomic Model, which is used to make medium-term projections for the US economy until today, and was able to predict the 2008 crisis. Godley's work also resulted in the book Monetary Economics (Godley and Lavoie 2007) which became the major reference for SFC modelling. Other preliminary efforts to consolidate the SFC approach, such as Dos Santos (2003) and Dos Santos (2005), among many others, should also be highlighted.

Therefore, it is clear that there is another fundamental principle which guided the work of Tobin and Godley, besides the clear recognition that it is necessary to consistently account for the flows of the economy. This second fundamental principle underlying the SFC approach is highlighted by Nikiforos and Zezza (2017, p.2): the behavior of the real side of the economy cannot be understood without considering the monetary side. This understanding became even more evident after the 2008 crisis. Given their characteristic of coherently integrating the monetary and real sides, SFC models are an important tool for studying modern financial capitalism, and they have gained much prominence after the crisis.

2.2.2 Essential Elements and Basic Structure

We can define the SFC approach as a family of macroeconomic models which attempt to coherently integrate all stocks and flows of the economy, also integrating the real side and the monetary side. These models generally consist of an accounting apparatus, where stocks, flows, sectors and assets are recorded. This apparatus consists of a set of matrices that reproduce the balance sheets, transactions flows and capital gains of each sector of the economy. In addition to this accounting apparatus, the models have a series of behavioral equations which describe the decisions and actions of each sector. It is worth noting that the accounting apparatus is an instrumental tool, atheoretical, whereas the theory is imputed by the researcher in the behavioral equations (Caverzasi and Godin 2015). Let us first address this accounting apparatus.

Nikiforos and Zezza (2017) highlight four accounting principles that define the SFC approach. They are: (1) Flow Consistency; (2) Stock Consistency; (3) Consistency between stocks and flows; (4) Quadruple Matching Principle.

1. Flow Consistency means that all cash flows come from somewhere and go somewhere. Thus, no flow is lost in the model.

2. Stock Consistency means that every liability of an agent or sector is also an asset of other agent or sector.

3. Consistency between stocks and flows means that every flow implies change in one or more stocks. As a result, end-of-period stocks can be obtained by accumulating the relevant flows in that period.

4. The Quadruple Matching Principle derives from the first three, and it means that each transaction should be accounted four times: the inflow to one agent, the outflow to another agent, an increase in a stock and a decrease in another stock.

These described characteristics are the accounting part of SFC models. Although the approach takes its name from Stock-Flow Consistency, the authors themselves argue that this consistency, highlighted by the four principles above, should be a requirement for any economic model, whether SFC or not, orthodox or heterodox. Nikiforos and Zezza (2017) reinforce that the name, in fact, creates confusion, if all models, orthodox or heterodox, should be consistent in this sense, so the name is not a good delimiter for a group of specific models (what we actually call here SFC models).

One probably more defining characteristic, apart from those principles, is that SFC models are usually represented by two matrices: the Balance Sheet Matrix, which records the assets and liabilities of each sector, and the Transaction Flows Matrix, which records the uses and sources of resources, and stocks variations. The use of these two matrices is one way of representing the accounting structure of an economy. Another possible way is by using Social Accounting. This is already a more particular feature of SFC models, as not every model that meets accounting consistency requirements is represented by the matrices. For example, orthodox DSGE models meet accounting requirements, but are not represented this way. In addition, the Balance Sheet Matrix is extremely powerful to describe the relationships between the real side and the monetary-financial side, one of the goals of SFC models.

But perhaps the most defining element of SFC models is in fact the theory behind it. As already stated, theory lies fundamentally in describing the behavioral equations, even though there are still some aspects of modelling that depend on theoretical assumptions, such as the choice of assets and some simplifications usually made. Mathematically, if a model has n endogenous variables and the accounting structure gives us k accounting identities (equations), n-k equations are still needed to solve the model. These are the behavioral equations, which specify the behavior of agents or sectors, and are generally of five possible types, according to Nikiforos and Zezza (2017):

- They specify how agents or sectors determine their spending. For example, one should determine how the household sector decides its consumption, how a given productive sector decides investment, and so on.

- They specify how agents or sectors finance their spending or potential financial positions. For example, firms should determine the share of investment, which is financed from their own resources, with loans, with stock market capitalization, etc.

- They specify how agents or sectors allocate their wealth. This type of behavior is more specific to households, for example, in deciding between which types of assets they apply their capital.
- They specify aggregates or macroeconomic variables such as productivity growth rate, wages and inflation.
- They specify the behavior of financial agents or sectors (including the monetary authority), for example, in the decision to lend and create credit.

In the theory behind the specification of those behavioral equations, the SFC approach usually uses a Keynesian "closure", that is, it assumes the Effective Demand Principle. The accounting framework meeting the consistency requirements, in addition to the Keynesian closure in the theory behind the behavioral equations defines SFC models, thus providing an integrated and consistent approach between the real side and the monetary side of the economy.

2.2.3 Main Literature Models

Again, we do not seek to make a broad review of existing SFC models, but only to contextualize them. Several reviews were done before. Dos Santos (2005) reviews the first moments of the approach, searching for sources and theoretical origins within Keynesian literature. Caverzasi and Godin (2015) did an extensive review more focused on the practice of SFC modeling, whereas Nikiforos and Zezza (2017) complement and update these two reviews, also presenting aspects under debate within the approach.

As shown by Nikiforos and Zezza (2017), there are theoretical SFC models and applied models, similarly to AB models of artificial economies. Theoretical models seek to describe complete economies, but without particularities and characteristics of specific systems or countries, whereas applied models use existing data to model specific countries or economies, thus they are used for more concrete policy analysis and even for forecasting. Among the applied models we highlight the Godley-Levy model, used to analyze the US economy (Godley 1999; Zezza 2009). The same methodology was used in models applied for Denmark and Greece. Other models were developed for the cases of Ireland, Austria and the United Kingdom.

Among the theoretical models, the main reference is Godley and Lavoie (2007). Unlike with AB models, where there is a great diversity of models due to a decentralization of the approach among SFC models, most of the theoretical models are based on that work, even if not completely. This is because their work is not only seminal for the dissemination of SFC models, but also didactic, as they build the model in stages. Each step is the basis for a different SFC model structure, for a particular specification, ranging from simple economies to bank economies, open economies, growth models, etc. Therefore, it is rare to find a model specification that has not been presented, even in a basic form, in Godley and Lavoie (2007).

One clearly perceived differentiation is between closed and open economies. This differentiation occurs because of the matrices which characterize the approach. For a consistent open economy model, the accounting structure of the domestic country to the foreign country (or the rest of the world) needs to be replicated, so that models are at least double in size. Thus, SFC models which analyze open economy issues are quite extensive, such as Lavoie and Zhao (2010) and Mazier and Tiou-Tagba Aliti (2012) for example, who elaborate models from three countries, or Lavoie and Daigle (2011), Greenwood-Nimmo (2013) and Valdecantos and Zezza (2015), who use models from two countries. As already noted, all of them are based on, or refer to Godley and Lavoie (2007), chapter 12, which establishes the basic open economy SFC model.

When it comes to studying topics unrelated to the external sector in general, closed economy SFC models are usually used. In this case, models may differ in many aspects, either in specifying behavioral equations or in choosing the number of assets, which is a crucial point in the formulation of models, as Caverzasi and Godin (2015) point out, but all of them fundamentally follow the basic structure proposed by Godley and Lavoie (2007). Among the closed economy models, we highlight models which discuss financialization, as Treeck (2008), Passarella (2012) and Passarella (2014), Botta, Caverzasi, and Tori (2015) and Sawyer and Veronese Passarella (2017), whereas Botta, Caverzasi, and Tori (2018) discuss shadow banking, Haas and Young-Taft (2018) explore quantitative easing, and Martins (2016) analyses fiscal policy.

As Godley and Lavoie (2007) is the reference model, it might be convenient to describe its structure very briefly. All chapters of the book gradually culminate in the complete model presented in chapter 11, described as a growth model with keynesian-kaleckian assumptions, using the Effective Demand Principle in the short and long runs, which has a complete financial system with banks, loans, credit, currency, stocks, bonds, etc. Initially, the model assumes that labor productivity grows at an exogenous rate, and that the workforce is constant over time. Government spending also grows at an exogenous rate, equal to the rate of productivity growth. The rate of capital accumulation is a function of the degree of capacity utilization and the interest rate. The capital growth rate is thus endogenous and tends to match the growth rate of government spending. The model is composed by five sectors: households, firms, banks, Central Bank and government.

Firms make decisions about production, inventories, investment, prices, costs, and ultimately financial positions. Firms produce based on extrapolative expected sales, and on desired inventory levels. Net investment depends on a constant component which reflects the *animal spirits*, the interest rate on loans and the degree of capacity utilization. Given the firms' desired level of output, they decide their costs, the number of workers employed, and the actual wage to be paid. The latter depends on the distributive conflict, the bargaining power of the workers, which ultimately depends on the unemployment rate. Prices, on the other hand, depend on the mark-up on historical production costs. Financially, firms finance their costs with retained earnings and shares. Bank loans are a third option which generally only finances new investments and inventory costs. The borrowing demand of firms is residual, relatively to retained earnings.

Households receive wages and distributed profits from firms and banks. Given these resources, they make portfolio choices and might allocate in bank deposits, shares, or securities. They also decide their consumption, which depends on both income and wealth. If the available resources are not sufficient, households can borrow bank loans. Banks, in turn, create money. They hold firm and household deposits, as well as compulsory reserves at the Central Bank. Banks offer loans to households and firms based on a customer credit analysis. Firms with no financial conditions receive no loans and do not even start production and investment. Finally, banks control the spread between interest rate on loans and the basic interest rate set by the central bank.

The model is able to reproduce a modern industrial and financial economy, which achieves a Steady State around the growth rate of government spending. However, the model does not generate full employment even in the long run without active fiscal and monetary policies. The bottom line is that public spending is the engine of growth, and that the fiscal deficit in Steady State is determined by private net savings, in line with Minsky's proposition and in opposition to advocates of balanced fiscal budgets.

2.3 AB-SFC Integration Agenda

As seen so far, the two heterodox approaches of simulation models have some elements in common, whereas there are significant differences between them. Both are methodologically heterodox, in contrast to the modelling methodology employed by orthodoxy, the DSGE models. It is also worth noting that in general both approaches can be seen as atheoretical, as instrumental or methodological tools, until the hypotheses are defined in the model specification. It is possible to achieve Neoclassical results using an AB methodology or SFC methodology. Nevertheless, both approaches can be theoretically heterodox as well. However, each of them is more employed by distinct heterodox theoretical strands. AB models, although dealing with micro-macro interaction, focus more on micro aspects, so that they are mostly used by neo-Schumpeterian authors in general. SFC models, despite having micro-foundations and behavioral equations for each sector, focus more on the macro and accounting aspect of flows and financial stocks of the economy, so they are widely used by post-Keynesian authors. But one can argue that they have complementary aspects.

A possible and common critique of most SFC models is that they are sectoral models, represented by sectors such as the household sector, the firm sector, the government sector, and so on, so their behavioral equations actually describe what the behavior of a representative agent of those sectors or an aggregate behavior would be. Thus, many authors, averse to the notion of representative agent, seek to improve the micro foundation of SFC models. At the same time, it is possible to criticize some basic AB models for lack of consistency between stocks and flows, especially when firms enter and exit the market, so many authors are already concerned with ensuring consistency of stocks and model flows (Caiani et al. 2016).

There is also theoretical complementarity, as AB models are generally concerned with more productive aspects, firm's investment decisions, innovation, technological progress, whereas SFC models generally focus on the financial sector, financial decisions, different assets, etc. Nikiforos and Zezza (2017, p.17) point out that "the SFC literature is not focused on productivity issues". Incorporating Schumpeterian elements, already studied and modelled by the AB approach, would be a way of endogenously determining productivity growth, rather than assuming it as a constant or exogenous growth, as we have seen in the brief description of Godley and Lavoie (2007) model and as many other SFC models do. On the other hand, as it has become clearer from the 2008 crisis, that the financial side is of extreme importance, as well as its connections with the real side. This is one of the guiding principles of the SFC approach. Incorporating this principle into AB models would make them even more potent in explaining economic phenomena. Many recent AB models are already developing the financial side, incorporating banks, monetary policy, and macroprudential regulation. Despite this effort, it is clear that the way SFC models portray the financial side is much more complex, detailed and consistent.

For those reasons, there is an open research agenda that proposes the integration of those two approaches, as they are methodologically heterodox, powerful for unconventional theoretical issues, and in some way complementary to each other. The basic idea involves populating each sector of a SFC model with heterogeneous agents in line with AB models, thus eliminating the representative agent problem. On the other hand, such integration would allow more sectors, particularly the banking sector, to be introduced into an AB model, and an accounting matrix in line with the SFC approach would help eliminate possible stock and flow inconsistencies, and describe and illustrate the models as well. Because of several advantages, many authors, such as Seppecher (2012) and Caverzasi and Godin (2015), argue that AB-SFC integration would be a strong alternative to DSGE models, both methodologically and theoretically.

As part of this research agenda, Caiani et al. (2016) build a reference model to serve as a basis for future works on more specific aspects, as used for example by Schasfoort et al. (2016). The model strongly opposes to DSGE models, which, according to the authors, even though they have incorporated complexities, heterogeneities, and non-linearities after the crisis, they failed to significantly represent the complexity of modern financial capitalism. Additionally, the authors propose a validation method to encompass both empirical validation of consistency between stocks and flows. Finally, the authors also present a calibration method for initial values, which is a controversial point in many simulation models.

Their model is composed by a population of households which supply labor, consume consumption goods and save money in the form of bank deposits. There are two sectors, one of homogeneous capital goods and one of homogeneous consumption goods, both with a population of firms that can take bank loans to finance their production and investments decisions, and whose profits can be distributed to their owners (households), or be retained in the form of bank deposits. There is a banking sector, with a population of banks, which collects deposits from households and firms, lends to firms and buys government bonds. Banks follow capital and liquidity ratios and might obtain reserves from the monetary authority to maintain those ratios as desired. The government hires public workers and pays a benefit to unemployed workers, financed by collected taxes on firms and households and by government bonds. Finally, the monetary authority issues money, owns a bank's reserve account, and can purchase unclaimed government bonds.

In establishing all flows generated by the model, authors present the balance sheet and the transaction matrices, showing that the model has consistency between stocks and flows. They then present the timeline of events for each period, and specify agent behaviors, such as in AB models. Subsequently, they present the consistency validation and stylized facts which validate the model empirically. Thus, they set the framework for future work on the AB-SFC agenda.

Despite the benchmark proposed model by Caiani et al. (2016), the authors acknowledge that other AB-SFC integration attempts had been made previously, such as Kinsella, Greiff, and Nell (2011) and Seppecher (2012), but the authors argue that those attempts are very heterogeneous in the way they implement the consistency rules, but especially in the main questions they seek to analyze. There is also the EURACE model, presented in the AB section, which is recognized as an AB model that has stock and flow consistency from its base. However, Caiani et al. (2016) highlight that the model is quite large and complex, with hyper-realism, as it is a model applied to the European case. Thus, despite its success, the model is difficult to replicate and overly complex for more timely and generic analysis. Due to those heterogeneous and complex attempts, they proposed a simple benchmark to an integrated AB-SFC model.

We have noticed, however, that a family of models prior to those, already anticipated, although still incipiently, this AB-SFC integration. The Multisectoral Micro-Macro (MMM) model proposed by Possas and Dweck (2004) and Dweck (2006), in its more consolidated version, already included elements of both the AB and SFC approaches. Dweck (2006) corroborates with this hypothesis, explaining the importance of the AB framework to the model, while showing that the model also has consistency between stocks and flows and presented balance-sheet and transaction flows matrices. Unlike the EURACE model, the MMM model is theoretical, abstract, and not empirically applied to the European case or other concrete economy, so it can be reproduced and used more easily. However, the model, although less complex than the EURACE model, is also less simple than the benchmark model proposed by Caiani et al. (2016), and if updated with recent developments, including those proposed by the authors, it might represent a step forward in the AB-SFC integration agenda. Although the real-financial relations, such as the financial constraint to firms' investment, already played an important role, the financial sector was modelled implicitly, without specifying decisions and behaviors of financial agents, like banks. The most recent studies in the AB-SFC integration agenda have explicitly considered the interrelationships of the financial agents with non-financial firms, and the MMM could benefit from recent developments in that line. However, there is no consensus on how to properly implement the financial sector into those models, and a review might be necessary.

2.4 The Financial Sector in recent AB and SFC Models

In this section we do a brief yet formal literature review on recent AB-SFC models to better understand how the financial sector was modelled. We first describe the balance sheet structure of each model in a Balance-Sheet Matrix, as in a SFC model and subsequently, we present formulations for four basic aspects of the credit system: (i) firm's demand for credit, (ii) bank's total amount of credit, (iii) individual supply of credit and credit rationing, and (iv) interest rates setting by the banks. We have chosen to describe those formulations and balance sheets using the same symbols, letters and indices, instead of the ones used by each author, to facilitate comparative expositions[2]. By reviewing the most relevant recent studies we try to identify what a minimal structure of the financial sector in the literature is. The models analyzed here are Dosi et al. (2015), Caiani et al. (2016), Dawid et al. (2012), Popoyan, Napoletano, and Roventini (2017) and Seppecher, Salle, and Lavoie (2018).

2.4.1 Balance Sheet Structure and Stock-Flow Consistency

Caiani et al. (2016) model is composed by households, capital goods firms, consumption goods firms, banks, the government, and the Central Bank. Households, capital goods firms and consumption goods firms hold bank deposits, which are liabilities to the banking sector. In its turn, the banking sector provides loans to firms and to the government, if needed. The government issues bonds, which are held by the Central Bank and the banking sector. The Central Bank provides a reserve account for the banks and advances. Table 2.1 describes this structure.

Table 2.1: Balance Sheet Structure in Caiani et al. (2016)

Assets	Households (h)	C.Firms (c)	K. Firms (k)	Banks (b)	Government (g)	Central Bank (cb)
Deposits (dep)	$+dep_h$	$+dep_c$	$+dep_k$	$-dep$		
Loans (l)		$-l_c$	$-f_k$	$+l$	$-l_g$	
Bonds (b)				$+b$	$-b$	$+b$
Reserves (rs)				$+rs$		$-rs$
CB Advances (l^{cb})				$-l^{cb}$		$+l^{cb}$

Dosi et al. (2015) model is also composed by households, capital goods firms, consumption goods firms, banks, the government, and the Central Bank. Households consume exactly what they earn, so they do not have assets or financial liabilities. Only capital goods firms and consumption goods firms hold bank deposits. The banking sector provides loans only to consumption goods firms and to the government, as capital goods firms receive in advance. The government issues bonds, held by the Central Bank and the banking sector. The Central Bank provides a reserve account for the banks and a deposit account for the government. Table 2.2 illustrates the above.

The model proposed by Dawid et al. (2012) is composed exactly as the models above described. Households and both types of firms hold bank deposits, and banks provide loans to firms and to the government. The government issues bonds, held only by the central bank. The Central Bank, in its turn, provides a reserve account for the banks and cash advances. Table 2.3 describes the structure.

[2]See the List of Symbols for a detailed description of our notation in this thesis.

Table 2.2: Balance Sheet Structure in Dosi et al. (2015)

Assets	Households (h)	C.Firms (c)	K. Firms (k)	Banks (b)	Government (g)	Central Bank (cb)
Deposits (dep)		$+dep_c$	$+dep_k$	$-dep$		
Loans (l)		$-l_c$		$+l$	$-l_g$	
Bonds (b)				$+b$	$-b$	$+b$
Reserves (rs)				$+rs$		$-rs$
Gov. Deposits (dp^g)					$+dp^g$	$-dp^g$

Table 2.3: Balance Sheet Structure in Dawid et al. (2012)

Assets	Households (h)	C.Firms (c)	K. Firms (k)	Banks (b)	Government (g)	Central Bank (cb)
Deposits (dep)	$+dep_h$	$+dep_c$	$+dep_k$	$-dep$		
Loans (l)		$-l_c$	$-l_k$	$+l$	$-l_g$	
Bonds (b)					$-b$	$+b$
Reserves (rs)				$+rs$		$-rs$
CB Advances (l^{cb})				$-l^{cb}$		$+l^{cb}$

Slightly different from this common structure, the model proposed by Popoyan, Napoletano, and Roventini (2017) is composed by agents (or households), shops (or firms), banks, the government, and the Central Bank. Agents and shops hold deposits accounts in the banks while only shops borrow bank loans. Shops can also use inventories as collateral for their loans, which become bank's assets. As usual, the government issues bonds, held by the Central Bank and by the banking sector, and the central bank provides reserve accounts for the banks. The main difference of this model is that agents, shops and banks hold high-powered money issued by the Central Bank. Table 2.4 illustrates the balance sheet structure of the model.

Table 2.4: Balance Sheet Structure in Popoyan, Napoletano, and Roventini (2017)

Assets	Households (h)	Firms (i)	Banks (b)	Government (g)	Central Bank (cb)
Deposits (dep)	$+dep_h$	$+dep_i$	$-dep$		
Loans (l)		$-l_i$	$+l$		
Bonds (b)			$+b$	$-b$	$+b$
Reserves (rs)			$+rs$		$-rs$
Money (m)	$+m_h$	$+m_i$	$+m_b$		$-m$
Inventories (inv)		$-inv$	$+inv$		

Finally, Seppecher, Salle, and Lavoie (2018) present a less simplified model, with two household sectors (workers and shareholders) and three productive sectors (but with the same balance sheet structure). The model also describes a single big bank, but the government and the central bank are absent. Both household sectors and all three production sectors hold deposits in the single bank, which are liabilities for it. That same bank also provides loans to all types of firms, but not for households. Lastly, all firms and the bank can issue equities to finance themselves, which are held by the shareholders' sector. Table 2.5 describes the balance sheet structure of the model.

In search for what a minimum general balance sheet and model structure would

Table 2.5: Balance Sheet Structure in Seppecher, Salle, and Lavoie (2018)

Assets	Workers (w)	Shareholders (s)	Firms (i)	Bank (b)
Deposits (dep)	$+dep_w$	$+dep_s$	$+dep_i$	$-dep$
Loans (l)			$-l_i$	$+l$
Equities (eq)		$+eq$	$-eq_i$	$-eq_b$

be to an AB-SFC model with a developed financial system, we can see that the presence of at least a single bank, or a banking sector, which provides loans to finance firms decisions (or at least one group of firms) is unanimous. That same bank provides deposit accounts for firms and households (if households save money). When a model includes the government, it is also a consensus that it finances itself by issuing bonds, usually held by banks. Some models allow the government to be financed by bank loans, but that is not a general case. When a model specifies the monetary authority, it usually holds bank reserve accounts at minimum, but in some cases, it also provides advances to banks or high-powered money to the system. This is a basic credit market specification. The financial system in reality is not only composed by a credit market. In real world we should look to equities, stocks and bonds markets, but it seems a consensus that a minimal financial structure in a model, to keep it still simple but able to capture financial dynamics and elements, involves the description of the credit market. Let us now turn to the credit market determinants and specifications in those models.

2.4.2 Firm's Demand for Credit

The first financial element or financial decision we should analyze is how and why firms demand credit, or external finance, in those example models. In Caiani et al. (2016), firms demand external financing when internal funds have been completely exhausted. Total disbursement of a firm includes its desired investment expenses (if it is a consumption good firm in the model, as capital goods firms do not invest), its expected dividends payment and a desired amount of liquid deposits, as a share of expected wage payments, for precautionary reasons.

$$l^d_{i,t} = i^d_{i,t} + \delta_i \cdot pr^e_{i,t} - \chi_i \cdot wr^e_{i,t} \cdot n^d_{i,t} - f^i_{i,t} \tag{2.4.2.1}$$

where

$l^d_{i,t}$ is the desired external finance (loans) of firm i in period t;

$i^d_{i,t}$ is the desired investment expenses of firm i in period t;

δ_i is the dividend rate of firm i in period t;

$pr^e_{i,t}$ is the expected profits of firm i in period t;
χ_i is a desired precautionary share of expected wages of firm i;
$wr^e_{i,t}$ is the expected nominal wage to be paid by firm i in period t;
$n^d_{i,t}$ is the demand for workers (desired employment) of firm i in period t; and
$f^i_{i,t}$ is the available internal funds of firm i in period t.

Dosi et al. (2013) and Dosi et al. (2015) follow a similar rule, in line with the growing literature of imperfect credit market, where external finance might be more costly than internal finance. So, firms also demand external finance if internal liquid assets are not enough for their investment and for production expenses. The current stock of liquid assets is determined by firm's net worth in the past period.

$$l^d_{i,t} = i^d_{i,t} + uvc_{i,t} \cdot x_{i,t} - f^i_{i,t} \tag{2.4.2.2}$$

where
$l^d_{i,t}$ is the desired external finance (loans) of firm i in period t;
$i^d_{i,t}$ is the desired investment expenses of firm i in period t;
$uvc_{i,t}$ is the unit variable cost of production of firm i in period t;
$x_{i,t}$ is the production of firm i in period t; and
$f^i_{i,t}$ is the available liquid assets to be used as internal funds of firm i in period t.

For Dawid et al. (2012), firms demand external funds at the beginning of a period to finance their production costs, wage bills and investment decisions. Some expenses are expected by the firm, for example the price of capital and wages, and firms use respectively the past price and the average wage level as *proxy*. Firms must also pay taxes, dividends on last period profits and part of the principal on their stock of loans and interest thereon. As usual, the effective demand for external finance is the amount that internal funds cannot cover.

$$l^d_{i,t} = i^d_{i,t} + wr_{i,t} \cdot n^d_{i,t} + tr_i \cdot pr_{i,t-1} + \delta_i(1-\tau_i)pr_{i,t-1} + \frac{l^s_{i,t-1}}{\tau} + ir_{i,t-1} \cdot l^s_{i,t-1} - f^i_{i,t} \tag{2.4.2.3}$$

where
$l^d_{i,t}$ is the desired external finance (loans) of firm i in period t;
$i^d_{i,t}$ is the desired investment expenses of firm i in period t;
$wr_{i,t}$ is the nominal wage to be paid by firm i in period t;
$n^d_{i,t}$ is the demand for workers of firm i in period t;
tr_i is the tax rate on profits of firm i;

$pr_{i,t-1}$ is gross profits of firm i in period $t-1$;
δ_i is the share of profits distributed as dividends of firm i;
$l^s_{i,t-1}$ is the stock of loans of firm i $t-1$;
τ is the loans term;
$ir_{i,t-1}$ is the interest rate on loans of firm i in period $t-1$; and
$f^i_{i,t}$ is the available liquid internal funds of firm i in period t.

In Popoyan, Napoletano, and Roventini (2017), although the authors reinforce banks decisions and creditworthiness and rationing processes, which will be detailed in the next sections, it is not clear what determines the amount of credit that each firm demands. In Seppecher, Salle, and Lavoie (2018), there is a distinction between short term credit, to automatically finance wage bill expenses at no interest rate, and long-term credit, to finance investment decisions, with amortization period equals to the capital good duration. Firms demand a fixed share l of their investment decisions as bank loans.

It seems a general consensus to adopt a pecking order theory of investment, in which firms always prioritize internal funds to finance investment, because external funds are usually more costly due to imperfect information or particularities of the credit market. Therefore, in a basic AB-SFC model, a firm's demand for credit is always the difference between desired expenses and internal funds. What usually differs among models is the composition of the desired expenses, what a firm considers paying in each time period. Some models assume only investment expenses in the decision, whereas others include production costs or financial costs.

2.4.3 Bank's Total Amount of Credit

We should now look how the total amount of credit that a bank can supply is determined. In general, this involves some macroprudential or regulatory rule in the model. For Caiani et al. (2016) and Dawid et al. (2012), the maximum credit supply of a bank depends on the minimum capital adequacy ratio defined by a regulatory rule. This does not occur in Seppecher, Salle, and Lavoie (2018), as the single bank, much more like a Central Bank, has no limits to total credit supply, and it accommodates all the demand, therefore the individual supply of credit will be equal to the amount demanded.

$$l^{max}_{b,t} = \frac{nw_{b,t}}{ca^{min}_t} \tag{2.4.3.1}$$

where
$l^{max}_{b,t}$ is maximum loans of bank b in period t;

$nw_{b,t}$ is net worth of bank b in period t; and
ca_t^{min} is the regulatory minimum capital adequacy ratio in period t.

Dosi et al. (2015) follow a similar rule but introduce some bank-specific sensitivity in relation to its own loans on default, capturing some bank responses to financial fragility. The higher the amount of loans on default, the lower the maximum supply of credit by this bank is.

$$l_{b,t}^{max} = \frac{nw_{b,t-1}}{ca_t^{min}(1 + \varphi_b \cdot dfr_{b,t-1})} \tag{2.4.3.2}$$

where
$l_{b,t}^{max}$ is maximum loans of bank b in period t;
$nw_{b,t}$ is net worth of bank b in period $t-1$;
ca_t^{min} is the minimum capital adequacy rule in period t;
φ_b is bank b sensitivity parameter to defaulted loans; and
$dfr_{b,t-1}$ is the amount of bad debt (defaulted loans) rate of bank b on period $t-1$.

For Popoyan, Napoletano, and Roventini (2017), the rule is also similar, but adjusted to bank's current stock of loans and stock of collaterals, inventories of final product.

$$l_{b,t}^{max} = \frac{nw_{b,t}}{ca_t^{min}} - (l_{b,t}^s + inv_{b,t}^s) \tag{2.4.3.3}$$

where
$l_{b,t}^{max}$ is maximum loans of bank b in period t, defined as the bank's total credit risk;
$nw_{b,t}$ is net worth of bank b in period t;
ca_t^{min} is the minimum capital adequacy rule in period t;
$l_{b,t}^s$ is stock of loans of bank b in period t;
$inv_{b,t}^s$ is stock of inventories as collateral of bank b in period t; and
$l_{b,t}^s + inv_{b,t}^s$ measures the bank's total exposure to credit risk.

The review shows us that in general, what limits bank's total amount of credit in AB-SFC models is a regulatory rule, plus some kind of individual decision regarding financial fragility. Bank's liquidity preference is expressed by the total amount of credit that a bank can provide, which could be reduced in face of a worse financial position of the bank. Otherwise, with no regulatory rule and/or some financial fragility response, banks are modelled as a full accommodative entity, providing credit to all clients as requested. In that case, total credit demand drives bank's total amount of credit.

2.4.4 Individual Supply of Credit and Credit Rationing

Given the total amount of credit that a bank can supply, it should evaluate the creditworthiness of its clients in order to define which one can receive credit, or in case of total demand higher than total supply, which firm will be subjected to credit rationing.

In the model presented by Caiani et al. (2016), banks will supply the exact amount demanded by the firm, if the expected return on that loan is positive. Banks compute expected return on the loan by summing up the payoffs of possible outcomes and their probability of occurrence. To do so, they need to know mainly the probability of default on the loan, but also the expected return on the collateral, the total amount of loan demand, the interest rate and the loans term (fixed in the model, equal to 20). The probability of default depends on a comparison of the current operating cash flows of the firm, or its available liquid funds, to the debt service on that loan defined as the first trench of payments, adjusted by a bank-specific risk aversion parameter. If the positive expected return rule is not satisfied, the bank reduces the amount of credit to that firm, until the expected return becomes positive.

$$P(def)_{i,t} = \frac{1}{1 + exp(\frac{f^i_{i,t} - \varphi_b(l^s_{i,t} + \frac{1}{\tau})l^d_{i,t}}{(l^s_{i,t} + \frac{1}{\tau})l^d_{i,t}})} \tag{2.4.4.1}$$

where

$P(def)_{i,t}$ is the probability of default of firm i in each of the periods t of the loan;
$f^i_{i,t}$ is the operating cash-flow or the available liquid assets of firm i in period t;
φ_b is a parameter that express risk aversion of bank b;
$l^s_{i,t}$ is the stock of loans of firm i in period t;
τ is the loans term; and
$l^d_{i,t}$ is the loans demanded by firm i in period t.

In contrast with the dynamic and specific intertemporal expected return calculation proposed by Caiani et al. (2016), Dosi et al. (2015) propose that each bank ranks its clients in a creditworthiness order. Given the total amount of credit that a bank can supply, higher ranked firms will receive the exact amount they demand, following the rank order until total credit supply is reached. Lower ranked firms could receive no credit at all. The creditworthiness of a firm, which defines its position in the rank, is determined by a single ratio between firm's net worth and sales.

$$\frac{1}{P(def)_{i,t}} = \frac{nw_{i,t-1}}{s_{i,t-1}} \tag{2.4.4.2}$$

where
$P(def)_{i,t}$ is the probability of default of firm i in period t, inverse of the creditworthiness of the firm;
$nw_{i,t-1}$ is the net worth of firm i in period $t-1$; and
$s_{i,t-1}$ is the sales of firm i in period $t-1$.

In Dawid et al. (2012), the interest rate on loans works as the credit rationing mechanism. We will see interest rates setting in the following subsection. The individual credit supply is limited by the total amount of credit defined by regulatory rules, and the total amount of liquidity available, given the liquidity ratio defined by the monetary authority.

$$l_{i,t}^{max} = min((l_{b,t}^{max} - l_{b,t}^{s}), (rs_{b,t} - rs^{t} \cdot dep_{b,t})) \tag{2.4.4.3}$$

where
$l_{i,t}^{max}$ is the maximum amount of loans available for the firm i in period t;
$l_{b,t}^{s}$ is the stock of loans of bank b in period t;
$l_{b,t}^{max}$ is the maximum loans of bank b on period t, defined by the regulatory rule;
$rs_{b,t}$ is the total amount of bank reserves in central bank;
rs^{t} is the regulatory target for compulsory reserves; and
$dep_{b,t}$ is the total amount of households' deposits on the bank.

Lastly, Popoyan, Napoletano, and Roventini (2017) specify a complex and detailed creditworthiness assessment rule, in comparison with the other presented models. As usual, individual credit supply is limited by the maximum amount imposed by regulatory constraints. Banks check creditworthiness using three rules. Besides, they also consider the value of collateral, which is a discounted value of the stock of inventories of the firm as an index. Then, they rank their clients based on various indicators.

$$QR_{i,t} = \frac{CurrentAssets - Inventories}{CurrentLiabilities} = \frac{dep_{i,t} + m_{i,t} - inv_{i,t}^{s}}{l_{i,t}^{s}} \geq QR_{b,t}^{max} \tag{2.4.4.4}$$

where
$QR_{i,t}$ is the *Quick Ratio* of firm i in period t;
$dep_{i,t}$ is the deposits of firm i in period t;
$m_{i,t}$ is the cash of firm i in period t;
$inv^s_{i,t}$ is the stock of inventories of firm i in period t;
$l^s_{i,t}$ is the stock of loans of firm i in period t; and
$QR^{max}_{b,t}$ is the threshold limit defined by bank i in period t;

$$ROA_{i,t} = \frac{NetProfits}{TotalAssets} = \frac{pr^{nt}_{i,t}}{dep_{i,t} + m_{i,t} - inv^s_{i,t}} \geq ROA^{max}_{b,t} \tag{2.4.4.5}$$

where
$ROA_{i,t}$ is the *Return on Asset* of firm i in period t;
$pr^{nt}_{i,t}$ is the net profit of firm i in period t;
$dep^{i,t}$ is the deposits of firm i in period t;
$m_{i,t}$ is the cash of firm i in period t;
$inv^s_{i,t}$ is the stock of inventories of firm i in period t; and
$ROA^{max}_{b,t}$ is the threshold limit defined by the bank b in period t;

$$DER_{i,t} = \frac{TotalLiabilities}{Equity} = \frac{l^s_{i,t}}{nw_{i,t}} \geq DER^{max}_{b,t} \tag{2.4.4.6}$$

where
$DER_{i,t}$ is the *Debt to Equity* of firm i in period t;
$l^s_{i,t}$ is the stock of loans of firm i in period t;
$nw_{i,t}$ is the net worth of firm i in period t; and
$DER^{max}_{b,t}$ is the threshold limit defined by the bank b in period t.

Individual credit supply and credit rationing mechanism seem to be the most controversial aspect of modelling a financial system in AB-SFC models. There is no consensus in the literature, and there might be several different ways that a bank can access the creditworthiness of its clients. Models can vary this assessment from a simple ranking order to a complex three-index rule, or an intertemporal calculation of the net present value. The level of simplification or, in contrast, the desired detail in this aspect might be the main differential between models.

2.4.5 Interest Rates Setting by the Banks

Finally, we should investigate how banks set the interest rate on their loans in each of those models, probably the most important feature for our analysis in this thesis. For Caiani et al. (2016), banks use the interest rate on loans to adjust their capital ratio towards the desired level, which is the average capital ratio of the banking sector in the last period. If current capital ratio is lower than desired, the bank increases interest rate on loans by a random coefficient. They use the exact same process to set the interest rates on deposits, except that they use liquidity ratio instead of using the capital ratio. Excessed liquidity is used by the banks to buy government bonds.

$$ir_{b,t} = \overline{ir}_{fs,t-1}(1 \pm rd) \tag{2.4.5.1}$$

where
$ir_{b,t}$ is the interest rate on loans of the bank b in period t;
$\overline{ir}_{fs,t-1}$ is the avg. interest rate on loans of the financial sector in period $t-1$; and
rd is a random draw from a Folded Normal distribution.

In Dosi et al. (2015), each bank applies a bank-specific mark-up over the Central Bank basic interest rate, which in turn follows a Taylor Rule. Additionally, they also set different interest rates for their clients, following the rank of creditworthiness. Banks divide their clients in four quartiles and apply a risk premium.

$$ir_{i,t} = ir_{cb,t}(1 + spr_b)(1 + (q-1)rp_b) \quad q = 1, 2, 3, 4 \tag{2.4.5.2}$$

where
$ir_{i,t}$ is the interest rate on loans for the firm i in period t;
$ir_{cb,t}$ is the basic interest rate set by the central bank in period t;
spr_b is a positive spread over the basic interest rate of bank b;
q is a indicator that defines in which quartile the firm i is; and
rp_b is a risk premium coefficient of bank b.

In the model proposed by Dawid et al. (2012), the interest rate on firm's loan is the basic rate added by a firm-specific credit risk premium. The credit risk is calculated by the bank based on the amount of loans demanded by the firm, current stock of debt and net worth of the firm.

$$ir_{i,t} = ir_{cb,t} + \varphi_{b,t} \cdot l^d_{i,t}(1 - e^{\frac{(d^s_{i,t}+l^d_{i,t})}{nw_{i,t}}})rd \qquad (2.4.5.3)$$

where
$ir_{i,t}$ is the interest rate on loans for the firm i in period t;
$ir_{cb,t}$ is the basic interest rate set by the central bank in period t;
$\varphi_{b,t}$ is a behavior parameter of the bank in period t (which reflects risk aversion);
rd is a random draw from a uniform distribution;
$l^d_{i,t}$ is the demanded loan of firm i in period t;
$l^s_{i,t}$ is the stock of loans of firm i in period t;
$nw_{i,t}$ is the net worth of firm i in period t.

In Seppecher, Salle, and Lavoie (2018), short-term loans to finance wage-bill expenses are interest-free. Only long-term loans to finance investment have a positive interest rate, which is fixed by the single bank, similarly to a central bank basic interest rate. In Popoyan, Napoletano, and Roventini (2017) all banks apply the same interest rate on loans, which is a fixed mark-up over the central bank interest rate following a Taylor Rule. The interest rate on deposits is the basic interest rate.

$$ir_{fs,t} = ir_{cb,t} + spr_{fs} \qquad (2.4.5.4)$$

where;
$ir_{fs,t}$ is the interest rate on loans for all banks on period t;
$ir_{cb,t}$ is the basic interest rate set by the central bank on period t; and
spr_{fs} is a mark-up spread of the whole financial sector.

To conclude, a basic interest rate set by the Central Bank following some kind of Taylor Rule might be a consolidated starting point for interest rate structure in AB-SFC models, as it was also consolidated in reality and used in several countries. Additionally, it is frequently assumed that base interest rate on deposits is defined by a mark-down over the basic rate, whereas the base or average interest rate on loans is determined by a mark-up over the Central Bank interest rate. However, models might differ on the level of detail and interest differentiation. While some models can apply a bank-specific mark-up and/or a client specific premium, other models might assume that the interest rate is the same for the entire economy.

2.5 Discussion

In this chapter we have seen two heterodox approaches to heterodox simulation models, which are more suitable to deal with the essential dynamic and complex nature of the economic object. The AB and the SFC approaches have some elements in common and significant differences between them, and each of them is more employed by distinct heterodox theoretical strands. We saw, however, that they have complementary aspects.

A common critique of most SFC models is that they are sectoral models, so authors averse to the notion of representative agent, and seek to improve the micro foundations of SFC models. It is possible to criticize some basic AB models for lack of consistency between stocks and flows. There is also theoretical complementarity, as AB models are generally concerned with more productive aspects, firm's investment decisions, innovation, technological progress, whereas SFC models generally focus on the financial sector, financial decisions, different assets, etc. For these reasons, there is an open research agenda that proposes the integration of those two approaches. Many authors, such as Seppecher (2012) and Caverzasi and Godin (2015), argue that AB-SFC integration would be a strong alternative to DSGE models, both methodologically and theoretically.

We have found, however, that a family of heterodox models already integrated, although initially, these two approaches. The Multisectoral Micro-Macro (MMM) model proposed by Possas and Dweck (2004) and Dweck (2006) in its consolidated version already included elements of both types of models mentioned above. Therefore, this chapter aims to review the AB and the SFC approaches and the recent integration research agenda, in order to rescue the MMM model and then develop it, essentially for analysis of monetary and financial issues. But before presenting and modifying the MMM model, we perform a brief yet formal review on the recent models of this integration agenda, especially on how they formalize the financial sector. This proposal to incorporate additional elements, especially the ones related to the financial sector, to an existing model follows closely and is quite inspired by the strategy adopted by Dosi, Fagiolo, and Roventini (2010), Dosi et al. (2013), and Dosi et al. (2015), model referred to and briefly presented in session AB, which is also part of the integration agenda.

In search for what a minimum general balance sheet and model structure to an AB-SFC model with a developed financial system would be, we found that the presence of at least a single bank, or a banking sector, that provides loans to finance firms' decisions (or at least one group of firms) is unanimous. That same bank provides deposit accounts for firms and households (if households save money). When a model includes the government, it is also a consensus that it finances itself by issuing bonds, usually held by banks. This is a basic credit market specification, while equities, stocks and bonds markets, which comprise a more complete financial sector, are abstracted. It seems a consensus that a minimal financial structure in a model, to keep it still simple but able to capture financial dynamics and elements, involves the description of the credit market.

In terms of firms' demand for credit, it seems a general consensus to adopt a pecking order theory of investment. Therefore, in a basic AB-SFC model, a firm's demand for credit is always the difference between desired expenses and internal funds. What usually differs among models is the composition of the desired expenses. Firms can be credit constrained, and the individual credit supply and credit rationing mechanism seem to be the most controversial aspect of the AB-SFC modelling so far. There are several different ways through which a bank can access the creditworthiness of its clients. However, almost every model assumes that banks' total amount of credit is limited by a regulatory rule, plus some kind of individual decision regarding financial fragility. Bank's liquidity preference is expressed by the total amount of credit that a bank can provide. Finally, a basic interest rate set by the Central Bank following some kind of Taylor Rule might be a consolidated starting point in interest setting. Moreover, it is frequently assumed that interest rate on deposits is defined by a mark-down over the basic rate while the base or average interest rate on loans is determined by a mark-up over the central bank interest rate. However, models might differ on the level of detail and interest differentiation. The search for a minimal consensus modelling of the financial sector in an AB-SFC approach will help us develop some new formulations in the MMM model, which will be presented in the next chapter.

Chapter 3

The Finance-Augmented MMM Model

In this chapter we present a new version of the MMM model, where we try to introduce most of the elements revised in the AB-SFC literature in a minimum possible structure, but considering the already existing structure of the consolidated model and its particularities. We present the origin, the theoretical roots and the main features of the original MMM model.

As the model is moderately complex, its description is presented in detail in several ways, and consequently it takes the largest part of this thesis. To provide the best possible description, the model is described in several forms including a typical SFC representation, using the Flow of Funds and the Balance Sheet Matrices, a simplified descriptive explanation, a stylized graphical representation of the flows and structure of the model, a detailed timeline of events which goes step by step through the order of variables calculated in each time step, a formalized exposition of the main equations using the notation presented in the List of Symbols, and a comparison with the literature.

It might seem redundant to present equations of the consolidated version of the model, which were already presented elsewhere, but the presentation here has three purposes: (i) to unify notations and symbols, facilitating the comparason with the literature review presented in the last chapter, already using the same symbols detailed in the List of Symbols; (ii) to allow us to identify punctual modifications from the consolidated version, which are basically on the functional forms of some equations, elimination of small details and parameters, or the introduction of new variables related to the new structure, keeping the main theoretical base the same; (iii) to facilitate the reading of this work so the reader does not need to search and open several papers.

Finally, although not explicit in the text of this thesis, the development of this new version also contributed to a broader goal of the research in general: to turn the model more user-friendly and modular, so future developments could be easily implemented in the future and the framework could be used for several other analyses and research questions far beyond the scope of the thesis.

3.1 Origin and Theoretical Basis

The origin of the MMM model can be traced back to Mario Possas's Ph.D. Thesis (Possas 1983). In order to explain the main components of the dynamics of a capitalist economy, Possas combines theoretical propositions of three of the most influential economists of the twentieth century: John Maynard Keynes, Michail Kalecki and Joseph Schumpeter. Despite the apparent theoretical differences among them, Possas recognizes that their ideas are complementary, in a way that the three[1], together, can establish a powerful theoretical basis to explain capitalist dynamics[2].

In a nutshell, we can say that Keynes is the fundamental rock of this theoretical trinity, because he presented the most robust theory of time in economics, showing how, in a nonergodic world, full of uncertainty, future time affects present time, as economic agents need to form expectations for the outcome of present decisions. Among these decisions, there is the decision to invest. Keynes (1936) highlights that investment is the most volatile component of aggregate demand, and as spending decisions determine income, production and employment, by the Effective Demand Principle, investment is the main cause of economic instability and dynamics. Kalecki and Schumpeter both contribute to explain investment decisions. While Kalecki shows that investment decisions, especially those to expand productive capacity to meet expected demand, generate economic fluctuations within fixed structure, Schumpeter shows that investment decisions, essentially those for innovation and market competition through differentiation, change the structures of the economy, creating a long-term trajectory. In sum, Kalecki explains the dynamic instability, whereas Schumpeter explains the structural instability of capitalism[3].

At the end of his thesis, Possas establishes a multisectoral model to represent the essential elements of economic dynamics in an integrated approach (Possas 1983, p.329)[4]. In this model basic units were the productive sectors, and intersectoral relationships gave birth to dynamics, not only sectoral but also aggregated. The model was based on input-output matrices to determine sectoral components of intermediate consumption of each sector. As highlighted by the author, the model

[1]The author also recognizes the theoretical contribution of Karl Marx, as the theoretical embryo for the ideas of the three economists and for being pioneer in the discussion about economic dynamics, or the laws of movement of capitalism (Possas 1983, p.33-38).

[2]Elements of this theoretical combination can also be seen in detail in Possas 1987.

[3]On the concepts of dynamic instability and structural instability, see Vercelli (1991) and Vercelli (1999)

[4]This model can also be seen in Possas (1984).

was already considerably complex, and it would require a solution by computer simulation. However, due to the inexistent computational and processing power at that time (Possas 1983, p.483), he opted for finding an analytical solution. Only at the end of the 90's the author started to work again in the model, now with enough computational power to use numeric solution. In parallel, some Neo-Schumpeterian features were incorporated to intersectoral demand, and the basic units became firms inside each sector. Possas et al. (2001) summarizes the Neo-Schumpeterian theoretical elements which were incorporated into the model.

At the beginning of the 2000's, a research group was created at the Federal University of Rio de Janeiro and the modelling process was intensified, paving the ground to establish the MMM model in its consolidated version. Possas, Dweck, and Visconti (2004) made the first steps towards the simulation resolution, still in a more aggregate version, without incorporating the Neo-Schumpeterian microfoundations proposed by Possas et al. (2001). Possas and Dweck (2004) presented the consolidated MMM model for the first time, while Dweck (2006) did an extensive analysis of the dynamic properties of the model.

3.2 Main Features of the Model

The MMM model is a multisectoral micro-macro dynamic simulation model, which combines theoretical foundations from Keynesian, Kaleckian and Schumpeterian approaches, useful to investigate general dynamic properties of capitalist economies.

Multisectoral: most of the general dynamic properties derive from the intersectoral relationships. The original analytical model proposed by Possas (1983) and Possas (1984) already used input-output matrices to determine intersectoral demands. Additionally, a matrix of income appropriation determines income distribution among different classes from functional distribution. As stated by Dweck (2006, p.97), the general specification of the model comprises H income classes; N productive sectors (at least three), each composed by F firms. Sectors basically differ on how they fit in the productive chain, which can be capital goods production, intermediate goods production or consumption goods production. Sectoral demands are determined endogenously by firms and income classes decisions.

Dynamic: the model generates dynamic trajectories in discrete time (time steps). The model is a disequilibrium model, as causality is based on decisions to produce and to spend, no equilibrium position is ever required (Possas and Dweck 2004, p.7). The basic time unit is the production period of the firm, which can be understood as one quarter in chronological time. In each time step, firms take production decisions. Other decisions can happen in different frequencies, for instance, investment decision and mark-up adjustment decision. These different frequencies are considered in the model in terms of production periods, so an investment period can be, for instance, 4 or 6 production periods[5].

Micro-Macro: decisions happen at the firm level, at the micro level. Consequences of such decisions, however, affect both sectoral level and macro level. Additionally, sectoral and macro structures can affect firms' decisions through feedback mechanisms.

Theoretical: the main goal of the model is to investigate general dynamic properties of capitalist economies, so results are general, theoretical, representing only essential elements of a non-specific capitalist economy. Historical, national and institutional particularities are, most of the time, ommitted from the model (Dweck 2006, p.88).

Agent-Based: the MMM model is an AB model, as it shares a lot of elements with this framework, as presented in the previous chapter. Firms are the main agents of the model. Firms' decisions can be divided in four groups: (i) production; (ii) mark-up and price; (iii) investment and (iv) technological search. Other agents are (i) income classes, (ii) banks, (iii) the government and (iv) the external sector.

Stock-Flow Consistent: the MMM model is a SFC model, as it possesses a complete and coherent accounting system. Firms and income classes have balance sheets, and the model keeps track of the financial-real transactions undertaken by agents and the flows of real-financial stocks they create. Tables 3.1 and 3.2 present the balance sheet matrix and the transaction flows of our model.

[5]The current version of the model was generalized, so those frequencies can be changed by the user and tested for sensitivity, but it will not be done in this thesis.

Table 3.1: MMM Model - Flow of Funds

	Income Classes (h)	Consumption Sector (c)		Capital Sector (k)		Intermediate Sector (in)		Financial Sector (fs)	External Sector (x)	Government (g)	Total
		Cur.	Cap.	Cur.	Cap.	Cur.	Cap.				
Domestic Consumption	$-c_h^i$	$+CON$							$-exp^c$	$-c_g$	0
Imported Consumption	$-c_h^x$								$+imp^c$		0
Domestic Inputs		$-inp_c^i$		$-inp_k^i$		$-inp_{in}^i + INP$			$-exp^{in}$	$-inp_g$	0
Imported Inputs		$-inp_c^x$		$-inp_k^x$		$-inp_{in}^x$			$+imp^{in}$		0
Domestic Investment			$-i_c^i$	$+INV$	$-i_k^i$		$-i_{in}^i$		$-exp^k$	$-i_g$	0
Imported Investment			$-i_c^x$		$-i_k^x$		$-i_{in}^x$		$+imp^k$		0
Wages (including R&D)	$+WG$	$-w_c$		$-w_k$		$-w_{in}$				$-w_g$	0
Taxes	$-tax_h$	$-tax_c$		$-tax_k$		$-tax_{in}$				$+TAX$	0
Interest on Deposits	$+ir^{dep}dep_{h,t-1}$	$+ir^{dep}dep_{c,t-1}$		$+ir^{dep}dep_{k,t-1}$		$+ir^{dep}dep_{in,t-1}$		$-ir^{dep}dep_{fs,t-1}$			0
Interest on Short Term Loans	$-ir^{st}l_{h,t-1}^{st}$	$-ir^{st}l_{c,t-1}^{st}$		$-ir^{st}l_{k,t-1}^{st}$		$-ir^{st}l_{in,t-1}^{st}$		$+ir^{st}l_{fs,t-1}^{st}$			0
Interest on Long Term Loans		$-ir^{lt}l_{c,t-1}^{lt}$		$-ir^{lt}l_{k,t-1}^{lt}$		$-ir^{lt}l_{in,t-1}^{lt}$		$+ir^{lt}l_{fs,t-1}^{lt}$			0
Interest on Public Debt								$+ir^{bc}b_{t-1}$		$-ir^{bc}b_{t-1}$	0
Profits	$+pr^{dis}$	$-pr_c^{dis}$	$+pr_c^{ret}$	$-pr_k^{dis}$	$+pr_k^{ret}$	$-pr_{in}^{dis}$	$+pr_{in}^{ret}$	$-pr_b^{dis}$			0
Subtotal	sv_h	0	sv_c	0	sv_k	0	sv_{in}	sv_{fs}	sv_x	sv_g	0
Δ Deposits	Δdep_h		Δdep_c		Δdep_k		Δdep_{in}	Δdep_{fs}			0
Δ Short Term Loans	Δl_h^{st}		Δl_c^{st}		Δl_k^{st}		Δl_{in}^{st}	Δl_{fs}^{st}			0
Δ Long Term Loans			Δl_c^{lt}		Δl_k^{lt}		Δl_{in}^{lt}	Δl_{fs}^{lt}			0
Δ International Reserve									Δint	Δint	0
Δ Public Debt (Bonds)								Δb		Δb	0
Total	0		0		0		0	0	0	0	0

Table 3.2: MMM Model - Balance Sheet Matrix

	Income Classes	Firms Sectors	Financial Sector	External Sector	Government	Total
Deposits (dep)	$+dep_h$	$+dep_j$	$-dep$			0
Short Term Loans (l^{st})	$-l_h^{st}$	$-l_j^{st}$	$+l^{st}$			0
Long Term Loans (l^{lt})		$-l_j^{lt}$	$+l^{st}$			0
International Reserves (int)				$-int$	$+int$	0
Public Bonds (b)			$+b$		$-b$	0
Net Worth (nw)	nw_h	nw_j	nw_b	nw_x	nw_g	0

One can already note that our model follows closely the minimal balance sheet structure found in our review of the last chapter, of an AB-SFC model which incorporates a simplified, yet sufficiently complex, credit system. We introduce a population of banks to generalize the banking system as much as possible, while a configuration with only one bank is still possible, much like most models. We also allow all firms, in all sectors to access loans, something that is not usually done in the literature for technical difficulties in most cases. We also allow income classes to incur debt or to accumulate assets. Beware that these aspects were already presented in the benchmark (Possas and Dweck 2004; Dweck 2006; Dweck, Vianna, and Cruz Barbosa 2020) and in the core simplified (Possas, Dweck, and Vianna 2020) versions of the model, so we did not want to get rid of this trait. We only refine it and develop it even more. We must however recognize that this balance sheet structure and the developments we present in the following sections are far from being exhaustive or to represent a full financial system. As described in the minimum structure of the AB-SFC literature, bonds and stocks are usually absent, for instance.

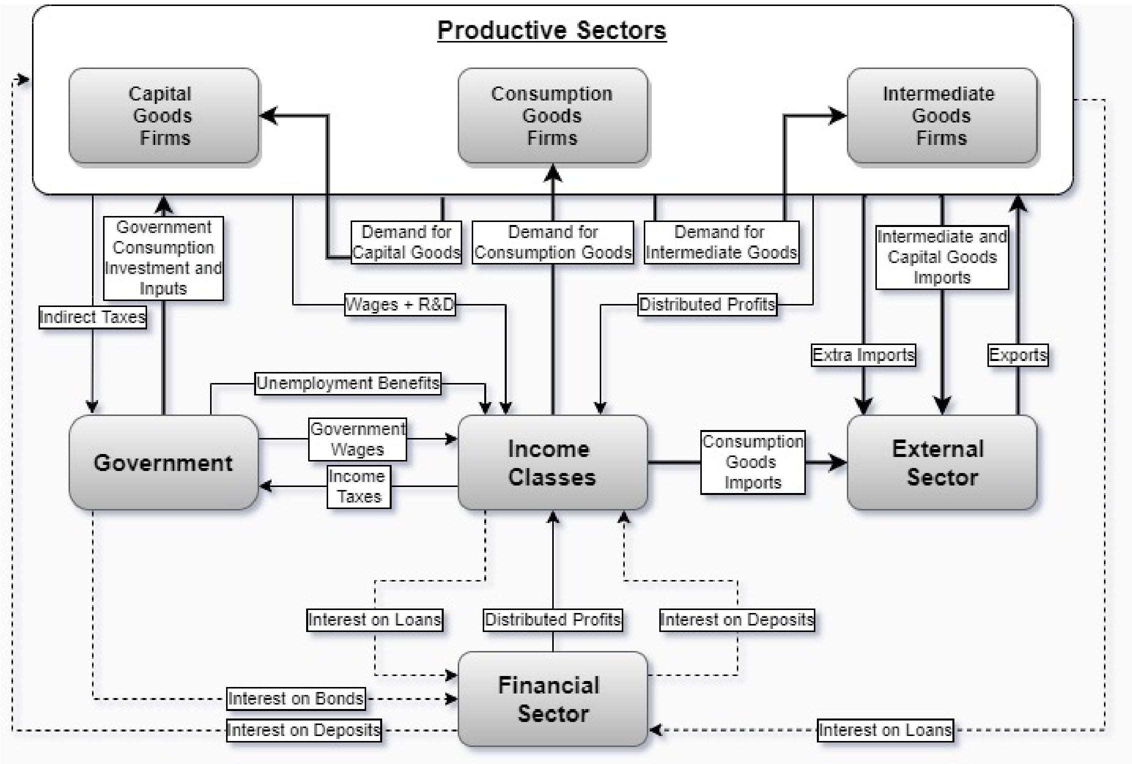
3.3 Description of the Basic Structure

This version of the MMM model describes a general theoretical economy composed by three[6] productive sectors, one consumption goods sector populated with F^c firms, one intermediate goods sector populated with F^{in} firms, and one capital goods sector populated with F^k firms. The household sector is divided in H income classes, the financial sector is populated with B banks, and the government and the external sector complete the model. Figure 3.1 shows some of the model structure and flows in a stylized way.

All firms make decisions to produce, to set prices, to invest and to perform technological search. To produce, all firms need capital and intermediate goods, and

[6]Dweck (2006) establishes that the model must have at least 3 productive sectors, one of each type. We use the simplest possible specification.

Figure 3.1: MMM Model Flows



Source: Author's Elaboration. Continuous arrows represent real flows whereas dashed arrows represent financial flows.

they produce based on expected demand, restricted to current productive capacity and current availability of inputs. All firms also employ labor on production, based on each capital's productivity and on current level of production. Labor productivity is embodied in each capital vintage, which comprises total productive capacity of each firm, where the most productive ones are used first. Production generates functional income, wages and profits, and a share of profits is distributed, while the other part is retained by the firms. Aggregate level of production generates endogenous sectoral demand for intermediate goods, based on input technical coefficients.

Firms set prices based on their degree of monopoly under imperfect competition, as proposed by Kalecki (1954), as a weighted average between their desired price and the market average price. Firms' desired price is determined applying a long-term desired mark-up over variable unit cost. Their price, in addition to their delivery delay and product differentiation, affects their competitiveness, and subsequently their market-share.

Firms also perform technological search. The resources available depend on a fixed proportion of revenue, and are divided in innovation and imitation R&D. By doing innovation R&D, firms are subjected to exogenous stochastic sectoral technological opportunities, and they search for new levels of labor productivity (process innovation) and new levels of product quality and differentiation (product innovation). Imitation, in its turn, also searches for higher levels of productivity and quality but looking at other firms in the sector. To implement new product quality only labor is required[7], but to implement new labor productivity new capital goods are required, affecting investment decisions.

Finally, firms take investment decisions, which can be subdivided into three main components: (i) physical depreciation, (ii) productive capacity expansion and (iii) technological obsolescense and modernization replacement. Firms demand capital goods in order to have enough productive capacity to meet long-term expected demand, already considering physical depreciation. The third component is determined by a simple payback rule for each capital goods, depending on the R&D success of current period. Investment decisions can be financially constrained, and firms can use retained profits, loans and available liquid assets (deposits) to finance investment. If total funds are not enough, firms prioritize expansion investment in relation to replacement investment. Aggregate level of investment decisions generates endogenous sectoral demand to the capital goods sector.

The functional income generated by all firms' production is appropriated by each income class by a matrix of income appropriation coefficients[8]. Income classes demand consumption goods based on a fixed marginal propensity to consume over past average income, in which a share is demanded domestically and another share externally. However, autonomous consumption does not depend on income, but evolves based on average quality of the consumption good sector. Income classes are also subjected to balance sheets positions, as they can incur in new loans to finance consumption decisions, or they can accumulate deposits from unspent current income. Aggregated consumption decisions of all income classes generate endogenous sectoral demand for the consumption goods sector.

The financial sector collects deposits from firms and income classes, and provides loans to firms and income classes, subjected to a Basel-type regulatory rule. The government can levy taxes on firms' revenue and/or households' income to be spend in public wages, consumption, intermediate and capital goods and unemployment benefits, subjected to one or more fiscal rule, such as a primary surplus target. The external sector demands goods from all three productive sectors based on a fixed exports coefficient, real external income and real exchange rate, and it can supply unmet demand with extra imports.

[7]This is a simplification done in this version. In the consolidated version, product innovation also generated autonomous demand for capital goods.

[8]In general, this matrix is a 2xH matrix, composed by two H-sized vectors of profit shares and wage shares, where all elements of each vector should sum up 1.

3.4 Timeline of Events

The following timeline describes the chronological sequence of events on each time step in detail:

1. Interest Rate Setting

    1.1. Basic Interest Rate: Central Bank fixes the basic interest rate following the monetary policy rule.

    1.2. Interest Rate on Deposits: negative spread over basic interest rate.

    1.3. Bank Base Interest Rate on Short-Term Loans: positive spread over basic interest rate.

    1.4. Bank Base Interest Rate on Long-Term Loans: positive spread over basic interest rate.

    1.5. Firm Interest Rate: firm-specific risk premium is applied over bank base short-term or long-term interest rate.

    1.6. Class Interest Rate: class-specific risk premium is applied over bank base short-term interest rate.

2. Costs and Prices

    2.1. Nominal Wages: firms adjust their nominal wages based on past inflation and productivity growth.

    2.2. Input Cost: firms calculate input costs based on the technical coefficient and past average input price.

    2.3. Variable Cost: firms calculate unit variable costs summing up wage costs and input costs, and unit normal financial costs if current debt rate is higher than maximum.

    2.4. Mark-up Decision: firms adjust their desired mark-up based on desired and effective market shares.

    2.5. Price Decision: firms set their prices based on desired mark-up over variable cost and average market price.

3. Production

    3.1. Planned Production: firms determine their level of planned production based on expected demand and current level of inventories.

    3.2. Effective Production: consumption and intermediate firms produce based on planned production, and capital firms produce based on effective orders, all of them restricted to current level of productive capacity and current availability of inputs.

4. External Sector Demand

    4.1. Exchange Rate: Exchange rate is adjusted based on last period's balance of payments.

    4.2. External Income: External Income is calculated based on an exogenous growth rate, subjected to some randomness.

    4.3. External Prices: Sector external prices are calculated based on an exogenous growth rate and/or the domestic price past growth, subjected to some randomness.

    4.4. Sector Exports: Sector external demand (exports) depend on sectoral specific coefficients, real exchange rate and the external income.

5. Government Demand

    5.1. Government Desired Expenses: Government calculates desired expenses in wages, unemployment benefits, consumption goods, capital goods and intermediate goods.

    5.2. Fiscal Rules: one or more fiscal rules determine the maximum amount of government expenses.

    5.3. Government Effective Expenses: Government effective expenses are limited by the maximum amount imposed by the fiscal rule.

6. Consumption and Class Finance

    6.1. Desired Consumption: income classes determine the desired consumption, domestic and imported, part induced based on average past disposable income, and part autonomous based on quality growth.

    6.2. Financial Obligations: income classes pay their financial obligations (interest and amortization on current loans).

    6.3. Class Internal Funds: classes determine their internal funds, current stock of deposits minus financial obligations, minus desired retained deposits (liquidity preference).

    6.4. Class Available loans: classes determine their maximum available loans, based on current stock of loans and maximum debt rate.

    6.5. Demand for Loans: income classes demand loans based on the difference between desired expenses and available internal funds, limited to available loans.

    6.6. Effective Consumption Demand: income classes determine their effective level of consumption demand, minimum between desired expenses and total available funds.

   6.7. Effective Imports: income classes prioritize domestic consumption, so effective imports will be the minimum between desired level and available funds after effective consumption demand.

7. Effective Demand

   7.1. Total Consumption Goods Demand: income classes' effective consumption demand, plus government consumption and exports.

   7.2. Total Intermediate Goods Demand: all firms' input demand for the next period, plus government inputs and exports.

   7.3. Total Capital Goods Demand: all firms' capital demand based on past investment decisions, plus government investment and exports.

   7.4. Effective Sectoral Demand: total sectoral demand depends on effective domestic demand of each specific type of goods and exports.

   7.5. Firm's Demand: sectoral demand is distributed to each firm based on their market share, by the replicator dynamics.

8. Sales, R&D and Profits

   8.1. Sales: the level of sales of each firm is the minimum between current effective orders and effective production plus inventories.

   8.2. Indirect Taxes Payment: the Government collects indirect taxes over firm's revenue.

   8.3. Technological Search: a share of firm's net revenue is allocated to technological search in each period, and firms perform R&D (innovation and imitation) in productivity and product quality.

   8.4. Net Interest Gains: firms pay interest on current loans and receive interest on current deposits.

   8.5. Profits: Firm's net profits are gross revenue minus tax payment, R&D expenses, production costs, plus net financial gains.

   8.6. Profits Distribution: if net profits are positive, firms distribute a fixed share to income classes and retain the rest. If they are negative, no losses are distributed, and a short-term loan will be demanded.

9. Capital Adjustment and Investment Decisions

   9.1. Physical Depreciation: in each period, physically depreciated capital goods are eliminated.

   9.2. Productive Capacity Effective Expansion: if it is investment period, new capital goods ordered in past investment period are implemented.

9.3. Desired Expansion Investment: if it is investment period for the firm, it calculates desired new productive capacity to meet long-term expected demand, considering current productive capacity and future capital goods depreciation.

9.4. Desired Replacement Investment: if it is investment period for the firm, it calculates desired new productive capacity to replace current productive capacity, based on a payback rule and considering the current technological frontier.

9.5. Desired Investment Expenses: if it is investment period, desired investment expenses are the sum of the two types of investment. If it is not investment period, then it is zero.

10. Firm Finance

10.1. Firm Internal Funds: firms determine their available internal funds based on current stock of deposits, plus retained profits minus desired level of retained deposits (liquidity preference). Negative internal funds imply that stock of deposits cannot cover current losses, and short-term loans must be taken to cover losses.

10.2. Firm Available Loans: firms determine their maximum available loans, based on current stock of loans and maximum debt rate (total stock of loans over stock of total capital, physical and deposits).

10.3. Demand for Loans: firms demand loans based on the difference between desired investment expenses and available internal funds, limited to available loans.

10.4. Banks Maximum Loans: banks determine their maximum loans based on regulatory rule and financial fragility sensitivity.

10.5. Supply of Loans: if banks have limited credit supply, effective loans are distributed proportionally to each sector, and inside the sector, they are distributed to firms according to a debt rate rank. High indebted firms could receive no loans.

10.6. Firm Total Funds: firms receive effective loans and determine total available funds.

11. Effective Investment

11.1. Effective Investment Expenses: effective expenses are limited to total available funds.

11.2. Effective Expansion Demand: firms prioritize expansion investment, so effective demand will be the minimum between desired expansion and total available funds.

11.3. Effective Replacement Demand: if there are still funds left after expansion investment, firms demand capital goods for replacement, so effective demand will be the minimum between desired replacement and total available funds, minus effective expansion expenses.

12. Entry and Exit

12.1. Exit: firms can exit the market due to low market share or high debt rate.

12.2. Debt Repayment: firms which exit the market must repay existing debt with available deposits. If that is not possible, banks incur in defaulted loans.

12.3. Deposits Redistribution: firms which exit the market with positive deposits distribute their deposits to income classes as profits.

12.4. Capital Stock Available: firms which exit the market leave some capital goods available for possible new firms.

12.5. Entry: new firms will only enter the market if sectoral demand is growing, copying the average market-share firm, but limited to available productive capacity in the sector.

13. Income Determination and Distribution

13.1. Bank's Profit: banks determine their profits based on interest paying and receiving, including from government bonds, and defaulted loans. They distribute part of their profits and retain the rest.

13.2. Income Determination: total profits and total wages, including financial sector profits and government wages, are determined.

13.3. Income Distribution: total wages and distributed profits are distributed to income classes based on specific wage shares and profit shares.

13.4. Income Tax Payment: Government collects income taxes.

3.5 Main Equations

In this section we present the main equations of the model, describing and specifying their theoretical basis and foundations. While several equations were already presented elsewhere and it might seem redundant to digress on them again here, we find it important to use a standardized notation[9] for a comparative approach with the other models reviewed in the last chapter, and we will highlight here some minor modifications implemented in this version as compared to the consolidated one. Moreover, to elaborate on a comparative exposition with other literature models, Appendix A presents a table describing the current version of the model following the terms and structure proposed in the review performed by Dawid and Gatti (2018). Let us follow the same chronological order presented in the timeline of events.

3.5.1 Interest Rates Setting

At the beginning of each period, interest rates are determined. The basic interest rate is set by the Central Bank following a monetary policy rule, such as a single mandate Taylor Rule[10], subjected to some smoothing:

$$ir^*_{cb,t} = (1-\kappa)(ir^n_{cb} + \varphi^{cpi}_{cb}((\Delta cpi)^e_{cb,t} - (\Delta cpi)^t_{cb})) + \kappa \cdot ir^*_{cb,t-1} \tag{3.5.1.1}$$

where
$ir^*_{cb,t}$ is the effective nominal basic interest rate in period t;
κ is the interest rate smoothing parameter;
$ir^*_{cb,t-1}$ is the effective nominal basic interest rate in period t-1;
ir^n_{cb} is the nominal interest rate of the Central Bank;
$(\Delta cpi)^t_{cb}$ is the Central Bank's annual inflation target;
φ^{cpi}_{cb} is the Central Bank's sensitivity to inflation; and
$(\Delta cpi)^e_{cb,t}$ is the Central Bank's expected annual CPI inflation in period t.

The interest rate on deposits will be the basic interest rate negatively spreaded, and will be the same for firms and income classes, and the same for all banks in the financial sector:

$$ir^{dep}_t = ir^*_{cb,t} - spr^{dep} \tag{3.5.1.2}$$

where
ir^{dep}_t is the interest rate on deposits in period t;
$ir^*_{cb,t}$ is the effective basic interest rate in period t; and
spr^{dep} is the deposits spread over the basic interest rate.

[9] See the List of Symbols for a detailed explanation of notations and symbols used in this section.
[10] A set of monetary policy rules will be extensively discussed in the next chapter.

There are two types of loans, short-term and long-term, and each one has a different interest rate, assuming a positive yield curve. Interest rate on short-term loans or on long-term loans will be the basic interest rate positively spreaded. Banks could have a margin to differentiate base interest rate on short-term and long-term loans, depending on the banking competition conditions. Each bank has a desired spread, but following the model's price formation based on Kalecki (1954) price setting under oligopoly conditions, the bank's base interest rate before applying firm-specific risk premium depends not only on their desired spread, but also on the financial sector average spread and consequently the average interest rate. This margin to differentiate long-term rates is generally small, when considered, in line with the empirical evidence and the literature which says that banks do not compete in interest rates. However, this formulation accounts for higher spreads and differentiation for cases with higher banking concentration[11].

$$ir^{st}_{b,t} = ((ir^{*}_{cb,t} + spr^{st,d}_{b,t}))\theta^{st}_{b} + (1 - \theta^{st}_{b})\overline{ir}^{st}_{fs,t-1} \tag{3.5.1.3}$$

where
$ir^{st}_{b,t}$ is the base interest rate on short-term loans of bank b in period t;
$ir^{*}_{cb,t}$ is the effective basic interest rate in period t;
$spr^{st,d}_{b,t}$ is the desired short-term spread of bank b in period t;
θ^{st}_{b} is the short-term strategy (degree of monopoly) parameter of bank b; and
$\overline{ir}^{st}_{fs,t-1}$ is the avg. short-term interest rate of the financial sector in the period t-1.

$$ir^{lt}_{b,t} = ((ir^{*}_{cb,t} + spr^{lt,d}_{b,t}))\theta^{lt}_{b} + (1 - \theta^{lt}_{b})\overline{ir}^{lt}_{fs,t-1} \tag{3.5.1.4}$$

where
$ir^{lt}_{b,t}$ is the base interest rate on long-term loans of bank b in period t;
$ir^{*}_{cb,t}$ is the effective basic interest rate in period t;
$spr^{lt,d}_{b,t}$ is the desired long-term spread of bank b in period t;
θ^{lt}_{b} is the long-term strategy (degree of monopoly) parameter of bank b; and
$\overline{ir}^{lt}_{fs,t-1}$ is the avg. long-term interest rate of the financial sector in the period t-1.

It is worth noting that if either short-term or long-term strategy parameter is zero for a given bank, it will not differentiate the respective interest rate, and it

[11] We will address different interest rate structures, yield curves and spreads in some exercises, although spread determination consists of an extensive debate with no consensus in the literature, so it is out of the scope of the present work

will use the financial sector average rate as the base rate for its loans. Regardless of what the bank's spread strategy is, the specific interest rate on short-term loans of each firm, which is a client of the bank, will be a firm-specific rate, based on the bank's base interest rate on short-term loans and long-term loans, adjusted by a risk premium applied on the firm's average debt rate. Specific interest rates were already included in the original model, so we decided to keep them, even though it is beyond the minimal literature structure we investigated in the last chapter:

$$ir^{st}_{i,t} = ir^{st}_{b,t}(1 + rp^{st}_b \cdot \overline{dr}_{i,t}) \tag{3.5.1.5}$$

where
$ir^{st}_{i,t}$ is the interest rate on short-term loans of firm i, client of bank b, in period t;
$ir^{st}_{b,t}$ is the base interest rate on short-term loans of bank b in period t;
rp^{st}_b is the risk premium adjustment parameter on short term loans of bank b; and
$\overline{dr}_{i,t}$ is the average debt rate of firm i in period t.

$$ir^{lt}_{i,t} = ir^{lt}_{b,t}(1 + rp^{lt}_b \cdot \overline{dr}_{i,t}) \tag{3.5.1.6}$$

where
$ir^{lt}_{i,t}$ is the interest rate on long-term loans of firm i, client of bank b, in period t;
$ir^{lt}_{b,t}$ is the base interest rate on long-term loans of bank b in period t;
rp^{lt}_b is the risk premium adjustment parameter on long-term loans of bank b; and
$\overline{dr}_{i,t}$ is the average debt rate of firm i in period t.

The same happens to income classes. However, income classes are not specifically tied to a given bank in a class-bank relationship as firms are, as an income class represents a collection of different agents. Income classes only demand short-term loans, so it is reasonable to suppose that the multitude of agents in the class can easily search for other banks and change banks. Then, we assume income classes' demand for loans are distributed based on bank's market-share. So, income class' base interest on short-term loans will be the average short-term interest of the financial sector, weighted by banks' market share.

$$ir_{h,t} = \overline{ir}^{st}_{fs,t}(1 + rp^h_{fs} \cdot \overline{dr}_{h,t}) \tag{3.5.1.7}$$

where
$ir_{h,t}$ is the interest rate on loans of income class h in period t;

$\overline{ir}^{st}_{fs,t}$ is the average short-term interest rate of the financial sector in period t;
rp^h_{fs} is the risk premium adjustment parameter for income classes loans; and
$\overline{dr}_{h,t}$ is the average debt rate of income class h in period t.

3.5.2 Price and Costs

Firm's nominal wages are adjusted annually (Λ periods), remaining constant in other periods, and they evolve based on firm's average labor productivity growth and past inflation[12], defined as annual growth of consumer price index, which is the average price of consumption goods sector including imports:

$$wr_{i,t} = wr_{i,t-1}\left(1 + \xi^p_{j,t} \cdot \left(\frac{cpi_{t-1} - cpi_{t-1-\Lambda}}{cpi_{t-1-\Lambda}}\right) + \xi^\phi_{j,t} \cdot \left(\frac{\phi_{i,t-1} - \phi_{i,t-1-\Lambda}}{\phi_{i,t-1-\Lambda}}\right)\right) \tag{3.5.2.1}$$

where
$wr_{i,t}$ is the nominal wage rate of firm i in period t;
$wr_{i,t-1}$ is the nominal wage rate of firm i in period t-1;
cpi_{t-1} is the consumer price index in period t-1;
$cpi_{t-1-\Lambda}$ is the consumer price index in period $t-1-\Lambda$;
$\phi_{i,t-1}$ is the productivity of firm i in period $t-1-\Lambda$;
$\phi_{i,t-1-\Lambda}$ is the productivity of firm i in period t-1;
$\xi^p_{j,t}$ is the sector j inflation passthrough in period t; and
$\xi^\phi_{j,t}$ is the sector j productivity passthrough in period t.

The respective elasticities on how each component affects firm's wage growth represent firms and workers bargain power, and they can be revised annually based on the sectoral employment past growth:

$$\xi_{j,t} = \begin{cases} \xi_{j,t-1} + \psi^{bg}_j & if \quad \frac{n_{j,t-1} - n_{j,t-1-\Lambda}}{n_{j,t-1-\Lambda}} > 0 \quad and \quad pcu_{j,t-1} > pcu^d_j \\ \xi_{j,t-1} - \psi^{bg}_j & if \quad \frac{n_{j,t-1} - n_{j,t-1-\Lambda}}{n_{j,t-1-\Lambda}} < 0 \quad and \quad pcu_{j,t-1} < pcu^d_j \\ \xi_{j,t-1} & otherwise \end{cases} \tag{3.5.2.2}$$

where

[12] This is a difference between this version and the consolidated version of the model. In the latter, nominal wages were sectoral variables and evolved based on sector average productivity growth and inflation. In this version, nominal wages are considered as a firm variable. Additionally, the consumer price index is used instead of the overall price index.

$\xi^{p}_{j,t}$ is the sector j inflation passthrough in period t;
$\xi^{\phi}_{j,t}$ is the sector j productivity passthrough in period t;
$\xi^{p}_{j,t-1}$ is the sector j inflation passthrough in period t-1;
$\xi^{\phi}_{j,t-1}$ is the sector j productivity passthrough in period t-1;
ψ^{bg}_{j} is the sector j bargain power adjustment;
$n_{j,t-1}$ is the sector j employment in period t-1;
$n_{j,t-1-\Lambda}$ is the sector j employment in period $t-1-\Lambda$;
$pcu_{j,t-1}$ is the sector j productive capacity utilization rate in period t-1; and
pcu^{d}_{j} is the sector j desired productive capacity utilization rate.

Firm's unit wage cost is therefore the wage rate divided by the firm's average labor productivity:

$$uwc_{i,t} = \frac{wr_{i,t}}{\overline{\phi}_{i,t-1}} \tag{3.5.2.3}$$

where
$uwc_{i,t}$ is the unit wage cost of firm i in period t;
$wr_{i,t}$ is the nominal wage rate of firm i in period t; and
$\overline{\phi}_{i,t-1}$ is the average labor productivity of firm i in period t-1.

Firm's variable unit cost depends not only on the wage cost, but also on the input cost. Input unit cost depends on the input technical coefficient, the firm's propensity to import inputs, the average price of the intermediate goods sector, the input external price and the exchange rate:

$$uic_{i,t} = (1-\iota^{in}_{i,t})(\alpha_i \cdot \overline{p}_{in,t-1}) + \iota^{in}_{i,t}(\alpha_i \cdot p^{x}_{in,t-1} \cdot er_{t-1}) \tag{3.5.2.4}$$

where
$uic_{i,t}$ is the unit input cost of firm i in period t;
α_i is the technical coefficient of inputs of firm i;
$\iota^{in}_{i,t}$ is the propensity to import inputs of firm i in period t;
$\overline{p}_{in,t-1}$ is the average price of the intermediate goods sector *in* in period t-1;
$\overline{p}^{x}_{in,t-1}$ is the external price of the intermediate good sector *in* in period t-1;
er_{t-1} is country exchange rate in period t-1;

The propensity to import can be adjusted based on the real exchange rate:

$$\iota^{in}_{i,t} = \iota^{in}_{i,t-1} \cdot \left(\frac{\overline{p}_{in,t-1}}{p^{x}_{in,t-1} \cdot er_{t-1}} \right)^{\epsilon^{p,in}_{j}} \tag{3.5.2.5}$$

where
$\iota^{in}_{i,t}$ is the propensity to import inputs of firm i in period t;
$\iota^{in}_{i,t-1}$ is the propensity to import inputs of firm i in period t-1;
$\overline{p}_{in,t-1}$ is the average price of the intermediate goods sector *in* in period t-1;
$p^{x}_{in,t-1}$ is the external price of the intermediate good sector *in* in period t-1;
er_{t-1} is country exchange rate in period t-1; and
$\epsilon^{p,in}_{j}$ is the price elasticity of imported inputs of sector j.

This version of the model contemplates the possibility of unit (normal) financial costs being considered in the price formation in case of high indebtedness of the firm, following the ideas of Moreira (2010). If firm's debt rate is higher than maximum, the firm calculates the desired unit financial cost as the average financial obligations, including amortization over desired productive capacity:

$$uvc_{i,t} = \begin{cases} uwc_{i,t} + uic_{i,t} + \xi^{fc}_{i,t} \cdot ufc_{i,t} & if \quad dr_{i,t-1} > dr^{max}_{i,t} \\ uwc_{i,t} + uic_{i,t} & otherwise \end{cases} \tag{3.5.2.6}$$

where
$uvc_{i,t}$ is the unit variable cost of firm i in period t;
$uic_{i,t}$ is the unit input cost of firm i in period t;
$uwc_{i,t}$ is the unit wage cost of firm i in period t;
$\xi^{fc}_{i,t}$ is financial cost passthrough of firm i in period t;
$ufc_{i,t}$ is the unit normal financial cost of firm i in period t;
$dr_{i,t-1}$ is the debt rate of firm i in period t-1; and
$dr^{max}_{i,t}$ is the maximum debt rate of firm i in period t-1;

Unit (normal) financial costs is the firm's total financial obligations divided by desired productive capacity:

$$ufc_{i,t} = \frac{fo_{i,t}}{pcu^{d}_{i} \cdot x^{p}_{i,t}} \tag{3.5.2.7}$$

where
$ufc_{i,t}$ is the unit normal financial cost of firm i in period t;
$fo_{i,t}$ is financial obligations of firm i in period t;

pcu^d_i is the desired degree of capacity utilization of firm i; and
$x^p_{i,t}$ is the productive capacity of firm i in period t.

Firms can also adjust their desired mark-up in case of competitiveness gains, but only if current market share is higher than a desired level. While the current market share is lower than desired, competitiveness gains will not be translated to mark-up increases, so prices will not increase either, and the firm will not lose the market share it gained.

$$mk^d_{i,t} = \begin{cases} mk^d_{i,t-1}\left(1+\psi^{mk}_{i,t}\left(\frac{ms_{i,t-1}-ms_{i,t-2}}{ms_{i,t-2}}\right)\right) & \textit{if } ms_{i,t-1} > ms^d_{i,t-1} \\ mk^d_{i,t-1} & \textit{otherwise} \end{cases} \tag{3.5.2.8}$$

where
$mk^d_{i,t}$ is the desired mark-up of firm i in period t;
$mk^d_{i,t-1}$ is the desired mark-up of firm i in period t-1;
$\psi^{mk}_{i,t}$ is the market share adjustment of firm i in period t;
$ms_{i,t-1}$ is the market share of firm i in period t-1;
$ms_{i,t-2}$ is the market share of firm i in period t-2;
$ms_{i,t-1}$ is the market share of firm i in period t-1; and
$ms^d_{i,t-1}$ is the desired market share of firm i in period t-1.

The price equation used in the model is the one used by Kalecki (1954) in his analysis of the degree of monopoly under imperfect competition, which is also identical to a discrete version of the one used by Silverberg (1987), as shown by Possas et al. (2001). It is an extension of the full cost principle under oligopolistic conditions, where it is impossible to ignore others' prices. So, firm's effective price will be an average between firm's desired price and the sector's average price. Firm's desired price is the desired mark-up over unit variable cost. However, Kalecki's original analysis was dealing with a closed economy. In our model, part of the sectoral demand comes from the external sector, and it is sensitive to the real exchange rate. So, if firms do not consider the external price, in domestic currency, they might lose demand, even if its price is the same of the sectoral average domestic price. We modify Kalecki's equation to introduce the external price, weighted by the share of exports over sectoral demand. The intuition is that the higher the relevance of the external sector on sectoral demand, more attention domestic firms have to pay to external prices. If the share of exports over sectoral demand is zero, this equation is exactly the same already presented in the consolidated version of the model:

$$p^*_{i,t} = \theta_i \cdot p^d_{i,t} + (1-\theta_i)p^{ref}_{i,t} \tag{3.5.2.9}$$

where
$p^*_{i,t}$ is the effective price of firm i in period t;
θ_i is the price strategy (degree of monopoly) parameter of firm i;
$p^d_{i,t}$ is the desired price of firm i in period t; and
$p^{ref}_{i,t}$ is the reference price of firm i in period t.

$$p^{ref}_{i,t} = \left(\overline{p}_{j,t-1}\left(1-\theta^x_i\left(\frac{exp^r_{j,t-1}}{o_{j,t-1}}\right)\right) + p^x_{j,t-1} \cdot er_{t-1} \cdot \theta^x_i\left(\frac{exp^r_{j,t-1}}{o_{j,t-1}}\right)\right) \tag{3.5.2.10}$$

where
$p^{ref}_{i,t}$ is the reference price of firm i in period t;
$\overline{p}_{j,t-1}$ is the sector j average price in period t-1;
θ^x_i is the external price weight parameter of firm i;
$exp^r_{j,t-1}$ is the real exports of sector j in period t-1;
$o_{j,t-1}$ is the effective orders of sector j in period t-1;
$p^x_{j,t-1}$ is the sector j external price in period t-1; and
er_{t-1} is exchange rate in period t-1.

$$p^d_{i,t} = mk^d_{i,t} \cdot uvc_{i,t} \tag{3.5.2.11}$$

where
$p^d_{i,t}$ is the desired price of firm i in period t;
$mk^d_{i,t}$ is the desired mark-up of firm i in period t; and
$uvc_{i,t}$ is the unit variable cost of firm i in period t.

3.5.3 Production

Firms' planned production aims at two goals: (i) to meet expected demand for the current period, and (ii) to keep inventories at a safe level to cope with unexpected demand fluctuations (Possas and Dweck 2004). Expected demand is calculated based on an extrapolative expectation rule, applying the past growth rate adjusted by an expectational parameter to the past level of demand. The desired level of inventories is assumed as a fixed proportion of sales:

$$o^e_{i,t} = o_{i,t-1} + \gamma_i \left(\frac{o_{i,t-1} - o_{i,t-2}}{o_{i,t-2}} \right) \tag{3.5.3.1}$$

where
$o^e_{i,t}$ is the expected orders of firm i in period t;
$o_{i,t-1}$ is the orders of firm i in period t-1;
$o_{i,t-2}$ is the orders of firm i in period t-2; and
γ_i is the expectational parameter of firm i.

Effective production is restricted by existing productive capacity, given by the sum of productive capacity of each capital good vintages of the firm[13]. As firms' productive capacity is composed of different capital vintages, it is assumed that most efficient capital goods, in terms of labor productivity, are used first. Effective production is also restricted by existing stock of intermediate goods:

$$x^*_{i,t} = o^e_{i,t}(1 + \sigma_i) - inv^s_{i,t-1} \tag{3.5.3.2a}$$

$$0 < x^*_{i,t} < x^p_{i,t} \tag{3.5.3.2b}$$

$$0 < x^*_{i,t} < \frac{inp^s_{i,t-1}}{\alpha_i} \tag{3.5.3.2c}$$

where
$x^*_{i,t}$ is the effective production of firm i in period t;
$o^e_{i,t}$ is the expected orders of firm i in period t;
σ_i is the desired inventories proportion of firm i;
$inv^s_{i,t-1}$ is the stock of inventories of firm i in period t-1;
$x^p_{i,t}$ is the productive capacity (potential output) of firm i in period t;
$inp^s_{i,t-1}$ is the stock of inputs of firm i in period t-1; and
α_i is the technical coefficient of inputs of firm i.

In each time period, firms demand intermediate goods for the next period, based on expected demand as well, already considering the current stock of intermediate

[13]In the consolidated version, effective productive capacity was defined as current productive capacity adjusted by an overuse parameter, to represent the possibility of extra-hours of labor and the use of scrapped equipment as last resource (Dweck 2006, footnote 172). This parameter was removed in the current version of the model.

goods and the amount used in current production. A share of inputs is demanded domestically, while another share is imported based on the firm's propensity to import inputs (Equation 3.5.2.5):

$$inp^d_{i,t} = \alpha_i \cdot x^*_{i,t} \left(1 + \gamma_i \left(\frac{o_{i,t-1} - o_{i,t-2}}{o_{i,t-2}}\right)\right) - (inp^s_{i,t-1} - \alpha_i \cdot x^*_{i,t}) \qquad (3.5.3.3)$$

where
$inp^d_{i,t}$ is the input demand of firm i in period t;
α_i is the technical coefficient of inputs of firm i;
$x^*_{i,t}$ is the effective production of firm i in period t;
γ_i is the expectational parameter of firm i;
$o_{i,t-1}$ is the orders of firm i in period t-1;
$o_{i,t-2}$ is the orders of firm i in period t-2; and
$inp^s_{i,t-1}$ is the stock of inputs of firm i in period t-1.

In the capital goods sector, firms do not produce based on expected demand. Instead, they produce on demand after receiving effective orders. However, we assume that capital production takes a whole investment period, so in each production period, capital goods firms will be producing a share of past effective orders:

$$x^*_{i,t} = \sum_{b=1}^{\Gamma} \frac{o_{i,t-b}}{\Gamma} \qquad (3.5.3.4)$$

where
$x^*_{i,t}$ is the effective production of firm i in the capital goods sector in period t;
Γ is the number of production periods that compose an investment period; and
$o_{i,t-b}$ is the orders of firm i in the capital goods sector in period t-b.

3.5.4 External Sector

At the beginning of each period, the exchange rate is adjusted based on the balance of payments result in the last period. The increase or decrease in the exchange rate is proportional to the absolute value of the balance of payments:

$$er_t = er_{t-1} - \psi^{er} \cdot bp_{t-1} \qquad (3.5.4.1a)$$

$$er^{min} \leq er_t \leq er^{max} \qquad (3.5.4.1b)$$

where
er_t is the exchange rate in period t;
er^{min} is the policy minimum exchange rate;
er^{max} is the policy maximum exchange rate;
er_{t-1} is the exchange rate in period t-1;
ψ^{er} is the exchange rate adjustment parameter;
bp_{t-1} is the balance of payments result in period t-1.

The balance of payments result depends on the trade balance and on the net capital flows. The trade balance (in domestic currency) is calculated at the end of the period as the simple difference between total exports and total imports, while the capital account is modelled here in a very simple way, but enough to capture the effects of monetary policy on the balance of payments[14]. The net capital flows depend on the interest rate differential, and they are a fraction of current nominal GDP. The multiplicative parameter captures how open the capital account of this economy is:

$$bp_t = (EXP_t - IMP_t) + (ir^*_{cb,t} - ir_x)\upsilon_x \cdot GDP_t \tag{3.5.4.2}$$

where
bp_t is the balance of payments result in period t;
EXP_t is the aggregate nominal exports in period t; and
IMP_t is the aggregate nominal imports in period t.
$ir^*_{cb,t}$ is the effective Central Bank interest rate in period t;
ir_x is the external sector interest rate;
υ_x is the capital flows proportion of GDP; and
GDP_t is the nominal GDP in period t.

External prices grow based on a fixed exogenous growth rate and/or the domestic sector past growth and external competitiveness, to consider the possibility of the domestic sector being relevant enough to influence international prices, in any combination of those two growth rates. To contemplate some random external shocks,

[14]We recognize that more sophistications or details could be desired, but a proper detailed implementation of the external sector, such as proposed by Reif (2006) and Busato (2010), requires more effort beyond the scope of this thesis. A complete integration of the multisectoral model with detailed external sector in the MMM model is due to future works.

the resulting growth rate is subjected to some stochastic variability:

$$p^x_{j,t} = p^x_{j,t-1}(1 + N((\Delta p^x_j + \vartheta_j \cdot \Delta \overline{p}_{j,t-1}), sd^p_j)) \tag{3.5.4.3}$$

where
$p^x_{j,t}$ is the external price of sector j in period t;
$p^x_{j,t-1}$ is the external price of sector j in period t-1;
Δp^x_j is the exogenous growth rate of external prices of sector j;
ϑ_j is sector j external competitiveness;
$\Delta \overline{p}_{j,t-1}$ is sector j average domestic price growth in period t-1; and
sd^p_j is the external price standard deviation of sector j.

External income grows based on a fixed exogenous growth rate, also subjected to some randomness.

$$y^x_t = y^x_{t-1}(1 + N(\Delta y^x_t, sd^y_j)) \tag{3.5.4.4}$$

where
y^x_t is the real external income in period t;
y^x_{t-1} is the real external income in period t-1;
Δy^x_t is the exogenous growth rate of external income of sector j; and
sd^y_j is the external income standard deviation.

Exports for each sector are determined by a fixed sectoral exports coefficient, current level of external income and the real exchange rate.

$$exp^r_{j,t} = \varepsilon_j \cdot \left(\frac{\overline{p}_{j,t} \cdot er_t}{p^x_{j,t}}\right)^{\epsilon^{p,x}_j} \cdot (y^x_t)^{\epsilon^{y,x}_j} \tag{3.5.4.5}$$

where
$exp^r_{j,t}$ is the real external demand (exports) of sector j in period t;
ε_j is the exports coefficient of sector j;
$\overline{p}_{j,t}$ is the average price of sector j in period t;
er_t is the exchange rate of the economy in period t;
$p^x_{j,t}$ is the foreign price of sector j products in period t;
y^x_t is the real external income in period t;
$\epsilon^{p,x}_j$ is the price elasticity of exports of sector j; and
$\epsilon^{y,x}_j$ is the income elasticity of exports of sector j.

3.5.5 Government

The government closely follows the specification presented by Dweck, Vianna, and Cruz Barbosa (2020). The Government pays public wages, it can pay unemployment benefits and transfers in a counter-cyclical manner, and it can act as direct consumer of the productive sectors, directly demanding consumption goods, capital goods and intermediate goods. The initial composition of the government budget is determined exogenously, and it grows based on the specific price growth and an exogenous desired real growth rate of the government.

$$w^d_{g,t} = w^d_{g,t-1}\left(1 + gr^d_g + \left(\frac{cpi_{t-1} - cpi_{t-2}}{cpi_{t-2}}\right)\right) \tag{3.5.5.1}$$

where
$w^d_{g,t}$ is the government desired wages in period t;
$w^d_{g,t-1}$ is the government desired wages in period t-1;
gr^d_g is the government desired real growth rate for its expenses;
cpi_{t-1} is the consumer price index in period t-1; and
cpi_{t-2} is the consumer price index in period t-2.

$$c^d_{g,t} = c^d_{g,t-1}\left(1 + gr^d_g + \left(\frac{\overline{p}_{c,t-1} - \overline{p}_{c,t-2}}{\overline{p}_{c,t-2}}\right)\right) \tag{3.5.5.2}$$

where
$c^d_{g,t}$ is the government desired consumption expenses in period t;
$c^d_{g,t-1}$ is the government desired consumption expenses in period t-1;
gr^d_g is the government desired real growth rate for its expenses;
$\overline{p}_{c,t-1}$ is the consumption sector average price in period t-1; and
$\overline{p}_{c,t-2}$ is the consumption sector average price in period t-2.

$$i^d_{g,t} = i^d_{g,t-1}\left(1 + gr^d_g + \left(\frac{\overline{p}_{k,t-1} - \overline{p}_{k,t-2}}{\overline{p}_{k,t-2}}\right)\right) \tag{3.5.5.3}$$

where
$i^d_{g,t}$ is the government desired investment expenses in period t;
$i^d_{g,t-1}$ is the government desired investment expenses in period t-1;
gr^d_g is the government desired real growth rate for its expenses;

$\overline{p}_{k,t-1}$ is the capital sector average price in period t-1; and
$\overline{p}_{k,t-2}$ is the capital sector average price in period t-2.

$$inp^d_{g,t} = inp^d_{g,t-1}\left(1 + gr^d_g + \left(\frac{\overline{p}_{in,t-1} - \overline{p}_{in,t-2}}{\overline{p}_{in,t-2}}\right)\right) \tag{3.5.5.4}$$

where
$inp^d_{g,t}$ is the government desired inputs expenses in period t;
$inp^d_{g,t-1}$ is the government desired inputs expenses in period t-1;
gr^d_g is the government desired real growth rate for its expenses;
$\overline{p}_{in,t-1}$ is the intermediate sector average price in period t-1; and
$\overline{p}_{in,t-2}$ is the intermediate sector average price in period t-2.

$$ub^d_{g,t} = \sum_{j=1}^{N} ubr \cdot \overline{wr}_{j,t-1}(max(0, n_{j,t-2} - n_{j,t-1})) \tag{3.5.5.5}$$

where
$ub^d_{g,t}$ is the desired unemployment benefits of the government in period t;
N is the number of sectors;
ubr is the unemployment benefit rate, as a share of average wages;
$\overline{wr}_{j,t-1}$ is the average nominal wage rate of the sector j in period t-1;
$n_{j,t-2}$ is the employment of sector j in period t-2; and
$n_{j,t-1}$ is the employment of sector j in period t-1.

If there is no fiscal rule of any kind, government effective expenses will be exactly the desired amount. However, if one or more fiscal rule is in play, they will determine the government maximum expenses which will limit effective expenses. It is worth noting that if more than one fiscal rule is active, the effective maximum will always be the minimum between maximum defined by the fiscal rule. Several fiscal rules were already discussed by Dweck, Vianna, and Cruz Barbosa (2020) but in the current baseline simulation we assume that the government follows a flexible primary surplus target rule in order to keep public debt under a limit:

$$g^{max}_t = \left(1 + \gamma_g\left(\frac{GDP_{t-1} - GDP_{t-2}}{GDP_{t-2}}\right)\right)(TAX_{t-1} - st_t \cdot GDP_{t-1}) \tag{3.5.5.6}$$

where

g_t^{max} is the government maximum expenses in period t;
γ_g is the government expectational parameter;
GDP_{t-1} is the nominal GDP in period t-1;
GDP_{t-2} is the nominal GDP in period t-2;
TAX_{t-1} is the total taxes in period t-1; and
st_t is the primary surplus target in period t.

Under the flexible primary surplus target, the government adjusts the target annually whenever the debt to GDP ratio is above the maximum or below the minimum desired value, and the primary target cannot exceed the defined minimum and maximum:

$$st_t = \begin{cases} st_{t-1} + \psi^{st} & if \quad \overline{dr}_{g,t-1} > dr_g^{max} \\ st_{t-1} - \psi^{st} & if \quad \overline{dr}_{g,t-1} < dr_g^{min} \\ st_{t-1} & if \quad otherwise \end{cases} \tag{3.5.5.7a}$$

$$st^{min} \leq st_t \leq st^{max} \tag{3.5.5.7b}$$

where
st_t is the primary surplus target in period t;
st_{t-1} is the primary surplus target in period t-1;
ψ^{st} is the primary surplus target adjustment parameter;
$\overline{dr}_{g,t-1}$ is the past average government debt to GDP ratio in period t-1;
dr_g^{max} is the maximum government debt to GDP ratio;
dr_g^{min} is the minimum government debt to GDP ratio;
st^{min} is the minimum primary surplus target; and
st^{max} is the maximum primary surplus target.

If the maximum government expenses are higher than the desired sum, effective expenses will be the desired amount, but if the maximum expenses imposed by the fiscal rule is lower than the desired amount, the government will prioritize some types of expenses in detriment of others. The priority scale is the following: government wages, unemployment benefits, consumption, inputs and investment.

$$w_{g,t}^* = min(w_{g,t}^d, g_t^{max}) \tag{3.5.5.8}$$

$$ub_{g,t}^* = min(ub_{g,t}^d, (g_t^{max} - w_{g,t}^*)) \tag{3.5.5.9}$$

$$c^*_{g,t} = min(c^d_{g,t}, (g^{max}_t - w^*_{g,t} - ub^*_{g,t})) \quad (3.5.5.10)$$

$$inp^*_{g,t} = min(inp^d_{g,t}, (g^{max}_t - w^*_{g,t} - ub^*_{g,t} - c^*_{g,t})) \quad (3.5.5.11)$$

$$i^*_{g,t} = min(i^d_{g,t}, (g^{max}_t - w^*_{g,t} - ub^*_{g,t} - c^*_{g,t} - inp^*_{g,t})) \quad (3.5.5.12)$$

$$GOV_t = w^*_{g,t} + ub^*_{g,t} + c^*_{g,t} + inp^*_{g,t} + i^*_{g,t} \quad (3.5.5.13)$$

where
$w^*_{g,t}$ is the government effective wages in period t;
$ub^*_{g,t}$ is the government effective unemployment benefits in period t;
$c^*_{g,t}$ is the government effective consumption expenses in period t;
$inp^*_{g,t}$ is the government effective inputs expenses in period t;
$i^*_{g,t}$ is the government effective investment expenses in period t;
g^{max}_t is the government maximum expenses defines by the fiscal rules in period t;
$w^d_{g,t}$ is the government desired wages in period t;
$c^d_{g,t}$ is the government desired consumption expenses in period t;
$i^d_{g,t}$ is the government desired investment expenses in period t;
$inp^d_{g,t}$ is the government desired inputs expenses in period t;
$ub^d_{g,t}$ is the desired unemployment benefits of the government in period t; and
GOV_t is the effective government expenses in period t.

Government real demand for the sectors is determined by the effective expenses divided by the respective sector average price:

$$c^r_{g,t} = \frac{c^*_{g,t}}{\overline{p}_{c,t}} \quad (3.5.5.14)$$

where
$c^r_{g,t}$ is the government real consumption demand in period t;
$c^*_{g,t}$ is the government effective consumption expenses in period t; and
$\overline{p}_{c,t}$ is the consumption sector average price in period t.

$$inp^r_{g,t} = \frac{inp^*_{g,t}}{\overline{p}_{in,t}} \tag{3.5.5.15}$$

where
$inp^r_{g,t}$ is the government real inputs demand period t;
$inp^*_{g,t}$ is the government effective inputs expenses in period t; and
$\overline{p}_{in,t}$ is the intermediate sector average price in period t.

$$i^r_{g,t} = \frac{i^*_{g,t}}{\overline{p}_{k,t}} \tag{3.5.5.16}$$

where
$i^r_{g,t}$ is the government real investment demand in period t;
$i^*_{g,t}$ is the government effective investment expenses in period t; and
$\overline{p}_{k,t}$ is the capital sector average price in period t.

At the end of the period, the government will have collected indirect taxes on firms, and income taxes on households[15]:

$$TAX_t = \sum_{i=1}^{F} tr_i \cdot re_{i,t} + \sum_{h}^{H} tr_h(\omega_h WG_t + \pi_h PR^{dis}_t) \tag{3.5.5.17}$$

where
TAX_t is the aggregate taxes in period t;
F is the total number of firms;
tr_i is the indirect tax rate of firm i;
re_i is the revenue of firm i in period t;
H is the total number of income classes;
tr_h is the income tax rate of income class h;
ω_h is the wage appropriation of class h;
WG_t is the aggregate wages in period t;
π_h is the profits appropriation of class h; and
PR^{dis}_t is the total distributed profits in period t.

The primary result is the total taxes minus government effective expenses as

[15]Note that income taxes are based on the profits and wages, and not on the total gross income of each income class, as gross income includes government's unemployment benefits which we assume are not taxed.

described above, excluding interest payment on current stock of government bonds, which comprise the government nominal result. If the government nominal result is negative, more bonds will be issued, increasing the current stock of bonds and possibly the government's debt rate. On the opposite side, if the nominal result is positive, the government can rebuy bonds to reduce its indebtedness:

$$b^s_t = b^s_{t-1} + (GOV_t - TAX_t) + ir^*_{cb,t} \cdot b^s_{t-1} \tag{3.5.5.18}$$

where
b^s_t is the stock of government bonds (debt) in period t;
b^s_{t-1} is the stock of government bonds (debt) in period t-1;
GOV_t is the effective total government expenses in period t;
TAX_t is the aggregate taxes in period t; and
$ir^*_{cb,t}$ is the effective central bank interest rate in period t.

Government debt to GDP ratio is then calculated:

$$dr_{g,t} = \frac{b^s_t}{GDP_t} \tag{3.5.5.19}$$

where
$dr_{g,t}$ is the government debt rate in period t;
b^s_t is the stock of government bonds (debt) in period t; and
GDP_t is the nominal GDP in period t.

3.5.6 Income Classes' Demand for Credit and Desired Consumption

The possibility of households, in the form of income classes, incurring in debt and accumulating deposits is an advance of the model in relation to the minimal structure of AB-SFC models in general. However, in the previous version of the model, income classes had no financial restriction, as effective expenses in consumption goods and imports were not limited by debt availability. Each income class would simply incur in automatic new debt if expenses were higher than nominal income and would accumulate deposits otherwise. There was no limit to new debt, except for a maximum debt rate that, if reached, the class would repay by a certain amount of debt to keep the debt rate as desired and could only pay it with current stock of deposits. We introduce financial restriction to classes' consumption in a similar fashion to the firms' restriction.

Each income class decision to consume and import, and several other class decisions will be based on average past disposable income:

$$\overline{y}^{dp}_{h,t} = \frac{\sum_{b=1}^{\Lambda} y^{dp}_{h,t-b}}{\Lambda} \tag{3.5.6.1}$$

where
$\overline{y}^{dp}_{h,t}$ is the average past disposable income of class h in period t;
Λ is the annual frequency; and
$y^{dp}_{h,t-b}$ is the nominal disposable income of class h in period t-b.

Total desired expenses depend on a fixed marginal propensity to consume over average past disposable income, which is divided into domestic and imported consumption by a flexible propensity to import over total induced expenses, plus an autonomous consumption:

$$e^{d}_{h,t} = c^{d}_{h,t} + imp^{d}_{h,t} \tag{3.5.6.2}$$

where
$e^{d}_{h,t}$ is the desired expenses of income class h in period t;
$c^{d}_{h,t}$ is the desired domestic consumption of income class h in period t;
$imp^{d}_{h,t}$ is the desired imported consumption of income class h in period t;

$$c^{d}_{h,t} = (1 - \iota_{h,t})(\zeta_h \cdot \overline{y}^{dp}_{h,t}) + c^{a}_{h,t} \tag{3.5.6.3}$$

where
$c^{d}_{h,t}$ is the desired domestic consumption of income class h in period t;
$\iota_{h,t}$ is the propensity to import on consumption of income of class h in period t;
ζ_h is the propensity to consume on income of class h;
$\overline{y}^{dp}_{h,t}$ is the average past disposable income of class h in period; and
$c^{a}_{h,t}$ is the autonomous consumption of class h in period t.

$$imp^{d}_{h,t} = \iota_{h,t}(\zeta_h \cdot \overline{y}^{dp}_{h,t}) \tag{3.5.6.4}$$

where

$imp^d_{h,t}$ is the desired imported consumption of income class h in period t;
$\iota_{h,t}$ is the propensity to import on consumption of income of class h in period t;
ζ_h is the propensity to consume on income of class h; and
$\overline{y}^{dp}_{h,t}$ is the average past disposable income of class h in period.

The desired autonomous consumption grows annually based on the average quality of the consumption good sector and depend on how each income class adjust its own consumption:

$$c^a_{h,t} = c^a_{h,t-1}\left(1 + \varphi^a_h\left(\frac{\overline{q}_{c,t-1} - \overline{q}_{c,t-1-\Lambda}}{\overline{q}_{c,t-1-\Lambda}}\right)\right) \tag{3.5.6.5}$$

where
$c^a_{h,t}$ is the autonomous consumption of class h in period t;
$c^a_{h,t-1}$ is the autonomous consumption of class h in period t-1;
φ^a_h is the autonomous consumption adjustment of class h in period t;
$\overline{q}_{c,t-1}$ is the average quality of the consumption good sector c in period t-1; and
$\overline{q}_{c,t-1-\Lambda}$ is the average quality of the consumption good sector c in period $t-1-\Lambda$.

The propensity to import can change based on the real exchange rate and on each income class' elasticity:

$$\iota_{h,t} = \iota_{h,t-1}\cdot\left(\frac{\overline{p}_{c,t-1}}{p^x_{c,t-1}\cdot er_{t-1}}\right)^{\epsilon^p_h} \tag{3.5.6.6}$$

where
$\iota^{in}_{i,t}$ is the propensity to import inputs of firm i in period t;
$\iota^{in}_{i,t-1}$ is the propensity to import inputs of firm i in period t-1;
$\overline{p}_{in,t-1}$ is the average price of the intermediate goods sector *in* in period t-1;
$p^x_{in,t-1}$ is the external price of the intermediate good sector *in* in period t-1;
er_{t-1} is country exchange rate in period t-1; and
$\epsilon^{p,in}_j$ is the price elasticity of imported inputs of sector j.

Given the total amount of desired expenses, classes prioritize available liquid resources, but if they are not enough, they can demand new loans to banks. Available liquid resources, or internal funds, are composed by disposable nominal income from the last period, plus current stock of deposits, minus financial obligations, interest payments and debt amortization, which must be paid before demanding consumption goods. We assume that whenever a class makes a new loan, it has a fixed term of a year, Λ time periods ($\Lambda = 4$ in the baseline), with fixed amortizations and interest rate fixed when the loan is taken, following Martins (2018). Thus, in each time period, each class must pay interest on the current amount of debt and repay the fixed amortization of all loans, summing up the financial obligations for that period:

$$fo_{h,t} = \sum_{l=1}^{L_{h,t}} \left(ir_l \cdot d_{l,t} + \frac{d_l^0}{\Lambda} \right) \tag{3.5.6.7}$$

where
$fo_{h,t}$ is the financial obligations of class h in period t;
$L_{h,t}$ is number of loans of class h in period t;
ir_l is the specific interest rate of loan l;
$d_{l,t}$ is the current amount of debt of the loans l in period t;
d_l^0 is the initial amount of loan l; and
Λ is the annual frequency parameter.

After financial obligations, each class can retain a share of their its available deposits as liquidity preference, as a proportion of average income. Following some ideas of Moreira (2010), this proportion is not fixed, and it can be revised annually, depending on the class' disposable income growth and on the current indebtedness:

$$lp_{h,t} = \begin{cases} lp_{h,t-1} - \psi_h^{lp} & if \quad \frac{\overline{y}_{h,t-1}^{dp} - \overline{y}_{h,t-1-\Lambda}^{dp}}{\overline{y}_{h,t-1-\Lambda}^{dp}} > 0 \quad and \quad dr_{h,t-1} < dr_{h,t-1}^{max} \\ lp_{h,t-1} + \psi_h^{lp} & if \quad \frac{\overline{y}_{h,t-1}^{dp} - \overline{y}_{h,t-1-\Lambda}^{dp}}{\overline{y}_{h,t-1-\Lambda}^{dp}} < 0 \quad and \quad dr_{h,t-1} > dr_{h,t-1}^{max} \\ lp_{h,t-1} & otherwise \end{cases} \tag{3.5.6.8}$$

where
$lp_{h,t}$ is the liquidity preference of class h in period t;
$lp_{h,t-1}$ is the liquidity preference of class h in period t-1;
ψ_h^{lp} is the liquidity preference adjustment parameter of class h;
$\overline{y}_{h,t-1}^{dp}$ is the class h average disposable income in period t-1;
$\overline{y}_{h,t-1-\Lambda}^{dp}$ is the class h average disposable income in period $t-1-\Lambda$;
$dr_{h,t-1}$ is the class h debt rate in period t-1; and
$dr_{h,t-1}^{max}$ is the class h maximum debt rate in period t-1.

Class' debt rate is calculated as the ratio between current stock of debt over average nominal income plus current stock of deposits:

$$dr_{h,t} = \frac{l^s_{h,t}}{\overline{y}^{dp}_{h,t} + dep^s_{h,t}} \tag{3.5.6.9}$$

where
$dr_{h,t}$ is the debt rate of income class h in period t;
$l^s_{h,t}$ is the stock of loans of income class h in period t;
$dep^s_{h,t}$ is the stock of deposits of income class h in period t; and
$\overline{y}^{dp}_{h,t}$ is the average past disposable income of class h in period t.

The difference between desired expenses and internal funds will be the demand for external funds from the class:

$$l^d_{h,t} = e^d_{h,t} - (y^n_{h,t-1} + dp^s_{h,t-1} - lp_{h,t} \cdot \overline{y}^{dp}_{h,t} - fo_{h,t}) \tag{3.5.6.10}$$

where
$l^d_{h,t}$ is the desired demand for new loans of income class h in period t;
$e^d_{h,t}$ is the desired expenses of income class h in period t;
$y^n_{h,t-1}$ is the net income of class h in period t-1;
$dp^s_{h,t-1}$ is the stock of deposits of class h in period t-1;
$fo_{h,t}$ is the financial obligations of class h in period t; and
$lp_{h,t}$ is the liquidity preference of class h in period t; and
$\overline{y}^{dp}_{h,t}$ is the average past disposable income of class h in period t.

However, each class is submitted to debt assessment by the banks. Each class has a maximum debt rate (or banks have a maximum debt rate on each income class), and if current debt rate is higher than maximum, the class cannot incur in new debt. If current debt rate is lower than desired, the class will be able to demand new loans, and if needed, it should be done only by the amount that would make the current debt rate reach the maximum rate. This represents credit rationing from the bank and, therefore, effective financial constraints to classes consumption:

$$l^{max}_{h,t} = dr^{max}_{h,t}(\overline{y}^{dp}_{h,t} + dep^s_{h,t}) - l^s_{h,t} \tag{3.5.6.11}$$

where
$l^{max}_{h,t}$ is the available loans for income class h in period t;
$dr^{max}_{h,t}$ is the desired debt rate of income class h;
$l^s_{h,t}$ is the stock of loans of income of class h;

$dep^{s}_{h,t}$ is the stock of deposits of income class h in period t; and
$\overline{y}^{dp}_{h,t}$ is the average past disposable income of class h in period t.

Similarly to the liquidity preference, classes and banks can revise the maximum debt rate annually, based on the average disposable income growth and on the current indebtedness:

$$dr^{max}_{h,t} = \begin{cases} dr^{max}_{h,t-1} + \psi^{dr}_{h} & if \quad \frac{\overline{y}^{dp}_{h,t-1} - \overline{y}^{dp}_{h,t-1-\Lambda}}{\overline{y}^{dp}_{h,t-1-\Lambda}} > 0 \quad and \quad dr_{h,t-1} < dr^{max}_{h,t-1} \\ dr^{max}_{h,t-1} - \psi^{dr}_{h} & if \quad \frac{\overline{y}^{dp}_{h,t-1} - \overline{y}^{dp}_{h,t-1-\Lambda}}{\overline{y}^{dp}_{h,t-1-\Lambda}} < 0 \quad and \quad dr_{h,t-1} > dr^{max}_{h,t-1} \\ dr^{max}_{h,t-1} & otherwise \end{cases} \quad (3.5.6.12)$$

where
$dr^{max}_{h,t}$ is the maximum debt rate of class h in period t;
$dr^{max}_{h,t-1}$ is the maximum debt rate of class h in period t-1;
ψ^{dr}_{h} is the maximum debt rate adjustment parameter of class h;
$\overline{y}^{dp}_{h,t-1}$ is the class h average disposable income in period t-1;
$\overline{y}^{dp}_{h,t-1-\Lambda}$ is the class h average disposable income in period $t-1-\Lambda$;
$dr_{h,t-1}$ is the class h debt rate in period t-1; and
$dr^{max}_{h,t-1}$ is the class h maximum debt rate in period t-1.

The effective amount of new loans is limited by the debt assessment:

$$l^{*}_{h,t} = min(l^{d}_{h,t}, l^{max}_{h,t}) \quad (3.5.6.13)$$

where
$l^{*}_{h,t}$ is the effective loans of income class h in period t;
$l^{d}_{h,t}$ is the desired demand for new loans of income class h in period t; and
$l^{max}_{h,t}$ is the available loans for income class h in period t.

Now, each income class can compute its total amount of funds available for consumption and import expenses, including its own internal funds and external funds provided by the banks. The total amount of funds could be lower than the total desired expenses. If that is the case, income classes prioritize domestic consumption over imports. If, after effective expenses on consumption and imports (which can be in fact restricted by the consumption goods supply) there are still funds available, each income class can keep it and add it to its stock of deposits. Class' total funds is composed by last period's disposable income, plus stock of deposits discounting liquidity preference, minus class' financial obligations plus effective new loans:

$$f_{h,t} = y^{dp}_{h,t-1} + dep^{s}_{h,t-1} - lp_{h,t} \cdot \overline{y}^{dp}_{h,t} - fo_{h,t} + l^{*}_{h,t} \tag{3.5.6.14}$$

where
$f_{h,t}$ is amount of funds available for income class h in period t;
$y^{dp}_{h,t-1}$ is the net income of class h in period t-1;
$dep^{s}_{h,t-1}$ is the stock of deposits of class h in period t-1;
$fo_{h,t}$ is the financial obligations of class h in period t;
$lp_{h,t}$ is the liquidity preference of class h in period t;
$\overline{y}^{dp}_{h,t}$ is the average past disposable income of class h in period; and
$l^{*}_{h,t}$ is the effective loans of income class h in period t.

Effective domestic consumption is limited by total amount of funds:

$$c^{*}_{h,t} = min(c^{d}_{h,t}, f_{h,t}) \tag{3.5.6.15}$$

where
$c^{*}_{h,t}$ is the effective domestic consumption demand of class h in period t;
$c^{d}_{h,t}$ is the desired domestic consumption of income class h in period t; and
$f_{h,t}$ is amount of funds available for income class h in period t.

As classes prioritize domestic consumption, effective imports will be limited by the available funds after domestic consumption:

$$imp^{*}_{h,t} = min(imp^{d}_{h,t}, (f_{h,t} - c^{*}_{h,t})) \tag{3.5.6.16}$$

where
$imp^{*}_{h,t}$ is the effective imported consumption of income class h in period t;
$imp^{d}_{h,t}$ is the desired imported consumption of income class h in period t;
$c^{*}_{h,t}$ is the effective domestic consumption of income class h in period t; and
$f_{h,t}$ is amount of funds available for income class h in period t.

Real consumption demand of each class is than calculated, dividing effective expenses by the consumption sector average price:

$$c^{r}_{h,t} = \frac{c^{*}_{h,t}}{\overline{p}_{c,t}} \tag{3.5.6.17}$$

where
$c^r_{h,t}$ is the real domestic consumption demand of income class h in period t;
$c^*_{h,t}$ is the effective domestic consumption demand of class h in period t; and
$\overline{p}_{c,t}$ is the average price of the consumption sector c in period t.

3.5.7 Effective Demand

Total sectoral demand is determined by domestic demand, government demand and external demand (real exports). The sectoral demand of each type of productive sector is determined differently.

For the consumption goods sector, domestic demand is determined by the sum of each income class consumption:

$$o_{c,t} = \sum_{h=1}^{H} c^r_{h,t} + exp^r_{c,t} + c^r_{g,t} \tag{3.5.7.1}$$

where
$o_{c,t}$ is the real sectoral orders of the consumption goods sector c in period t;
H is number of income classes;
$c^r_{h,t}$ is the real effective domestic consumption demand of class h in period t;
$exp^r_{c,t}$ is the real exports of the consumption good sector in period t; and
$c^r_{g,t}$ is the real effective consumption demand of the government in period t.

For the intermediate goods sector, domestic demand is determined by the sum of domestic input demand of all firms:

$$o_{in,t} = \sum_{i=1}^{F}(1 - \iota^{in}_{i,t})inp^d_{i,t} + exp^r_{in,t} + inp^r_{g,t} \tag{3.5.7.2}$$

where
$o_{in,t}$ is the real sectoral orders of intermediate goods sector *in* in period t;
F is total number of firms;
$\iota^{in}_{i,t}$ is the propensity to import inputs of firm i in period t;
$inp^d_{i,t}$ is the input demand of firm i in period t;
$exp^r_{in,t}$ is the real exports of the intermediate good sector *in* in period t; and
$inp^r_{g,t}$ is the real input demand of the government in period t.

Finally, for the capital goods sector, domestic demand is determined by the sum of effective investment decisions of all firms, considering all three components of investment and already limited by financial constraints. Firms only demand capital goods when it is an investment period, and investment periods are not simultaneous for all firms. Instead, they are mismatched, but every production period is an investment period for some firms:

$$o_{k,t} = \sum_{i=1}^{F} i^r_{i,t} + exp^r_{k,t} + i^r_{g,t} \tag{3.5.7.3}$$

where
$o_{k,t}$ is the real sectoral orders of the capital goods sector in period t;
F is total number of firms;
$i^r_{i,t}$ is the real effective investment of firm i in period t;
$exp^r_{k,t}$ is the real exports of the capital good sector in period t; and
$i^r_{g,t}$ is the real effective investment (capital demand) of the government in period t.

Total sectoral demand is then divided among firms based on their relative competitiveness:

$$o_{i,t} = ms_{i,t} \cdot o_{j,t} \tag{3.5.7.4}$$

where
$o_{i,t}$ is the orders of firm i, belonging to sector j, in period t;
$ms_{i,t}$ is the market share of firm i in period t; and
$o_{j,t}$ is the sectoral orders of sector j in period t.

In fact, their relative competitiveness affects their market share evolution, formalized in a replicator dynamics equation. Firm's market share evolves based on the difference between firm's competitiveness and sector's average competitiveness:

$$ms_{i,t} = ms_{i,t-1}\left(1 + \mu^{ms}_j \left(\frac{co_{i,t} - \overline{co}_{j,t}}{\overline{co}_{j,t}}\right)\right) \tag{3.5.7.5}$$

where
$ms_{i,t}$ is the market share of firm i in period t;
$ms_{i,t-1}$ is the market share of firm i in period t-1;
μ^{ms}_j is market share adjustment parameter of sector j;
$co_{i,t}$ is the competitiveness of firm i in period t; and
$\overline{co}_{j,t}$ is the average competitiveness of the sector j in period t.

As already shown by Possas and Dweck (2004) and Dweck (2006), this formulation was first presented in Possas et al. (2001) based on a discrete version of Silverberg (1987) formulation, where the main difference is the market-share adjustment parameter μ_j^{ms}, which defines the selection mechanism intensity. We follow Silverberg (1987) proposition that firm's competitiveness index depends negatively on price and delivery delay, and positively on product quality:

$$co_{i,t} = \frac{q_{i,t}^{\epsilon_j^q}}{p_{i,t}^{\epsilon_j^p} \cdot dd_{i,t}^{\epsilon_j^{dd}}} \tag{3.5.7.6}$$

where
$co_{i,t}$ is the competitiveness of firm i in period t;
$q_{i,t}$ is the quality of firm i in period t;
$p_{i,t}$ is the price of firm i in period t;
$dd_{i,t}$ is the delivery delay of firm i in period t; and
ϵ is the respective elasticity of each component of the sector j.

3.5.8 Sales and Profits

Effective sales are determined by current firm's effective orders, which can be different from expected sales used in production:

$$s_{i,t} = \min(o_{i,t}, (x_{i,t}^* + inv_{i,t-1}^s)) \tag{3.5.8.1}$$

where
$s_{i,t}$ is sales of firm i in period t;
$o_{i,t}$ is the orders of firm i in period t;
$x_{i,t}^*$ is the effective production of firm i in period t; and
$inv_{i,t-1}^s$ is the stock of inventories of firm i in period t-1.

In case current effective orders are lower than expected, effective sales will be the effective orders, and unsold products will be accumulated as inventories. In case current effective orders are higher than expected, effective sales will be restricted by current effective production plus current level of inventories:

$$inv_{i,t}^s = inv_{i,t-1}^s + (x_{i,t}^* - s_{i,t}) \tag{3.5.8.2}$$

where

$inv^s_{i,t}$ is the stock of inventories of firm i in period t;
$inv^s_{i,t-1}$ is the stock of inventories of firm i in period t-1;
$x^*_{i,t}$ is the effective production of firm i in period t; and
$s_{i,t}$ is sales of firm i in period t.

Additionally, if the level of effective orders is higher than effective sales, this is computed as delivery delay, and it negatively affects firm's competitiveness. This generates temporal feedbacks, as firms will adjust future expected demand based on the past levels, and production will also take into consideration accumulated level of inventories:

$$dd_{i,t} = \frac{o_{i,t}}{s_{i,t}} \tag{3.5.8.3}$$

where
$dd_{i,t}$ is the delivery delay of firm i in period t;
$o_{i,t}$ is the orders of firm i in period t-1; and
$s_{i,t}$ is sales of firm i in period t.

Firm's revenue depends on the effective sales and the firm price:

$$re_{i,t} = p^*_{i,t} \cdot s_{i,t} \tag{3.5.8.4}$$

where
$re_{i,t}$ is the revenue of firm i in period t;
$p^*_{i,t}$ is the effective price of firm i in period t; and
$s_{i,t}$ is sales of firm i in period t.

Firm's net profits are calculated deducing indirect tax payment and R&D expenses from gross revenue, minus production costs, plus net financial gains, interest received on deposits minus interest paid on loans:

$$pr^{nt}_{i,t} = re_{i,t}(1-tr_i)(1-\lambda_i)-(uwc_{i,t}+uic_{i,t})\cdot x^*_{i,t}+ir^{dep}_t\cdot dep^s_{i,t-1}-\sum_{l=1}^{L_{i,t}} ir_l\cdot d_{l,t-1} \tag{3.5.8.5}$$

where
$pr^{nt}_{i,t}$ is the net profits of firm i in period t;
$re_{i,t}$ is the revenue of firm i in period t;

tr_i is direct tax rate of firm i;
λ_i is the R&D revenue proportion of firm i;
$uwc_{i,t}$ is the unit wage cost of firm i in period t;
$uic_{i,t}$ is the unit input cost of firm i in period t;
$x^*_{i,t}$ is the effective production of firm i in period t;
ir^{dep}_t is the interest rate on deposits in period t;
$dep^s_{i,t-1}$ is the stock of deposits of firm i in period t-1;
$L_{i,t}$ is number of loans of firm i in period t;
ir_l is the specific interest rate of each loan l; and
$d_{l,t}$ is the current amount of debt of each loan l in period t.

A share of net profits is distributed to the income classes, and part is retained to serve as internal funds for firm's investment. However, if net profits are negative, firms internalize all losses, and none is distributed to the income classes:

$$pr^{dis}_{i,t} = \begin{cases} \delta_i \cdot pr^{nt}_{i,t} & if \quad pr^{nt}_{i,t} > 0 \\ 0 & otherwise \end{cases} \tag{3.5.8.6}$$

where
$pr^{dis}_{i,t}$ is the distributed profits of firm i in period t;
$pr^{nt}_{i,t}$ is the net profits of firm i in period t; and
δ_i is the profits distribution rate of firm i.

3.5.9 Technological Search

Firms allocate some share of revenue to R&D, hiring researchers and paying these resources as wages. They divide those resources into innovation and imitation, and the division determines whether the firm is more innovative or imitative. The technological search process in the model very closely follows the two-stage process proposed by Nelson and Winter (1982). The technological frontier of the firm in each period will be determined by the maximum productivity between current frontier productivity, the one reached by innovation process and the one reached by imitation process. The same works for product quality[16]:

$$rnd_{i,t} = re_{i,t}(1 - tr_i)\lambda_i \tag{3.5.9.1}$$

[16]Here is another simplification of this version in relation to the consolidated version of the model. In the latter, the implementation of new quality, as a result of innovation or imitation required new capital goods, and consequently new investment. However, the product quality can be understood as product differentiation, marketing and propaganda, for example, therefore not requiring new capital goods. Product quality can be implemented with labor only.

where
$rnd_{i,t}$ is the R&D expenses of firm i in period t;
$re_{i,t}$ is the revenue of firm i in period t;
tr_i is direct tax rate of firm i;
λ_i is the R&D revenue proportion of firm i;

The probability of imitation success depends on the amount of resources allocated to imitation R&D:

$$P(dummy^{im} = 1) = 1 - e^{(-im_i \cdot rnd_{i,t})} \tag{3.5.9.2}$$

where
$dummy^{im}$ is a dummy variable that assumes values 1 or 0;
im_i is the imitation proportion of R&D expenses of firm i; and
$rnd_{i,t}$ is the R&D expenses of firm i in period t.

Then, the firm is subjected to a random draw. If the firm is successful, it is able to find the maximum productivity of the sector and the maximum quality of the sector:

$$\phi_{i,t}^{im} = dummy^{im} \cdot \phi_{j,t-1}^{max} \tag{3.5.9.3}$$

where
$\phi_{i,t}^{im}$ is the possible labor productivity due to imitation of firm i in period t;
$dummy^{im}$ is a dummy variable that assumes values 1 or 0; and
$\phi_{j,t-1}^{max}$ in the maximum productivity of sector j in period t-1.

$$q_{i,t}^{im} = dummy^{im} \cdot q_{j,t-1}^{max} \tag{3.5.9.4}$$

where
$q_{i,t}^{im}$ is the possible quality due to imitation of firm i in period t;
$dummy^{im}$ is a dummy variable that assumes values 1 or 0; and
$q_{j,t-1}^{max}$ in the maximum quality of sector j in period t-1.

The probability of innovation success also depends on the amount of resources allocated to innovation R&D:

$$P(dummy^{inn} = 1) = 1 - e^{(-inn_i \cdot rnd_{i,t})} \tag{3.5.9.5}$$

where
$dummy^{inn}$ is a dummy variable that assumes values 1 or 0;
inn_i is the innovation proportion of R&D expenses of firm i; and
$rnd_{i,t}$ is the R&D expenses of firm i in period t.

Then the firm is subjected to a random draw. If the firm is successful it is able to find a new productivity and a new quality based on a normal distribution, with average and standard deviation given by sector technological opportunities parameters. Note that the result of the random draw can be lower or higher than the firm's current productivity or quality, thus representing the uncertainty involved in the innovation process. The firm might allocate resources and might be able to find a new technology but, in practice, the new technology might not be as productive as expected:

$$\phi_{i,t}^{inn} = dummy^{inn} \cdot N((\phi_j^0 + opp_j^{\phi} \cdot t), sd_j^{\phi}) \tag{3.5.9.6}$$

where
$\phi_{i,t}^{inn}$ is the possible labor productivity due to innovation of firm i in period t;
$dummy^{inn}$ is a dummy variable that assumes values 1 or 0;
ϕ_j^0 is the initial productivity of sector j;
opp_j^{ϕ} is the productivity technological opportunities of sector j;
t is the current time period; and
sd_j^{ϕ} is the standard deviation of productivity distribution of sector j.

$$q_{i,t}^{inn} = dummy^{inn} \cdot N((q_j^0 + opp_j^{q} \cdot t), sd_j^{q}) \tag{3.5.9.7}$$

where
$q_{i,t}^{inn}$ is the possible quality due to innovation of firm i in period t;
$dummy^{inn}$ is a dummy variable that assumes values 1 or 0;
q_j^0 is the initial quality of sector j;
opp_j^{q} is the quality technological opportunities of sector j;
t is the current time period; and
sd_j^{q} is the standard deviation of quality distribution of sector j.

Considering innovation and imitation, and the uncertainty involved in both processes, the firm will potentially implement the higher productivity and quality among the one obtained in the innovation process, the one from the imitation process and its current productivity and quality:

$$\phi^p_{i,t} = \max(\phi^{im}_{i,t}, \phi^{inn}_{i,t}, \phi^p_{i,t-1}) \tag{3.5.9.8}$$

where
$\phi^p_{i,t}$ is the potential or frontier labor productivity of firm i in period t;
$\phi^{im}_{i,t}$ is the possible labor productivity due to imitation of firm i in period t;
$\phi^{inn}_{i,t}$ is the possible labor productivity due to innovation of firm i in period t; and
$\phi^p_{i,t-1}$ is the frontier labor productivity of firm i in period t-1.

$$q_{i,t} = \max(q^{im}_{i,t}, q^{inn}_{i,t}, q_{i,t-1}) \tag{3.5.9.9}$$

where
$q_{i,t}$ is the product quality of firm i in period t;
$q^{im}_{i,t}$ is the possible quality due to imitation of firm i in period t;
$q^{inn}_{i,t}$ is the possible quality due to innovation of firm i in period t; and
$q_{i,t-1}$ is the quality of firm i in period t-1.

3.5.10 Investment Decisions

Firms make investment decisions at the end of each investment period. There are three components of investment decisions, but the first two, physical depreciation and productive capacity expansion, can be determined together. In order to know how much productive capacity will be needed for the next investment period, firms apply the same extrapolative expectational rule, but for average sales of past investment period. Additionally, since the demanded productive capacity will take a whole investment period to be produced, and will only be operative in the second subsequent investment period, the expectational parameter is applied twice:

$$o^e_{i,T+2} = \overline{o}_{i,T-1} + 2\gamma_i \left(\frac{\overline{o}_{i,T-1} - \overline{o}_{i,T-2}}{\overline{o}_{i,T-2}} \right) \tag{3.5.10.1}$$

where

$o^e_{i,T+2}$ is the expected orders of firm i in the investment period $T+2$;
$\overline{o}_{i,T-1}$ is the average orders of firm i in investment period $T-1$;
$\overline{o}_{i,T-2}$ is the average orders of firm i in investment period $T-2$; and
γ_i is the expectational parameter of firm i.

The desired productive capacity to meet the long-term expected demand is adjusted by the desired degree of capacity utilization of the firm. Then, to determine the desired productive capacity demanded, the existing productive capacity must be subtracted, already discounting the physically depreciated capital goods of the last investment period, and the productive capacity which will depreciate in the next investment period while new capital goods do not arrive:

$$(x^p)^d_{i,T} = \frac{o^e_{i,T+2}}{pcu^d_i} - x^p_{i,T} \tag{3.5.10.2}$$

where
$(x^p)^d_{i,T}$ is the desired capacity expansion of firm i in the investment period T;
$o^e_{i,T+2}$ is the expected orders of firm i in the investment period $T+2$;
pcu^d_i is the desired degree of capacity utilization of firm i; and
$x^p_{i,T}$ is the current productive capacity of firm i in the investment period T.

Desired expansion investment expenses will be the nominal value of the amount of capital goods needed, in order to meet desired productive capacity expansion in terms of products:

$$xi^d_{i,T} = \beta_i \cdot (x^p)^d_{i,T} \cdot \overline{p}_{k,t} \tag{3.5.10.3}$$

where
$xi^d_{i,T}$ is the desired expansion investment expenses of firm i in investment period T;
β_i is the capital output ratio of firm i;
$\overline{p}_{k,t}$ is the average price of the capital goods sector k in period t; and
$(x^p)^d_{i,T}$ is the desired capacity expansion of firm i in the investment period T.

Desired replacement investment is determined by a simple payback rule, where the cost of the new capital good, already adjusted by the expected interest rate on loans [17], must be paid by the productivity difference between the potential found in R&D and the current productivity of each already installed capital, in a desired

[17] This is another introduction made in this version. As most of replacement investment is externally financed, we introduce the interest rate in the payback rule, also accounting for interest rate channel of monetary policy.

number of periods, the payback period:

$$ri^d_{i,T} = k^d_{i,T} \cdot \overline{p}_{k,t} \tag{3.5.10.4}$$

where
$ri^d_{i,T}$ is the desired replacement investment expenses of firm i in investment period T;
$\overline{p}_{k,t}$ is the average price of the capital goods sector k in period t; and
$k^d_{i,T}$ is the desired number of capital goods of firm i in the investment period T which satisfies the payback rule.

The Payback rule is thus:

$$\frac{\overline{p}_{k,t}(1 + ir^{lt}_{i,t})}{\frac{wr_{i,t}}{\phi^p_{i,t}} - \frac{wr_{i,t}}{\phi_{k,t}}} < pb_i \tag{3.5.10.5}$$

where
$\overline{p}_{k,t}$ is the average price of the capital goods sector k in period t;
$ir^{lt}_{i,t}$ is the interest rate on long-term loans of firm i in period t;
$wr_{i,t}$ is the nominal wage rate of firm i in period t;
$\phi^p_{i,t}$ is the potential labor productivity obtained by R&D of firm i in period t;
$\phi_{k,t}$ is the labor productivity of each capital good k of firm i in period t; and
pb_i is the payback period of firm i.

Desired investment expenses comprise both expansion and modernization investments:

$$i^d_{i,t} = xi^d_{i,t} + ri^d_{i,t} \tag{3.5.10.6}$$

where
$i^d_{i,t}$ is the desired investment expenses of firm i in period t;
$xi^d_{i,t}$ is the desired expansion investment expenses of firm i in period t; and
$ri^d_{i,t}$ is the desired replacement investment expenses of firm i in period t.

Effective investment expenses in productive capacity expansion will be limited by the total amount of funds available, including internal funds (retained profits of the current period), external funds (available loans) and available deposits (already accumulated retained profits). Investment decisions can be financially constrained.

3.5.11 Firms' Demand for Credit

The firm's demand for credit was already well developed in the model. We refine here some points and introduce slight modifications and endogenizations, in line with Moreira (2010). The model already followed the most used definition of demand for credit to finance investment, the Pecking Order Theory, as used in the reviewed models of the last chapter. So, firms need to finance investment decisions, and prioritize internal funds over external funds. Investment decisions, however, do not occur in every time (production) period, so firms have a sequence of production periods to retain profits as liquid resources to internally finance future investments.

Following Moreira (2010) and some other authors who make use of the distinct-tion, we assume that when a firm takes a new loan, it can be of two types: (i) short term, if it is not investment period for the firm, so to cover current net losses, and (ii) long-term, to finance investment. In both cases, interest rates are fixed at the period the loan is taken and amortization is constant, as proposed by Martins (2018). The effective difference between both types is in fact their duration, as we assume that firms have one year (Λ production periods) to repay short-term loans and ten investment periods to repay long-term loans, which is equivalent to the average lifetime of the capital goods[18]. Thus, in each period, a firm must pay a fixed amortization of each loan already taken, plus interest on the current stock of debt, with interest fixed for each loan in the period the loan was taken[19]. The debt structure might represent the biggest structural difference in the firm side of this finance-augmented version of the model, in comparison with the consolidated version.

The sum of current retained profits (even if negative) with current stock of deposits, discounting the amortization of all loans, comprises firm's total internal funds. If total internal funds are negative, meaning that not even the current stock of deposits was able to cover net losses, a short-term loan will be demanded. If total internal funds are positive, and it is not an investment period, there are no other desired expenses in that period, so the firm can keep these funds as deposits, accumulating them as stock of deposits to be spent in the next periods. However, if it an is investment period, the firm might need to use them to finance investment:

$$f^{i}_{i,t} = pr^{ret}_{i,t} + (dep^{s}_{i,t-1} - lp_{i,t} \cdot k_{i,t-1}) - \sum_{l=1}^{L_{i,t}} am_l \tag{3.5.11.1a}$$

[18]Those durations are in fact parameters we can modify and test to understand the impact of a more amortized credit structure in comparison with a short amortization period, for instance.

[19]We set a background possibility of flexible interest rates, in a way that instead of paying a rate which was fixed when the loan was taken, the rate is calculated and set every time period. However, we do not explore this distinct arrangement in this thesis, but the possibility exists in the model's code for future analysis.

$$0 \leq lp_{i,t} \cdot k_{i,t-1} \leq pr^{ret}_{i,t} + dep^{s}_{i,t-1} \tag{3.5.11.1b}$$

where
$f^{i}_{i,t}$ is internal funds of firm i in period t;
$pr^{ret}_{i,t}$ is the retained profits of firm i in period t;
$dep^{s}_{i,t-1}$ is stock of deposits of firm i in period t-1;
$lp_{i,t}$ is the liquidity preference of firm i in period t, as a share of capital;
$k_{i,t-1}$ is stock of capital of firm i in period t-1;
$L_{i,t}$ is number of loans of firm i in period t;
am_{l} is the fixed amortization of of each loan j;

Firms, however, have liquidity preference and they might decide to keep an amount of deposits as liquid assets (if they are already positive, so the firm will not demand loans to acquire deposits and keep them as liquid assets), as a share of current stock of physical capital, before spending everything in new capital goods. A buffer of liquid assets is justified to counter unexpected results in following periods. Even though these retained deposits might earn interest to the firm, firms will not increase deposits accumulation for rentability reasons, but only for liquidity reasons[20]. Available internal funds for investment must discount the liquidity preference. Following Moreira (2010), this share of capital represents firm's liquidity preference, and it can evolve annually based profits trends and debt rate. If net profits are growing, indicating a positive perspective to the firm, and current debt rate is lower than the desired level, it might reduce the share of capital to be retained as liquid assets or, if net profits are decreasing, signalling possible future losses, and current debt rate is higher than maximum, it might increase its liquidity preference:

$$lp_{i,t} = \begin{cases} lp_{i,t-1} - \psi^{lp}_{i} & if \quad \frac{pr^{nt}_{i,t-1} - pr^{nt}_{i,t-1-\Lambda}}{pr^{nt}_{i,t-1-\Lambda}} > 0 \quad and \quad dr_{i,t-1} < dr^{max}_{i,t-1} \\ lp_{i,t-1} + \psi^{lp}_{i} & if \quad \frac{pr^{nt}_{i,t-1} - pr^{nt}_{i,t-1-\Lambda}}{pr^{nt}_{i,t-1-\Lambda}} < 0 \quad and \quad dr_{i,t-1} > dr^{max}_{i,t-1} \\ lp_{i,t-1} & otherwise \end{cases} \tag{3.5.11.2}$$

where
$lp_{i,t}$ is the liquidity preference of firm i in period t;
$lp_{i,t-1}$ is the liquidity preference of firm i in period t-1;
ψ^{lp}_{i} is the liquidity preference adjustment parameter of firm i;
$pr^{nt}_{i,t-1}$ is the net profits of firm i in period t-1;

[20]This could be incorporated to the model in a future research about firm's financialization.

$pr^{nt}_{i,t-1-\Lambda}$ is the net profits of firm i in period $t-1-\Lambda$;
$dr_{i,t-1}$ is the firm i debt rate in period t-1; and
$dr^{max}_{i,t-1}$ is the firm i maximum debt rate in period t-1.

At a given investment period, the firms' demand for new loans will be the difference between desired expenses and available internal funds. However, before effective capital goods demand, each firm is submitted to debt assessment by the banks. Each firm has a maximum debt rate, and if current debt rate is higher than maximum, the banks will not provide additional loans to that firm in the current period, if requested. If current debt rate is lower than maximum, the firm will be able to incur in new debt, demand new loans, if needed, only by the amount that would make the current debt rate reach the maximum. That represents effective credit rationing by the banks for each specific firm, and it is applied to both long and short-term loans, so even if it is not an investment period, the firm might not be able to access new loans to cover net losses:

$$l^{max}_{i,t} = dr^{max}_{i}(k_{i,t} + dep^{s}_{i,t}) - l^{s}_{i,t} \tag{3.5.11.3}$$

where
$l^{max}_{i,t}$ is the available loans for firm i in period t;
dr^{max}_{i} is the maximum debt rate of firm i;
$l^{s}_{i,t}$ is the stock of loans of firm i;
$k_{i,t}$ is the capital of firm i in period t; and
$dep^{s}_{i,t}$ is the stock of deposits of firm i in period t.

Also following the ideas of Moreira (2010), this maximum debt rate can evolve annually based profits trends. If net profits are in an increasing trajectory, the firm and the bank might accept a higher debt in relation to total capital, as such indicator signals future positive accumulation. However, if net profits are decreasing, this could indicate future problems to repay debt and so both the firm and the bank reduce their maximum indebtedness rate:

$$dr^{max}_{i,t} = \begin{cases} dr^{max}_{i,t-1} + \psi^{dr}_{i} & if \quad \frac{pr^{nt}_{i,t-1} - pr^{nt}_{i,t-1-\Lambda}}{pr^{nt}_{i,t-1-\Lambda}} > 0 \quad and \quad dr_{i,t-1} < dr^{max}_{i,t-1} \\ dr^{max}_{i,t-1} - \psi^{dr}_{i} & if \quad \frac{pr^{nt}_{i,t-1} - pr^{nt}_{i,t-1-\Lambda}}{pr^{nt}_{i,t-1-\Lambda}} < 0 \quad and \quad dr_{i,t-1} > dr^{max}_{i,t-1} \\ dr^{max}_{i,t-1} & otherwise \end{cases} \tag{3.5.11.4}$$

where

$dr_{i,t}^{max}$ is the maximum debt rate of firm i in period t;
$dr_{i,t-1}^{max}$ is the maximum debt rate of firm i in period t-1;
ψ_i^{dr} is the maximum debt rate adjustment parameter of firm i;
$pr_{i,t-1}^{nt}$ is the net profits of firm i in period t-1;
$pr_{i,t-1-\Lambda}^{nt}$ is the net profits of firm i in period $t-1-\Lambda$;
$dr_{i,t-1}$ is the firm i debt rate in period t-1; and
$dr_{i,t-1}^{max}$ is the firm i maximum debt rate in period t-1.

Firm's debt rate is the ratio between current stock of debt over firm's capital plus stock of deposits:

$$dr_{i,t} = \frac{l_{i,t}^s}{(k_{i,t} + dep_{i,t}^s)} \tag{3.5.11.5}$$

where
$dr_{i,t}$ is the current debt rate of firm i in period t;
$l_{i,t}^s$ is the stock of loans of firm i in period t;
$k_{i,t}$ is the capital of firm i in period t; and
$dep_{i,t}^s$ is the stock of deposits of firm i in period t.

The new loans will be the difference between desired expenses and available internal funds, limited by the maximum amount of loans of each firm. This new loan will have a fixed amortization, and the loan interest rate will be the firm specific interest rate in that period.

$$l_{i,t}^d = min(i_{i,t}^d - f_{i,t}^i, l_{i,t}^{max}) \tag{3.5.11.6}$$

where
$l_{i,t}^d$ is the desired demand for new loans of firm i in period t;
$i_{i,t}^d$ is the desired investment expenses of firm i in period t;
$f_{i,t}^i$ is the internal funds of firm i in period t; and
$l_{i,t}^{max}$ is the available loans for firm i in period t.

Additionally to firm-specific credit rationing, the banks control the total amount of liquidity, or the maximum amount of credit supply, as it can be seen in the next subsection, meaning that effective loans received by the firms might differ from the already specific-restricted demand for new loans. Now, each firm can compute its total amount of funds available for investment expenses, including its own available funds and the external funds provided by the banks:

$$f_{i,t} = f^i_{i,t} + l^*_{i,t} \tag{3.5.11.7}$$

where
$f_{i,t}$ is the total amount of funds available for firm i in period t;
$f^i_{i,t}$ is the internal funds of firm i in period t;
$l^*_{i,t}$ is the effective loans of firm i in period t.

The total amount of funds could be lower than the total desired expenses. If that is the case, firms prioritize expansion investment over replacement. If after effective investment expenses there are funds still available, firms can add them to their stock of deposits:

$$xi^*_{i,t} = min(xi^d_{i,t}, f_{i,t}) \tag{3.5.11.8}$$

where
$xi^*_{i,t}$ is the effective expansion investment expenses of firm i in period t;
$xi^d_{i,t}$ is the desired expansion investment expenses of firm i in period t; and
$f_{i,t}$ is the amount of funds available for firm i in period t.

$$ri^*_{i,t} = min(ri^d_{i,t}, (f_{i,t} - xi^*_{i,t})) \tag{3.5.11.9}$$

where
$ri^*_{i,t}$ is the effective replacement expenses of firm i in period t;
$ri^d_{i,t}$ is the desired replacement expenses of firm i in period t;
$f_{i,t}$ is the amount of funds available for firm i in period t; and
$xi^*_{i,t}$ is the effective expansion investment expenses of firm i in period t.

$$i^*_{i,t} = ri^*_{i,t} + xi^*_{i,t} \tag{3.5.11.10}$$

where
$i^*_{i,t}$ is the effective investment expenses of firm i in period t;
$xi^*_{i,t}$ is the effective expansion investment expenses of firm i in period t; and
$ri^*_{i,t}$ is the effective replacement expenses of firm i in period t.

$$i^r_{i,t} = \frac{i^*_{i,t}}{\overline{p}_{k,t}} \quad (3.5.11.11)$$

where
$i^r_{i,t}$ is the real effective investment (capital demand) of firm i in period t;
$\overline{p}_{k,t}$ is the average price of the capital goods sector k in period t; and
$i^*_{i,t}$ is the effective investment expenses of firm i in period t.

3.5.12 Banks' Supply of Credit and Credit Rationing

In a small advance in relation to Moreira (2010) and to the current version of the model, and in line with most of the models reviewed in the literature, we introduce a financial sector populated with possible several agents, banks. In an effort to make it as general as possible, we introduce banks in a very simplified manner.

The financial sector collects the demand for loans of all income classes and firms. Each bank, however, has a maximum amount of loans it can supply, defined by the minimum capital adequacy ratio, a regulatory rule, and a financial fragility sensitivity, similarly to Dosi et al. (2015). If no regulatory rule is set, and financial fragility is not considered, banks will have no limit to credit, representing a full endogenous-money system with accommodative banks. Even in that case, individual credit rationing still occurs as we already saw in the firms and classes specific debt assessment.

We assume that income classes are not subjected to credit rationing if total demand of loans are higher than bank's maximum loans, as an income class represents a collection of agents, households. Some of them can be individually constrained or not, but as a class, they are not constrained. Individual firms however can be constrained if total demand is higher than bank's maximum loans. If that is the case, the bank supplies to the first firm in a rank from lower debt rate to higher. Firms with higher debt rate might not receive any loan at all, even if they were able to receive it in their specific debt assessment and credit rationing. Following the same logic as the income classes, a productive sector as a whole cannot be constrained, so, before supplying individual loans to firms in the increasing debt rate order, the bank divides its possible loans to each sector proportionally to the sector demand, and then firms can be constrained inside the sector.

Similarly to Dosi et al. (2015), we introduce financial fragility aspects to banks total amount of credit. Their formulation is already an advance in relation to the other reviewed models, as banks can assume different postures and decisions regarding total amount of credit based individual conditions, whereas a formulation considering only a minimum capital adequacy rule does not take into account individual conditions of each bank. We also introduce an overall financial fragility sensitivity, showing that banks can assume different positions if the economy, as a whole, is in a more fragile financial position. Different sensitivity parameters indicate particular postures and decisions from specific banks. Therefore, the maximum amount of loans that a bank can supply is given by:

$$l_{b,t}^{max} = \frac{nw_{b,t-1}}{ca_t^{min} + \varphi_b^{dr} \cdot \overline{dr}_{t-1} + \varphi_b^{dfr} \cdot dfr_{b,t-1}} \tag{3.5.12.1}$$

where
$l_{b,t}^{max}$ is the maximum loans of bank b in period t;
$nw_{b,t}$ is the net worth of bank b in period $t-1$;
ca_t^{min} is the minimum capital ratio defined by regulatory rules in period t.
φ_b^{dr} is bank b sensitivity parameter to overall financial fragility;
φ_b^{dfr} is the bank b sensitivity parameter to its own default rate;
$\overline{dr}_{t-1}$ is the average debt rate of firms in the economy in period $t-1$; and
$dfr_{b,t-1}$ is the bank b accumulated defaulted loans rate in period t-1.

In each period, bank profits will be calculated as the difference between interest received on loans and public bonds, and interest paid on deposits. Defaulted loans are discounted from the bank's current profits. If current profits are negative, they are not distributed to income classes and might negatively impact bank's net worth, consequently affecting the bank's total amount of credit:

$$pr_{b,t} = re_{b,t} - ir_t^{dep} \cdot dep_{b,t-1}^{s} - def_{b,t} \tag{3.5.12.2}$$

where
$pr_{b,t}$ is the profits of bank b in period t;
$re_{b,t}$ is the revenue of bank b in period t;
ir_t^{dep} is the interest rate on deposits in period t;
$dep_{b,t-1}^{s}$ is the stock of deposits of bank b in period $t-1$; and
$def_{b,t}$ is the defaulted loans of bank b in period t.

Bank revenue depends on interest received from its clients, firms and income classes, plus interest received on stock of public bonds:

$$re_{b,t} = \sum_{i=1}^{C_{b,t}} \sum_{l=1}^{L_{i,t}} (ir_{l,i} \cdot d_{l,i,t}) + ms_{b,t} \sum_{h=1}^{H} \sum_{l=1}^{L_{l,t}} (ir_{l,h} \cdot d_{l,h,t}) + ms_{b,t}(ir_{bc,t} \cdot b^s_{g,t-1}) \quad (3.5.12.3)$$

where
$re_{b,t}$ is the revenue of bank b in period t;
$C_{b,t}$ is the number of firms which are clients of bank b in period t;
$L_{i,t}$ is the number of loans the firm i has in period t;
$ir_{l,i}$ is the interest rate of the loan l of firm i, fixed when the loan was taken;
$d_{l,i,t}$ is current debt of the loan l of firm i in period t;
$ms_{b,t}$ is the market share of bank b in period t;
H is the number of income classes;
$L_{h,t}$ is the number of loans the class h has in period t;
$ir_{l,h}$ is the interest rate of the loan l of class h, fixed when the loan was taken;
$d_{l,h,t}$ is current debt of the loan l of class h in period t;
$ir_{bc,t}$ is the basic interest rate set by the central bank in period t; and
$b^s_{g,t-1}$ is stock of government debt (bonds) in period t-1.

Banks, however, do not distribute a fixed proportion of profits as dividends. The amount of retained profits, or own capital, is a strategic variable for the bank. There is a minimum amount the bank must have, set by the regulatory rule, plus any perception the bank has in relation to its own fragility, and/or the overall financial fragility of the economy, but the bank cannot simply retain all the profits as excess liquidity is undesirable. Therefore, banks will retain profits only if they are positive, and only in the amount to meet the expected credit demand of the next period given the regulatory rule, sensitivities and the current stock of own capital:

$$pr^{ret}_{b,t} = \min((pr_{b,t}), (l^{s,e}_{b,t}(ca^{min}_t + \varphi^{dr}_b \cdot \overline{dr}_t + \varphi^{dfr}_b \cdot dfr_{b,t}) - nw_{b,t-1})) \quad (3.5.12.4)$$

where
$pr^{ret}_{b,t}$ is the retained profits of bank b in period t;
$l^{s,e}_{b,t}$ is the expected stock of loans bank b in period t;
ca^{min}_t is the minimum capital ratio defined by regulatory rules in period t.
φ^{dr}_b is bank b sensitivity parameter to overall financial fragility;
φ^{dfr}_b is the bank b sensitivity parameter to its own default rate;

$\overline{dr}_t$ is the average debt rate of firms in the economy in period t;
$dfr_{b,t}$ is the accumulated default ratio of bank b in period t; and
$nw_{b,t-1}$ is the net worth of bank b in period $t-1$;

The net worth of the bank is determined by its accumulated retained profits. In each period, the bank distributes a share of current profits to income classes as dividends, if current profits are positive, and the bank retains the rest as its own capital:

$$nw_{b,t} = nw_{b,t-1} + pr^{ret}_{b,t} \tag{3.5.12.5}$$

where
$nw_{b,t}$ is net worth of bank b in period t;
$nw_{b,t-1}$ is net worth of bank b in period t-1; and
$pr^{ret}_{b,t}$ is the retained profits of bank b in period t.

3.5.13 Competition in the Financial Sector

The financial sector collects households' and firms' demand for credit. However, in our model households are grouped in income classes. Our agents, the income classes, represent a collection of households, and therefore we cannot tie specific households to specific banks in a client-bank relationship as we can do it for the firms. Income classes' demand for credit is distributed by banks' market share, following a replicator dynamics, similarly to the productive sectors' demand distribution currently implemented in the model. There is no fixed income class-bank relationship, as the replicator dynamics abstractly represents the possibility for each implicit household changing banks in each time step. Since income classes incur only in short-term loans, and all short-term loans have the same base interest rate and same amortization period of one year, this assumption is more plausible. Each bank will collect a share of total income classes' demand for loans equal to its market share.

For the sake of simplicity, firms choose a random bank, and the firm-bank relationship will not change for the rest of the simulation run or until the firm quits the market eventually. Therefore, each bank will only collect demand for loans from firms which are the bank's specific clients. The probability of choosing a bank is weighted by its market share. For initial firms, when banks are homogeneous, the probability is the same, but in subsequent time steps, whenever a new firm enters the market, the probability is weighted by current market shares. Although firms cannot change their firm-bank relationship during their existence, this formulation allows banks' number of clients to be relatively proportional and endogenous to their market-share, but still with a stochastic component.

$$o_{b,t} = ms_{b,t} \sum_{h=1}^{H} l^d_{h,t} + \sum_{i=1}^{C_{b,t}} l^d_{i,t} \tag{3.5.13.1}$$

where
$o_{b,t}$ is the credit orders (demand) of bank b in period t;
$ms_{b,t}$ is the market share of bank b in period t;
H is the number of income classes;
$l^d_{h,t}$ is the demand for loans of income class h in period t;
$C_{b,t}$ is the number of clients (firms) of bank b in period t; and
$l^d_{i,t}$ is the demand for loans of firm i, client of bank b, in period t.

Banks' market-shares evolves based on the difference between bank's competitiveness index and the financial sector average competitiveness, similarly to the productive sectors.

$$ms_{b,t} = ms_{b,t-1}\left(1 + \mu_{fs}\left(\frac{co_{b,t} - \overline{co}_{fs,t}}{\overline{co}_{fs,t}}\right)\right) \tag{3.5.13.2}$$

where
$ms_{b,t}$ is the market share of bank b in period t;
$ms_{b,t-1}$ is the market share of bank b in period t-1;
μ_{fs} is market share adjustment parameter of the financial sector;
$co_{b,t}$ is the competitiveness of bank b in period t; and
$\overline{co}_{fs,t}$ is the average competitiveness of the financial sector in period t.

Bank's competitiveness depends on bank's default loans over total stock of loans. Even though defaulted loans are not directly bank's fault, a bank with high default rate is usually seen as more problematic, and it might affect its competitiveness and the chance to receive new clients. The bank is subjected to some random shocks, as it will be affected if one firm goes bankrupt and default on its loans, but the probability of that firm being that specific bank's client is random but weighted by market-shares. Therefore, the biggest the bank is, in terms of number of clients, the highest the probability of defaults in absolute terms (not necessarily in relation to total stock of loans).

Bank's competitiveness also depends negatively on bank's overall credit rationing, which in turn basically depends on bank's specific financial fragility sensitivity and bank's net worth, given the regulatory capital adequacy rule, as already seen. The intuition is that a bank which constantly denies credit to its clients will be seen as a less competitive bank and will have a lower chance to receive new clients, new firms entering the market or household's demanding short-term loans. This formulation reinforces the empirical evidence that banks compete by rationing credit to their clients. We also allow the bank specific short-term and long-term interest rates to negatively affect its competitiveness, but the respective elasticity tends to be low or zero[21].

$$co_{b,t} = \frac{(1 - dfr_{b,t})^{\epsilon^{dfr}_{fs}} \cdot (1 - cr_{b,t})^{\epsilon^{cr}_{fs}}}{(ir^{st}_{b,t})^{\epsilon^{st}_{fs}} \cdot (ir^{lt}_{b,t})^{\epsilon^{lt}_{fs}}} \tag{3.5.13.3}$$

where
$co_{b,t}$ is the competitiveness of bank b in period t;
$dfr_{b,t}$ is the default ratio of bank b in period t;
$cr_{b,t}$ is the credit rationing of bank b in period t;
$ir^{st}_{b,t}$ is the short-term interest rate of bank b in period t;
$ir^{lt}_{b,t}$ is the long-term interest rate of bank b in period t; and
ϵ is the elasticity for each respective component.

Given this functional form, in a baseline scenario with no competition on interest rates, meaning interest elasticities equal to zero, the denominator will be one. Since the demand met ratio and default ratio are always ratios between 0 and 1, the competitiveness index of the bank will be a number between zero and 1, where 1 means the bank is the most competitive as possible, with no defaults or credit rationing.

The fixed firm-bank relationships create the possibility of contagion effect. Let us say a random firm goes bankrupt and default on its loans. The firm's bank net worth will be negatively impacted, and that bank's maximum loans will reduce, assuming everything else constant. If it reduces to a level low enough to impose credit rationing to other clients, other firms might not be able to finance necessary investment and might incur in negative profits in the medium term. Additionally, credit rationing affects competitiveness and market share, leading to possible less clients if new firms enter the market.

Finally, banks define their desired spreads based on their market-share evolution:

$$spr^{st,d}_{b,t} = spr^{st,d}_{b,t-1}\left(1 + \psi^{st}_{b} \cdot \left(\frac{ms_{b,t-1} - ms_{b,t-2}}{ms_{b,t-2}}\right)\right) \tag{3.5.13.4}$$

[21]However, this possibility allows us to study different banking structures, and maybe test the contrafactual of the empirical evidence.

where
$spr^{st,d}$ is the desired short-term spread of bank b in period t;
$spr^{st,d}_{b,t-1}$ is the desired short-term spread of bank b in period t-1;
ψ^{st}_{b} is the short-term spread adjustment of bank b;
$ms_{b,t-1}$ is the market share of bank b in period t-1; and
$ms_{b,t-2}$ is the market share of bank b in period t-2.

$$spr^{lt,d}_{b,t} = spr^{lt,d}_{b,t-1}\left(1 + \psi^{lt}_{b} \cdot \left(\frac{ms_{b,t-1} - ms_{b,t-2}}{ms_{b,t-2}}\right)\right) \tag{3.5.13.5}$$

where
$spr^{lt,d}$ is the desired long-term spread of bank b in period t;
$spr^{lt,d}_{b,t-1}$ is the desired long-term spread of bank b in period t-1;
ψ^{lt}_{b} is the long-term spread adjustment of bank b;
$ms_{b,t-1}$ is the market share of bank b in period t-1; and
$ms_{b,t-2}$ is the market share of bank b in period t-2.

3.5.14 Income Generation and Appropriation

Total income is calculated summing up total profits, total wages and total indirect taxes collected by the government. The result is the model's GDP:

$$GDP_t = PR_t + WG_t + \sum_{i=1}^{F}(tr_i \cdot re_{i,t}) \tag{3.5.14.1}$$

where
GDP_t is the nominal GDP in period t;
PR_t is the aggregate profits in period t;
WG_t is the aggregate wages in period t;
F is the total number of firms;
tr_i is the tax rate of firm i; and
$re_{i,t}$ is the revenue of firm i in period t.

Total profits are the sum of net profits of all firms and banks:

$$PR_t = \sum_{j=1}^{F} pr^{nt}_{i,t} + \sum_{b=1}^{B} pr_{b,t} \tag{3.5.14.2}$$

where
PR_t is the aggregate profits in period t;
F is the number of firms;
$pr_{i,t}^{nt}$ is the net profits of firm i in period t;
B is the number of banks;
$pr_{b,t}$ is the profits of bank b in period t;

$$PR_t^{dis} = \sum_{j=1}^{F} pr_{i,t}^{dis} + \sum_{b=1}^{B} pr_{b,t}^{dis} \tag{3.5.14.3}$$

where
PR_t^{dis} is the aggregate distributed profits in period t;
F is the number of firms;
$pr_{i,t}^{dis}$ is the distributed profits of firm i in period t;
B is the number of banks;
$pr_{b,t}^{dis}$ is the distributed profits of bank b in period t;

Total wages are the sum of wages of all firms plus government wages. Wages paid by each firm depend on nominal unit wage and firm's employment, defined as firm's effective production over firm's average labor productivity, plus R&D expenses, which are paid to workers in the R&D division of the firm[22]:

$$WG_t = \sum_{i=1}^{F} (wr_{i,t} \cdot n_{i,t} + rnd_{i,t}) + w_{g,t}^{*} \tag{3.5.14.4}$$

where
WG_t is the aggregate wages in period t;
F is the total number of firms;
$wr_{i,t}$ is the wage rate of firm i in time period t;
$n_{i,t}$ is the employment of firm i in time period t;
$rnd_{i,t}$ is the R&D expenses of firm i in period t;
$w_{g,t}^{*}$ is the government effective wages in period t.

Total income is appropriated by each income class based on its respective wage share and profit share parameters. Class disposable income already discounts paid income taxes. Unemployment benefits are distributed by wage shares and are never

[22]In the consolidated version, R&D expenses were not distributed as wages.

taxed:

$$y_{h,t}^{dp} = (1 - tr_h)(\omega_h WG_t + \pi_h PR_t^{dis}) + \omega_h ub_t \qquad (3.5.14.5)$$

where
$y_{h,t}^{dp}$ is net income of income class h in period t;
tr_h is direct tax rate of class h;
ω_h is the wage appropriation of income class h;
WG_t is the aggregate wages in period t;
ub_t is the total unemployment benefits in period t;
π_h is the profit appropriation of income class h; and
PR_t^{dis} is the aggregate distributed profits in period t.

3.6 Firms' Entry and Exit

One of the most common critique on AB models is possible stock and flow inconsistencies in the entry and exit of firms, as already highlighted in Chapter 2 and therefore, a positive aspect of the AB-SFC agenda is the attention given to that possible problem. In fact, we have found some inconsistencies in firm's entry and exit regarding the stock of capital, stock of deposits and loans.

In our model, firms might exit the market due to two reasons: (i) low near-zero market share and (ii) high debt rate (bankruptcy). In the second case, there was a possibility of the bankrupt firm be bought by another owner, if sectoral demand was increasing, and firm's debts were renegotiated. In that case, the firm would continue to exist without any problem in the stocks accounting. However, in any other case, if the firm exited the market due to low market share or due to high indebtedness, but without being bought by another firm, the firm would simply disappear, all the stock of capital, debt and deposits would be lost. So, to hopefuly solve this problem, we introduced some modifications to the exit of firms.

In the current financial version, firms might exit the market due to the same two reasons. However, before exiting, some payments and transfers should be done. We have the following possibilities:

1. Exited firm has a higher stock of deposits than stock of loans.
2. Exited firm has a lower stock of deposits than stock of loans.
3. Exited firm has no stock of deposits and a positive stock of loans.

4. Exited firm has no stock of loans and a positive stock of deposits.

In case 1, the firm would pay all the stock of debt with current stock of deposits. The stock of deposits left is then distributed to income classes. In case 2, the firm would pay the possible amount of debt with current stock of deposits, there would be no deposits left to be distributed to income classes, and the amount of debt unpaid would be considered in default, reducing the financial sector's profit. In case 3, all stock of debt is considered in default, and in case 4 all stock of deposits is distributed to income classes. Whenever deposits are distributed to income classes, it is done by following profit shares, the same way profits are distributed by firms and banks.

Capital stocks, however, are not adjusted in that manner. We assume the bank does not use physical capital as collateral, and it is not interested in collecting exited firms' stock of capital to resale it thereafter. Instead, we collect all exited stock of capital in a variable called "Sector's Available Capitals", to be used for new firms. For simplicity, we assume that capitals do not depreciate physically while in this available stock, as they are not employed in any firm, and they are not in use. Therefore, no capital goods are physically lost.

Regarding entry, the previous version of the model had a limited entry as new firms could only enter if other firms exited the market due to high indebtedness. Therefore, the initial number of firms in each sector was in fact a ceiling. Now, we allow one possible entry in each time period, regardless of whether the firm has exited, but the entry condition of a growing real demand in the sector is still needed to be met. So, if sectoral demand is not growing, the possible firm will not enter. When a firm enters the sector, we assume that it follows all properties and characteristics of the average firm of the sector, more specifically, the properties of the firm with the average market share, except for two elements: (i) the new firm productive capacity is limited by the available productive capacity in the sector, even though the required productive capacity to meet the average firm characteristics is higher, and (ii) stock of debt, as we assume the firms incur in debt to buy this initial productive capacity[23]. This initial loan is considered as a long-term loan, with fixed amortization equivalent to the capital goods lifetime and fixed interest rate, in that special case, the base long-term interest rate of the financial sector, without applying firm-specific risk premium, since there was no previous debt. We also allow new firms to forcedly survive for two investment periods, meaning that new firms will not be eliminated due to low market-share or high indebtedness for two investment periods, giving them a chance to invest and buy the necessary capital goods to reach

[23]Other sources of initial capital financing, like income classes stock of deposits, or a combination of both, could be also possible, but we assume that all new firms start with debt for simplicity.

the average firm productive capacity in case of limited available productive capacity in the sector.

That way we solve all possible stock-flow inconsistencies in entry and exit, and we were also able to reach the same results without the maximum number of firms. In fact, in this new version, we have an variable number of firms in every sector, but still with concentration trends, capturing a more dynamic entry and exit, and potential entrepreneurs. Not only that, but a more dynamic entry impacts the financial sector, as when a firm enters the market it must choose a bank to form a fixed bank-firm relationship, and the probability of choosing each bank is weighted by the banks' market share, although still stochastic. Therefore, we linked the financial and the real sides dynamics, as the SFC approach highlights. A more dynamic productive sector, in terms of entry and exit, might impact the financial sector from the exit, bankruptcy and defaulted loans point of view, leading to possible contagious effects and even credit crisis, and from the entry, bank competition and number of clients point of view, leading to possible different dynamics of concentration in the financial sector, and consequently different interest rates structures. These relationships between real and financial dynamics are virtues of our model, in comparison with DSGE models, for example, that failed to account those interconnections.

3.7 Discussion

In this chapter we have presented a new version of the MMM model, consolidated by Possas and Dweck (2004) and Dweck (2006). This new version introduces a detailed financial sector, in line with the minimum literature structure found in the review of the AB-SFC integration agenda, but considering the characteristic already present in the original model. We have done an effort to describe in detail, and in several different forms, not only the modification implemented here, but also the whole structure of the model, in an attempt to make the complex relationships, and decisions it represents as clear as possible. We also adopt the same notation used in the AB-SFC review to facilitate a comparative analysis. To make this comparison even deeper, we also present the model (Appendix A) following the classification of a robust literature review presented by Dawid and Gatti (2018).

One specific topic was also stressed here: the stock-flow consistency of entry and exit of firms, a relevant point of critique to AB models which would possibly benefit from the SFC approach. It is a relevant point of the AB-SFC integration agenda, a research agenda in which we have identified our model as one of its predecessors, so discussing it would bring the model to the frontline of the agenda.

Finally, this version of model, although considerably complex, was reimplemented in a generalized, detailed, and user-friendly way. The idea is to try to reduce the entry costs, which is another point of critique both to the AB and the SFC literature, allowing more people to use this powerful tool to investigate and analyze several research questions, including the one that motivates this thesis. That is why several variables, parameters, equations and structures were implemented and described here, but they will not be addressed in this thesis. Instead, the implementation effort of this version revealed several important research topics to be studied in future works after this thesis.

In the next chapter we will present the calibration strategy, the baseline results of the model and some experiments on monetary policy.

Chapter 4

Model Results and Experiments

In this chapter we present the baseline result and some experiments based on the model just discussed. In addition, we discuss a new calibration strategy, following Stock-Flow Consistency rules to avoid any initial unbalance and undesirable trend. The entire parametric space for the baseline simulation is also presented herein.

The model is fully written in LSD code (Version 7.2)[1]. LSD (Laboratory for Simulation Development) is a language and a platform to write simulation models. It is simple to use, a stand-alone program that even non-expert computer users can use to run and to test the results from simulation models. LSD is copyrighted by Marco Valente and Marcelo C. Pereira (version 7.x additions) but it is freely distributed according to the GNU General Public License. The version presented here is included in the software as one of the example models, and it can be found in https://github.com/thttnn/MMM_v.3.

We show that the model is empirically validated as it replicates a considerable list of stylized facts on growth, cycles, financial facts and even micro aspects, thus showing how robust the model is. With the model calibrated and validated, we perform several policy experiments. Different inflation targets are tested, and a sensitivity analysis procedure is implemented to better understand the structural factors which influence inflation. The transmission mechanisms of monetary policy in the model are discussed and tested in an attempt to identify the intensity of each channel. Finally, the monetary policy interaction with fiscal and exchange rate policies is stressed when we test some different policy combinations and check how they could perform better than the NCM policy recommendation in terms of economic stabilization. Alternative monetary policy rules are also subject of experiments.

[1]The software can be downloaded in https://github.com/marcov64/Lsd

4.1 Baseline Simulation

4.1.1 Calibration

Any computational simulation model, given the model specification and equations, presents only two causes of variability in its outputs, the results: (i) changes in the inputs (initial values and parameters), and (ii) stochastic variability. As our model has a few stochastic components, which are the innovation and the imitation success of the firms, the sectoral technological opportunities distribution, the random bank selection when a firm enters the sector, and the random external income and prices growth, changes in initial values and parameters are the main cause of result variety. Therefore, the model, as any other simulation model, must be very well calibrated.

As highlighted by Fagiolo et al. (2019), sometimes it is hard to isolate these two methodological procedures: calibration and validation. Let us try to define them briefly, using some concepts better detailed by those authors. A model is an attempt to approximate the real world data generating process, it is a virtual data generating process in which, after the model specification and equations are defined by the theory, inputed data are transformed, stochastically, non-ergodically, and non-linearly in outputed data. Model inputs are generally initial conditions and parameters, although specifications and functional forms could also be understood as inputs. Model outputs are the time series generated by the simulation process. Calibration is the process of defining input values, and there are several strategies for that. Validation is the process of confirming if the model is a good approximation of the unknown real world data generating process. Both procedures can be the two sides of the same coin, as a calibration strategy is not good if the model is not validated while the model validation strongly depends on the calibration.

There is an extensive debate between qualitative calibration methods, where the model must be calibrated to generate qualitative or general results, and quantitative calibration methods proposed by DSGE models, for example, where parameters and initial conditions should be set based on real empirical data. This quantitative method is possible only if a huge dataset of empirical data is available and it is used, in most cases, for forecasting. In small-scale models or stylized models, the use of real data is exceedingly difficult, especially for some parameters which adjust economic decisions and behaviors in the model, which are impossible to get empirical data. Lastly, if the goal of the model is to explain economic causality and economic properties in general, without historical or institutional particularities, this quantitative approach can in fact bias the model, and it might not be desired. That is why, in the previous version of the model, initial conditions and parameters were defined by a qualitative method called indirect calibration (Dweck 2006, p.136). This method consists of the following steps:

1. Identification of the stylized facts which the model is supposed to explain or replicate.

2. Use every available information on parameters with real economic meaning in order to reduce the parametric space to be tested.

3. Set an initial combination of parameters and initial values based on the reduced parametric space and *educated guesses*.

4. Run the model and check if the current combination replicates the desired stylized facts.

5. If not, other rounds of *educated guesses* and simulation runs should be done in order to reduce parametric space even more, until the model is able to replicate the stylized facts.

The indirect calibration strategy scrambles the two methodological processes into one, as the model is empirically validated if a set of stylized facts is replicated, and the model is not calibrated until it is validated, by repeating rounds of educated guesses. This methodology is computational and time costly, and it might contain some degree of arbitrariness, which is sometimes a critique to this type of models. Calibration strategies are a possible vast field to be explored in the AB literature, since as pointed out by Caiani et al. (2016), many articles do not explain or specify the calibration procedure. That is why, with some insights of the SFC literature, those authors propose a calibration method, also used by Martins (2018), reinforcing a possible advantage of the AB-SFC combination. This new strategy, to be implemented here with some modifications, relies on initial symmetry and homogeneity, a steady-state configuration and stock-flow norms to determine initial values. By constraining and aggregating the model, the modeler is in power of only a small set of parameters, whereas many others are determined by the steady-state condition and stock-flow consistency requirements. This is the key to reduce arbitrariness, and to allow the robust sensitivity analysis on a reduced parametric space.

Even if most of the variability of our model occurs due to changes in parameters and initial conditions, it is not desired that model inputs represent the main cause of the results *per se*. The results in fact should be explained by the theory behind the model specification and the complex interactions between agents during the simulation. Therefore, a good practice is to calibrate the model in order to avoid any initial trend. That is why some parameters and initial values are determined endogenously, based on the small sets of parameters which define the calibration state. For previous versions of our model, calibration was done in a separate spreadsheet file (Dweck 2006, footnote 256). In the current version presented here, we incorporated this initial calculation to the code itself, in the same file. This way, users can change any parameter in the reduced controllable subset, and the code itself recalculates the initial conditions and the endogenous parameters before the simulation run starts. But some hypotheses had to be made. Let us indeed present here the initial calibration procedure and the hypothesis in detail.

Calibration Hypothesis

As we would like our model to replicate general dynamic properties and regularities, we do not want it to begin in a specific condition. So, we should set our initial configuration as much general as possible. For example, we do not want any firm to start already with a higher market share than others within a certain sector[2]. So, the first hypothesis we made is the homogeneity assumption that all firms start the same way, with the same market share, same productivity, same price, same costs. Firms' differentiation, competition and selection will be generated endogenously during the simulation runs. Therefore:

Hypothesis 1 *All firms start the same way in terms of prices, costs, mark-up, productivity, quality, and market share.*

Corollary 1.1 *All initial sectorial averages, maximums, and minimums are equal to the initial firm value.*

Corollary 1.2 *If all firms start with the same market-share, the initial market shares of each firm are equal to the inverse number of firms in each sector.*

Because of Corollary 1.1 we can simplify the calibration to sectoral level. To be clear, we can define an initial quality, for example, for each sector, and this value will be the same for each firm in the sector. Additionally, sectoral averages and maximums will also be that same value. This reduces the number of parameters to the number of sectors in the current specification, instead of having one parameter for each firm. The endogenous calculations are also simplified, as we are computing a more aggregate level of the model.

The most important effect of the initial configuration is the impact of past variables in present variables, especially by expectations. As an example, firms define their production based on expected demand, which is in turn calculated based on past effective demand and past growth. So, the lagged values of demand we input will affect firms' decisions to produce. As we would like the trends and trajectories, desirably endogenous growth and fluctuations, to be generated by the simulation process and not by the initial values, we stipulate the following:

[2]This could be desirable in a specific analysis, for example, testing different economic policies under certain sectoral structures, but that is not our focus now.

Hypothesis 2 *No past growth.*

Corollary 2.1 *Expected demand is equal to current demand.*

Corollary 2.2 *No investment to expand productive capacity initially.*

Corollary 2.3 *Demand equals production that equals sales. No initial change in inventories. No initial delivery delays.*

By Hypothesis 2, the initial configuration is a non-growth steady state, but it will not last even one time step, as the mechanisms which generate dynamics in the model will start to trigger from the first time step and so on. This could in fact generate some strong values at the very beginning, as the economy will rapidly change from the non-growth steady state to endogenous growth trajectories, but we will discard the first time steps in our analysis to account that problem, which is a common good practice in the AB literature. It also implies that expected demand is equal to current demand for all lagged periods, so there are no past errors in expectations, meaning that demand equals production that equals sales. There are no initial changes in inventories, no initial delivery delay, and no initial investment to expand productive capacity, effectively reducing the number of variables we must endogenously calculate their lagged values.

We assume that both exogenous blocks start balanced, so government total expenses, including interest payment, must be equal to total taxes (determined endogenously) and total exports plus net capital flows are equal to total imports (determined endogenously). The initial stock of government debt and of international reserves are calculated as ratios (exogenous parameters) of GDP. Given the initial Central Bank interest rate and the external interest rate, both exogenous parameters, we know the initial amount of net capital flows, and therefore the total imports. Similarly, given the initial Central Bank interest rate and the initial stock of government debt, we know the initial amount of interest payment, and so we can calculate the initial total taxes.

Hypothesis 3 *Both the Government and the External Sector start balanced.*

Corollary 3.1 *Total taxes must be equal to government expenses, including interest payment.*

Corollary 3.2 *Total Imports must be equal to total exports plus net capital flows.*

Appendix B explains in detail how each variable is calculated in the calibration, identifying the endogenous variables and the exogenous parameters. The calculations follow the same equations already presented under our specific hypothesis.

4.1.2 Parametric Space

The calibration strategy just presented here not only assures stock-flow consistency from the beginning, but also reduces the number of parameters and initial values which should be defined by the user. Even so, as it is a medium-scale model, the parametric space is still large. We present here the values for the model's parameters. There are five types of parameters: initialization, structural, endogenous, free and policy. To clarify:

- **Initialization parameters** (I): parameters which are used only in the initialization process, usually defining initial proportions and the sacle of the model. Once they are used to endogenous calculate other parameters and lagged values, their influence on the model is finished. Example: initial share of investment on government expenses.

- **Structural parameters** (S): parameters which are used for initialization and affect calculations during the simulation runs. They influence the initial scale and structure of the model and continue to influence agents' decisions over the course of the simulations. Example: sectoral input technical coefficients.

- **Endogenous parameters** (E): calculated during the initialization and calibration process, based on initialization and structural parameters, and they influence the simulation runs afterwards. Example: sectoral profits distribution rate.

- **Free parameters** (F): parameters that do not influence the initialization and calibration process but affect the simulation results, usually defining how variables are endogenously adjusted or grow. Example: sectoral productivity technological opportunities.

- **Policy parameters** (P): usually free parameters which can be subjected to direct change and they represent some policymaking decision. Example: Central Bank's inflation sensitivity.

Table 4.1 shows the entire parametric space for the baseline results to be presented. Parameters are presented by their notation, their description and their type, as listed above. The values are then showed for each instance of the current object.

Table 4.1: MMM Model Parametric Space - Baseline Values

Notation	**Description**	**Type**	**Instance**		
			1	**2**	**3**
Country Parameters					

Λ	Annual frequency	S	4	-	-
$\Theta_{k,0}$	Initial private investment share of GDP	I	0.1	-	-
$\Theta_{x,0}$	Initial exports share of GDP	I	0.1	-	-
$\Theta_{g,0}$	Initial government share of GDP	I	0.2	-	-
Government Parameters					
$\Phi_{c,0}$	Initial consumption share of Gov. Expenses	I	0	-	-
$\Phi_{k,0}$	Initial investment share of Gov. Expenses	I	0	-	-
$\Phi_{in,0}$	Initial input share of Gov. Expenses	I	0	-	-
$dr_{g,0}$	Initial government debt to GDP ratio	I	0.5	-	-
γ_g	Government expectational parameter	F	1	-	-
ubr	Unemployment benefit rate	P	0.5	-	-
dr_g^{max}	Maximum government debt rate	P	0.7	-	-
dr_g^{min}	Minimum government debt rate	P	0.3	-	-
st^{max}	Maximum government surplus target	P	0.1	-	-
st^{min}	Minimum government surplus target	P	-0.1	-	-
ψ^{st}	Primary surplus target adjustment	P	0.001	-	-
gr_g^d	Government desired real growth	P	0.003	-	-
External Sector Parameters					
er_0	Initial exchange rate	I	1	-	-
er^{max}	Maximum exchange rate	P	5	-	-
er^{min}	Minimum exchange rate	P	0.001	-	-
ψ^{er}	Exchange rate adjustment	F	1	-	-
Δy^x	External income real growth	F	0.0025	-	-
ir_x	External interest rate	S	0.005	-	-
υ_x	Capital flows scale proportion of GDP	S	50	-	-
$\eta_{x,0}$	Initial external income proportion of GDP	I	1	-	-
$\nu_{x,0}$	Initial international reserves proportion of GDP	I	0	-	-
Sector Parameters					
ψ_j^{bg}	Bargain power adjustment of sector j	F	0.01	0.01	0.01
Υ_j	Capital lifetime of sector j	S	40	40	40
β_j	Capital-output ratio of sector j	S	1	1	1
μ_j	Market share adjustment of sector j	F	1	1	1
ψ_j^{dr}	Debt rate adjustment of sector j	F	0	0	0
pcu_j^d	Desired degree of capacity utilization of sector j	S	0.89	0.81	0.9
σ_j	Desired inventories proportion of sector j	S	0.1	0.1	0.1
ms_j^d	Desired market share of sector j	E	0.02	0.05	0.033
ϵ_j^{dd}	Delivery delay elasticity of sector j	F	0.25	0.25	0.25
ϵ_j^q	Price elasticity of sector j	F	1	1	1
ϵ_j^q	Quality elasticity of sector j	F	0.5	0.5	0.5
γ_j	Expectations parameter of sector j	F	0.3	0.3	0.3
ε_j	Exports coefficient of sector j	E	0.97	0.48	1.29
ϵ_j^{px}	Exports price elasticity of sector j	F	0.5	0.5	0.5
ϵ_j^{yx}	Exports income elasticity of sector j	S	0.5	0.5	0.5
$\epsilon_j^{p,in}$	Imported inputs price elasticity of sector j	F	0	0	0
ϑ_j	External price competitiveness of sector j	F	0	0	0
Δp_j^x	External price growth of sector j	F	0.005	0.005	0.005

sd^p_j	External price standard deviation of sector j	F	0.01	0.01	0.01
ξ^{fc}_j	Financial costs passthrough of sector j	F	1	1	1
tr_j	Indirect tax rate of sector j	P	0.1	0.1	0.1
$dr_{j,0}$	Initial debt rate of sector j	I	0.4	0.4	0.4
$\Xi_{j,0}$	Initial exports share of sector j	I	0.3	0.3	0.4
$p^x_{j,0}$	Initial external price of sector j	E	1	2	1
$lp_{j,0}$	Initial liquidity preference of sector j	I	0.05	0.05	0.05
$p_{j,0}$	Initial price of sector j	I	1	2	1
$\phi_{j,0}$	Initial productivity of sector j	I	1	1	1
$\rho_{j,0}$	Initial profit rate of sector j	I	0.3	0.6	0.3
$q_{j,0}$	Initial quality of sector j	I	1	1	1
$\iota^{in}_{j,0}$	Initial propensity to import inputs of sector j	I	0.05	0.05	0.05
α_j	Input technical coefficient of sector j	S	0.4	0.4	0.4
Γ_j	Investment frequency of sector j	S	4	4	4
ψ^{lp}_j	Liquidity preference adjustment of sector j	F	0	0	0
ψ^{mk}_j	Mark-up adjustment of sector j	F	0.001	0.001	0.001
$F_{j,0}$	Initial number of firms in sector j	I	100	40	60
$\xi^p_j j, 0$	Initial inflation passthrough of sector j	F	0.8	0.8	0.8
$\xi^{phi}_{j,0}$	Initial productivity of sector j	F	0.8	0.8	0.8
pb_j	Payback period of sector j	F	20	20	20
δ_j	Profits distribution rate of sector j	E	0.81	0.53	0.87
λ_j	R&D revenue proportion of sector j	S	0.05	0.05	0.05
sd^ϕ_j	Std. dev. of productivity innovation of sector j	F	0.01	0.01	0.01
sd^q_j	Std. dev. of quality innovation of sector j	F	0.01	0.01	0.01
θ_j	Pricing strategy weight of sector j	F	0.5	0.5	0.5
θ^x_j	External price weight of sector j	F	1	1	1
opp^ϕ_j	Productivity technological opportunities sector j	F	0.0025	0.0025	0.0025
opp^q_j	Quality technological opportunities sector j	F	0.0025	0.0025	0.0025
$wr_{j,0}$	Initial wage rate sector j	E	0.06	0.64	0.06
Class Parameters					
φ^a_h	Autonomous consumption sensitivity of class h	F	1	0.5	0.1
tr_h	Tax rate of class h	E	0.1	0.1	0.1
ϵ^p_h	Imports price elasticity of class h	F	0.5	0.7	0.9
ζ_h	Propensity to consume of class h	S	0.5	0.8	1
$\nu_{h,0}$	Initial propensity to import of class h	E	0.32	0.1	0.04
ω_h	Wage appropriation of class h	S	0.1	0.4	0.5
π_h	Profit appropriation of class h	S	0.5	0.4	0.1
$dr^{max}_{h,0}$	Initial max debt rate of class h	I	1	1	1
$lp_{h,0}$	Initial liquidity preference of class h	I	0	0	0
ψ^{dr}_h	Max debt rate adjustment of class h	F	0	0	0
ψ^{lp}_h	Liquidity preference adjustment of class h	F	0	0	0
Financial Sector Parameters					
$\epsilon^{dfr_{fs}}$	Default elasticity of the fs.	F	0	-	-
ϵ^{lt}_{fs}	Long-term interest elasticity of the fs.	F	0	-	-
ϵ^{st}_{fs}	Short-term interest elasticity of the fs.	F	0	-	-
ϵ^{cr}_{fs}	Credit rationing elasticity of the fs.	F	0	-	-
γ_{fs}	Expectational parameter of the fs.	F	0.3	-	-

$lev_{fs,0}$	Initial leverage of the fs.	I	1	-	-
B_{fs}	Number of banks of the fs.	S	10	-	-
θ^{lt}_{fs}	Long-term pricing strategy of the fs.	F	1	-	-
θ^{st}_{fs}	Short-term pricing strategy of the fs.	F	1	-	-
rp^{h}_{fs}	Class risk premium of the fs.	F	0.1	-	-
rp^{st}_{fs}	Short-term risk premium of the fs.	F	0.1	-	-
rp^{lt}_{fs}	Long-term risk premium of the fs.	S	0.2	-	-
φ^{dr}_{fs}	Overall fragility sensitivity of the fs.	F	0.1	-	-
φ^{dfr}_{fs}	Default rate sensitivity of the fs.	F	0.1	-	-
spr^{dep}	Deposits spread of the fs.	S	0.1	-	-
$spr^{st}_{fs,0}$	Initial short-term spread of the fs.	I	0.01	-	-
$spr^{lt}_{fs,0}$	Initial long-term spread of the fs.	I	0.05	-	-
ψ^{st}_{fs}	Short-term spread adjustment of the fs.	F	0	-	-
ψ^{lt}_{fs}	Long-term spread adjustment of the fs.	F	0	-	-
μ_{fs}	Market share adjustment of the fs.	F	0	-	-
Central Bank Parameters					
ir_{cb}	Quarterly interest rate of the central bank	S	0.005	-	-
κ	Interest rate smoothing parameter	P	0.8	-	-
ca^{min}	Minimum capital adequacy ratio	P	0.05	-	-
φ^{cpi}_{cb}	Inflation sensitivity of the central bank	P	1	-	-
$(\Delta cpi)^{t}_{cb}$	Annual inflation target of the central bank	P	0.02	-	-

4.1.3 Validation and Stylized Facts

It is desirable that a new version of the model is able to replicate the same qualitative results of the consolidated version. We try to replicate as close as possible the initial conditions and parameter of the consolidated version but the exact same results, in a quantitative aspect, are impossible to be obtained due to the structural differences presented. The original model was developed to analyze dynamic trajectories of capitalist economies, including cycles and growth trends, and their main determinants. Dweck (2006) describes a list of stylized facts which the model is supposed to replicate. We should be able to replicate as much growth and cycle stylized facts as possible. Stylized facts on growth were first highlighted by Kaldor (1958).

Stylized facts on business cycles were already identified since the first NBER empirical studies back in the 30's, synthesized by Zarnowitz (1984). However, only with more recent works, such as Stock and Watson (1998), more specific facts were identified. They were able to identify how several macroeconomic and sectorial variables move with the business cycles. Some variables are pro-cyclical, meaning they increase in the expansionary phase of the cycle and decrease in the recession phase, whereas counter-cyclical variables perform the opposite movement. Some variables tend to Granger-cause the cycle, or move first, characterizing leading variables, while some others move after, or are Granger-caused by the cyclical economic activity.

But if the new version of the model could only replicate the same stylized facts of the last version, there would be no reason for all modifications implemented. As we modelled the financial sector slightly more detailed than the original version, we should try to replicate some stylized facts related to the financial sector in addition to all facts already replicated by the original model. Financial related stylized facts are encountered in studies which evaluate credit dynamics and business cycles, such as Zarnowitz (1992), Bikker and Metzemakers (2005), Lown and Morgan (2006), Leary (2009), Nuño and Thomas (2012), and Mendoza and Terrones (2012). Thus, Table 4.2 presents a list of growth, cycles and financial stylized facts reproduced by our model[3].

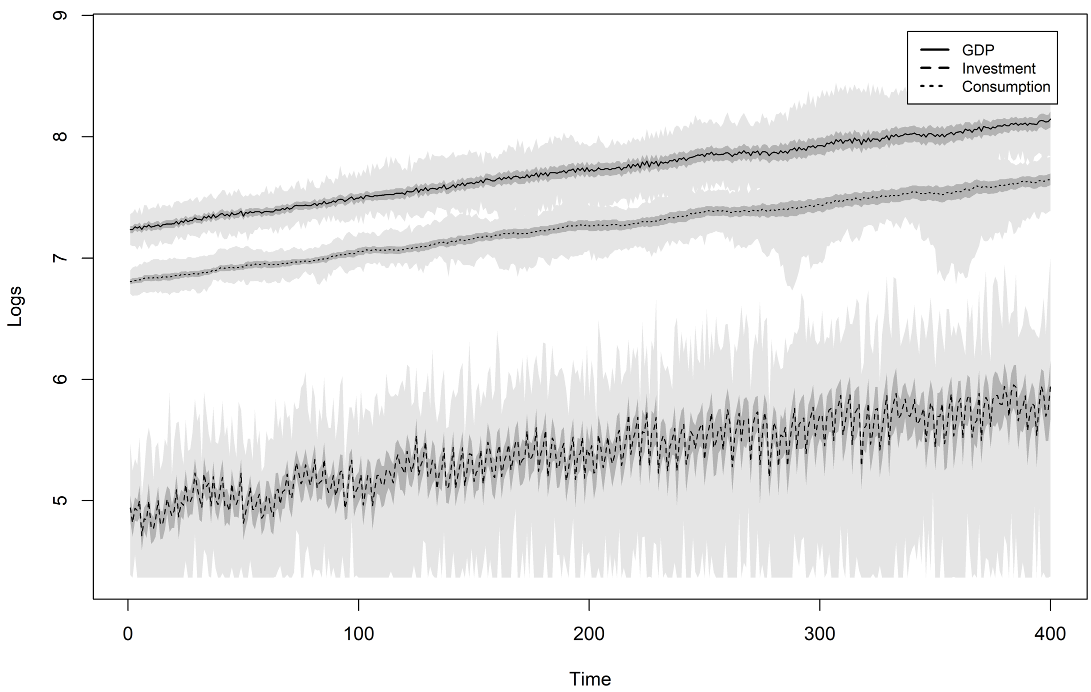
Table 4.2: MMM Model - Reproduced Stylized Facts

Stylized Facts on Growth	
SF1	Continuous growth trend of GDP
SF2	Continuous growth trend of labor productivity
SF3	Continuous growth trend of the capital/labor ratio
SF4	Profit rate is constant in the long-run
SF5	No long-term trend in the observed capital/output ratio
SF6	Wage-share and Profit-share are constant in the long-run
Stylized Facts on Cycles	
SF7	Consumption is pro-cyclical and lagged
SF8	Investment is pro-cyclical and leading
SF9	Imports are pro-cyclical and lagged
SF10	Exports are acyclical and lagged
SF11	Net exports are counter-cyclical, and lagged
SF12	Capacity utilization is pro-cyclical and coincident
SF13	Employment, in terms of hours of labor, is pro-cyclical
SF14	Wages are pro-cyclical and lagged
SF15	Profits are pro-cyclical and leading
SF16	Wage-share is counter-cyclical
SF17	Profit-share is pro-cyclical
SF18	Inflation is pro-cyclical and lagged
Financial Stylized Facts	
SF19	Stock of debt is pro-cyclical
SF20	Bank profits are pro-cyclical
SF21	Loan losses are counter-cyclical
SF22	Banks' leverage indexes are weakly pro-cyclical
SF23	Firms' leverage indexes are weakly pro-cyclical

[3]The model also replicates a series of sectoral and micro stylized facts, as listed by Dweck (2006), but we will restrict our analysis herein only to macro variables

All results presented here are MonteCarlo averages of 100 independent simulation runs, discarding the first 200 time steps of 600, leaving us with 400 time periods, or 100 years in chronological time. We also present the MonteCarlo confidence interval, showing that the MonteCarlo average is statistically significant. The baseline results of the consolidated version can be verified in Dweck (2006) and Possas and Dweck (2011). The model is able to generate endogenous growth. Consumption is the largest and most stable component of GDP, while Investment is the most volatile, as shown in Figure 4.1, contemplating **SF1**.

Figure 4.1: Baseline Result - GDP, Consumption and Investment (Series in Logs)



Source: Author's elaboration. MonteCarlo averages from 100 simulations of GDP, consumption and investment in logs. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

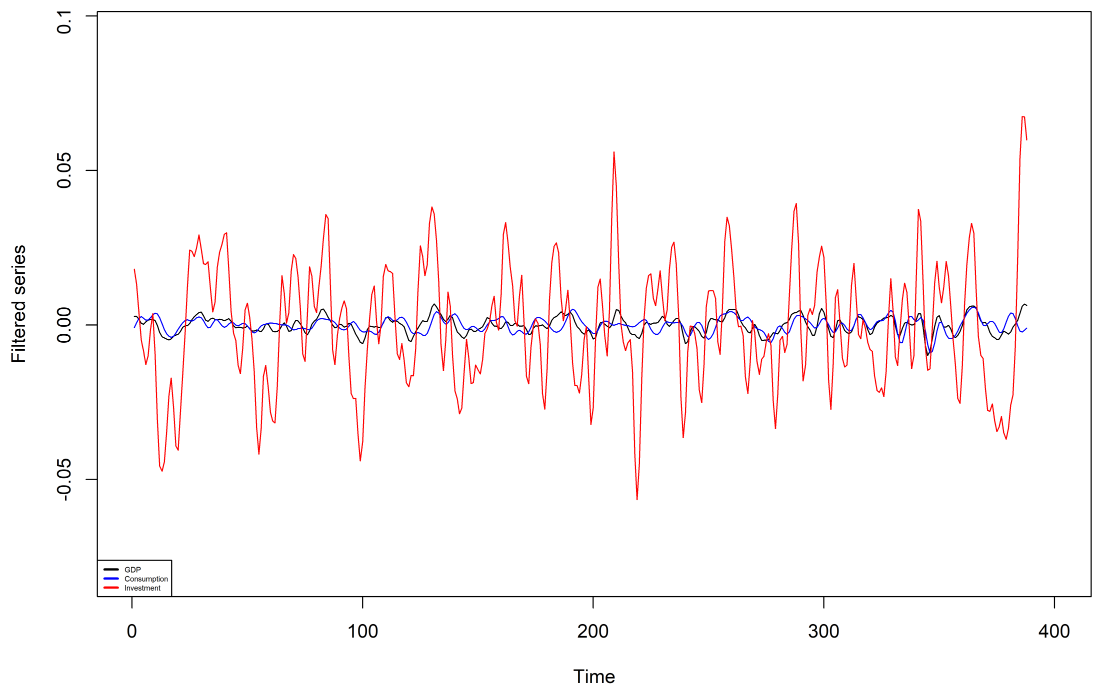
Most graphical representations of model results are presented in Appendix C while here we will focus on the most important variables. However, the extensive list of graphics confirm that the model is able to replicate all Kaldor's stylized facts on growth: productivity (**SF2** - Figure C.9) and capital/labor ratio (**SF3** - Figure C.13) growth, no long-run trend of the profit rate (**SF4** - Figure C.7), no long run trend on the observed capital-output ratio (**SF5** - Figure C.12) and finally, the long-run constancy of the functional income distribution (**SF6** - Figure C.10).

The model can also generate endogenous business cycles. Figure 4.2 shows the cyclical components of the Band-Pass filtered series[4] of real GDP, Consumption and

[4]Already well stablished parameters for quarterly data were used in the filter (6, 32, 12).

Investment.

Figure 4.2: Baseline Result - GDP, Consumption and Investment (Filtered Series)



Source: Author's elaboration. Band-pass filtered series (6,32,12) of GDP, consumption and investment in log.

Table 4.3 shows the correlation between aggregate variables. All results are at least statistically significant at 10% but most of them are significant at 1% confidence. The higher the value, the higher the correlation between variable's lag and current GDP.

The correlation structure confirms the co-movements of the most relevant macro variables, including the ones not mentioned in the list. Consumption lags the GDP in one period, and it is clearly pro-cyclical (**SF7**), although not so strongly correlated as in most models as a considerable share of consumption in our model is autonomous. Investment leads the GDP by one period and is strongly pro-cyclical (**SF8**). The government expenses present a highly pro-cyclical behavior due to the flexible primary budget fiscal rule with debt rate targets. As expected, imports are lagged and pro-cyclical (**SF9**), similarly to consumption, while exports present an almost acyclical behavior (**S10**), resulting in a counter-cyclical and lagged by two periods net exports (**SF11**).

The average capacity utilization rate is strongly pro-cyclical and almost coincident, leading by one period (**SF12**), whereas employment is pro-cyclical (**SF13**). Regarding the functional distribution, total wages and total profits are both pro-cyclical, although wages present a lag of one period with GDP and profits are more coincident (**SF14** and **SF15**). When measured as shares of total income, the wage

Table 4.3: Model Baseline Results - Correlation with GDP

Variable	-4	-3	-2	-1	0	1	2	3	4
GDP (output)	0.0655	0.2839	0.5952	0.8812	1.0000	0.8812	0.5952	0.2839	0.0655
Consumption	0.3540	0.5275	0.6590	0.6901	0.6011	0.4219	0.2181	0.0437	-0.0804
Investment	-0.0049	0.0597	0.2183	0.4337	0.6003	0.6127	0.4603	0.2362	0.0688
Gov. Expenditure	0.0766	0.3241	0.6518	0.9073	0.9474	0.7463	0.4258	0.1441	-0.0072
Imports	0.2867	0.5609	0.7357	0.7472	0.6145	0.4190	0.2530	0.1502	0.0853
Exports	-0.1085	-0.1784	-0.1488	-0.0238	0.1290	0.2201	0.2007	0.0948	-0.0232
Net Exports	-0.2608	-0.4926	-0.6210	-0.5977	-0.4544	-0.2771	-0.1488	-0.0902	-0.0643
Price	0.0760	0.1616	0.2753	0.3696	0.3859	0.3007	0.1614	0.0455	0.0025
Inflation	-0.1029	0.0821	0.2378	0.2837	0.2119	0.0925	0.0200	0.0354	0.1029
CPI Inflation	0.1498	0.1403	0.1080	0.0972	0.1150	0.1313	0.1131	0.0568	-0.0074
Basic Interest Rate	0.2457	0.2246	0.1798	0.1491	0.1393	0.1281	0.0928	0.0331	-0.0259
Profits	-0.1199	0.0989	0.3689	0.5774	0.6337	0.5328	0.3672	0.2423	0.2007
Wages	0.2000	0.4310	0.6987	0.8743	0.8556	0.6434	0.3516	0.1077	-0.0258
Profit Share	-0.2728	-0.2810	-0.1653	0.0730	0.3386	0.4933	0.4704	0.3165	0.1479
Wage Share	0.2728	0.2810	0.1653	-0.0730	-0.3386	-0.4933	-0.4704	-0.3165	-0.1479
Markup	-0.1582	-0.1160	-0.0825	-0.0764	-0.0916	-0.1045	-0.0954	-0.0585	-0.0066
Profit Rate	-0.1199	0.0989	0.3689	0.5774	0.6337	0.5328	0.3672	0.2423	0.2007
Productivity	0.0729	-0.0973	-0.2050	-0.2376	-0.2260	-0.2127	-0.2220	-0.2432	-0.2480
Capacity Utilization	0.0097	0.1872	0.3355	0.4412	0.5086	0.5390	0.5297	0.4707	0.3639
Stock of Inventories	-0.2315	-0.3641	-0.4633	-0.4624	-0.3485	-0.1775	-0.0388	0.0172	0.0087
Stock of Capital	0.1912	0.0690	-0.0503	-0.1038	-0.0804	-0.0314	-0.0286	-0.1005	-0.2089
Employment	0.2873	0.4475	0.5717	0.6418	0.6458	0.5743	0.4365	0.2554	0.0690
Total Loans	0.3955	0.5064	0.5718	0.5341	0.3769	0.1450	-0.0744	-0.2140	-0.2625
Short Term Loans	-0.0591	-0.0942	-0.1255	-0.1246	-0.0858	-0.0277	0.0211	0.0454	0.0500
Long Term Loans	0.4095	0.5341	0.6127	0.5764	0.4071	0.1571	-0.0761	-0.2207	-0.2688
Total Deposits	0.2381	0.2907	0.2808	0.1920	0.0514	-0.0826	-0.1588	-0.1665	-0.1346
Firms' Debt Rate	0.0641	0.2305	0.3565	0.3406	0.1791	-0.0267	-0.1509	-0.1426	-0.0539
Classes' Debt Rate	-0.3539	-0.4503	-0.4813	-0.4138	-0.2672	-0.1012	0.0227	0.0844	0.1066
Financial Sector Leverage	0.2875	0.3765	0.4497	0.4552	0.3621	0.1880	-0.0024	-0.1436	-0.2092
Financial Sector Profits	-0.1134	-0.1541	-0.1134	0.0110	0.1639	0.2610	0.2516	0.1478	0.0160
Financial Sector Default Rate	0.1831	0.2442	0.2064	0.0571	-0.1437	-0.2921	-0.3146	-0.2128	-0.0606
Defaulted Loans	0.1638	0.2228	0.2050	0.0874	-0.0886	-0.2342	-0.2771	-0.2067	-0.0795
Share of Ponzi Firms	-0.2399	-0.2853	-0.2678	-0.1965	-0.1099	-0.0470	-0.0229	-0.0202	-0.0100
Share of Speculative Firms	0.3527	0.3721	0.3876	0.3837	0.3418	0.2579	0.1543	0.0592	-0.0099
Share of Hedge Firms	-0.3241	-0.3359	-0.3562	-0.3665	-0.3397	-0.2636	-0.1589	-0.0588	0.0127

share is counter-cyclical (**SF16**) and the profit share is pro-cyclical (**SF17**). Finally, both CPI and GDP deflator annual inflation rates are weakly pro-cyclical, with deflator inflation being more correlated with GDP than CPI inflation (**SF18**).

Table 4.3 also confirms most financial stylized facts, as total stock of debt (loans) is pro-cyclical and lagged by two periods (**SF19**). The total stock of loans includes both short-term and long-term loans. Interestingly, the stock of short-term loans presents a counter-cyclical behavior, as they are taken to finance short-term net losses, more common when the economy is in a downturn, and long-term loans present a pro-cyclical movement, as they are taken to finance investment decisions, and investment is pro-cyclical, as already seen. The banks' profits are weakly pro-cylical and leading (**SF20**), whereas the default rate, which measures bank' losses as a share of total stock of loans, is counter-cyclical (**SF21**). Leverage can be measured by the indebtedness rate, total stock of debt over total stock of assets, and both firms' (**SF22**) and banks' (**SF23**) debt rates are moderately pro-cyclical, both lagged with GDP.

To conclude the model's validation, we present the MonteCarlo Average, Standard Deviation, Minimum and Maximum for the most relevant macro variables in Table 4.4. While the average rate does not show the variable's trajectory through time, the graphics in Appendix C do the job.

Table 4.4: Model Baseline Results - MonteCarlo Distribution

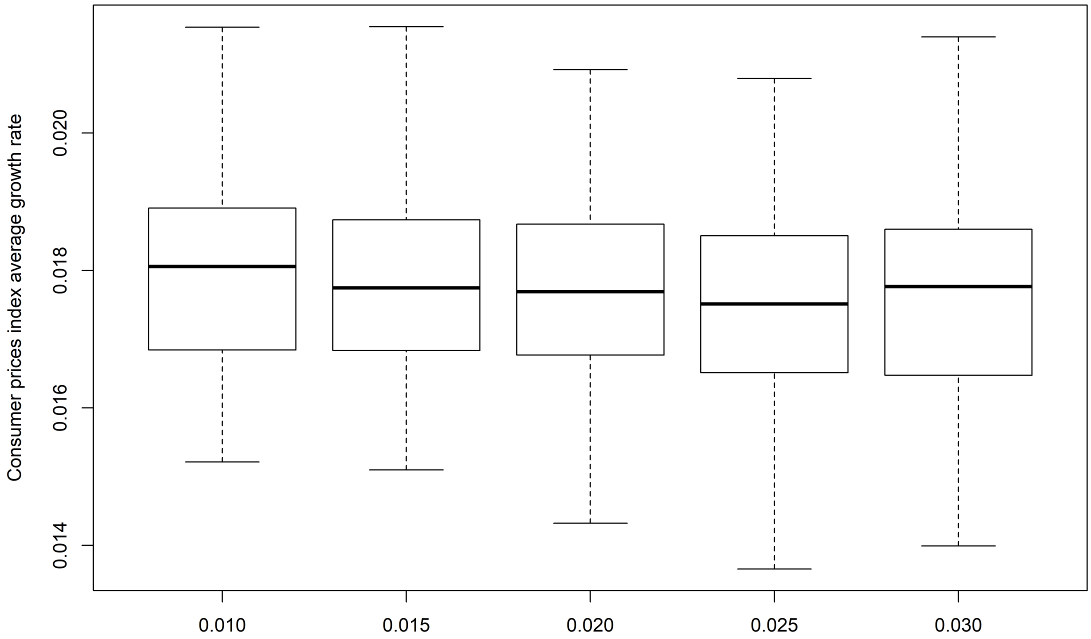
Variable	Avg.	St.Dv.	Min.	Max.
Real GDP Growth	0.0065	0.0009	0.0037	0.0086
Volatility of GDP Growth	0.0367	0.0072	0.0252	0.0589
Capacity Utilization	0.8892	0.0094	0.8537	0.9064
Volatility of Capacity Utilization	0.0316	0.0059	0.0233	0.0527
Likelihood of Crisis	0.1073	0.0086	0.0875	0.1325
CPI Inflation	0.0178	0.0012	0.0156	0.0213
Volatility of CPI Inflation	0.0097	0.0014	0.0071	0.0164
Deflator Inflation	0.0174	0.0013	0.0149	0.0214
Exchange Rate	0.9941	0.0059	0.9782	1.0035
Volatility of Exchange Rate	0.0232	0.0033	0.0173	0.0384
Primary Surplus/GDP	0.0021	0.0012	0.0000	0.0061
Government Debt/GDP	0.6583	0.0364	0.5846	0.8291
Profit Rate	0.1786	0.0134	0.1421	0.2091
Profit Share	0.6504	0.0039	0.6412	0.6598
Wage Share	0.3496	0.0039	0.3402	0.3588
Firms' Avg. Debt Rate	0.3878	0.0343	0.2776	0.4421
Classes' Avg. Debt Rate	0.3743	0.0910	0.1319	0.5900
Financial Sector Default Rate	0.0060	0.0013	0.0035	0.0117
Financial Sector Demand Met	0.8865	0.0171	0.8444	0.9322
Share of Ponzi Firms	0.0300	0.0100	0.0098	0.0557
Share of Speculative Firms	0.4812	0.0448	0.3703	0.5776
Share of Hedge Firms	0.4888	0.0495	0.3759	0.6200

4.2 Inflation Targeting

Our baseline configuration follows all NCM policy prescription, including a single mandate inflation target regime, with the target for annual CPI inflation set to 2%. The actual MonteCarlo average for CPI annual inflation is 1.77%, and it ranges between 1.56% and 2.13% across simulations. The first question we pose thus is: is this result a feature of the inflation target regime implemented, or the average inflation rate is determined by other factors? As it is the primary goal of this monetary policy to bring inflation towards the target, we start our investigation by the effectiveness of monetary policy in that sense.

To test the effectiveness of monetary policy, we run other simulations with different inflation targets. Figures 4.3 and 4.4 show the MonteCarlo distribution of average annual CPI inflation rate and volatility for different inflation targets (1%, 1.5%, 2%, 2.5%, 3%).

Figure 4.3: Inflation Targets - CPI Annual Inflation Rate



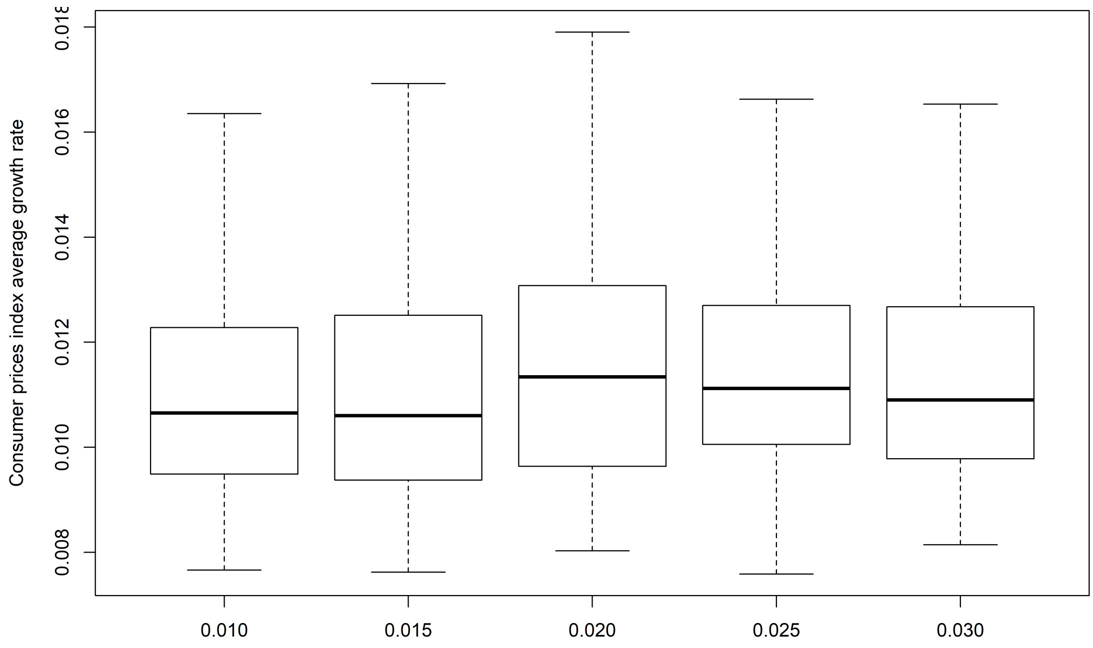
Source: Author's elaboration. 100 simulations MonteCarlo distribution of the CPI annual inflation rate for different inflation targets. Bar: medians. Box: 2nd and 3rd quartiles. Whiskers: minimum and maximum values. Points: outliers.

A preliminary comparison indicates that monetary policy has little influence in the average inflation level, which seems to be determined by other structural factors. The average CPI inflation rate (Figure 4.3) seems to be unsensitive to the level and volatility of the basic interest rate, shown in Figure 4.5. The lower the inflation target, that is, the more restrictive monetary policy is, the higher both the average level and the volatility of the basic interest rate. Therefore, monetary policy cannot force inflation below or above the economy's structural level. It is essential to the Central Bank to understand the structural factors which determine the average level of inflation to set its target, in an attempt to at least reduce inflation volatility around the target.

One factor that has a strong impact on the inflation level in an open economy as our model is the external inflation. The external sector is modelled as an exogenous block, therefore all external variables (external income and external prices) grow at an exogenous growth rate, subjected to some randomness. A two-country model would be more appropriate to account for the interconnections between the domestic economy and the rest of the world, but in the absence of such a framework[5], we

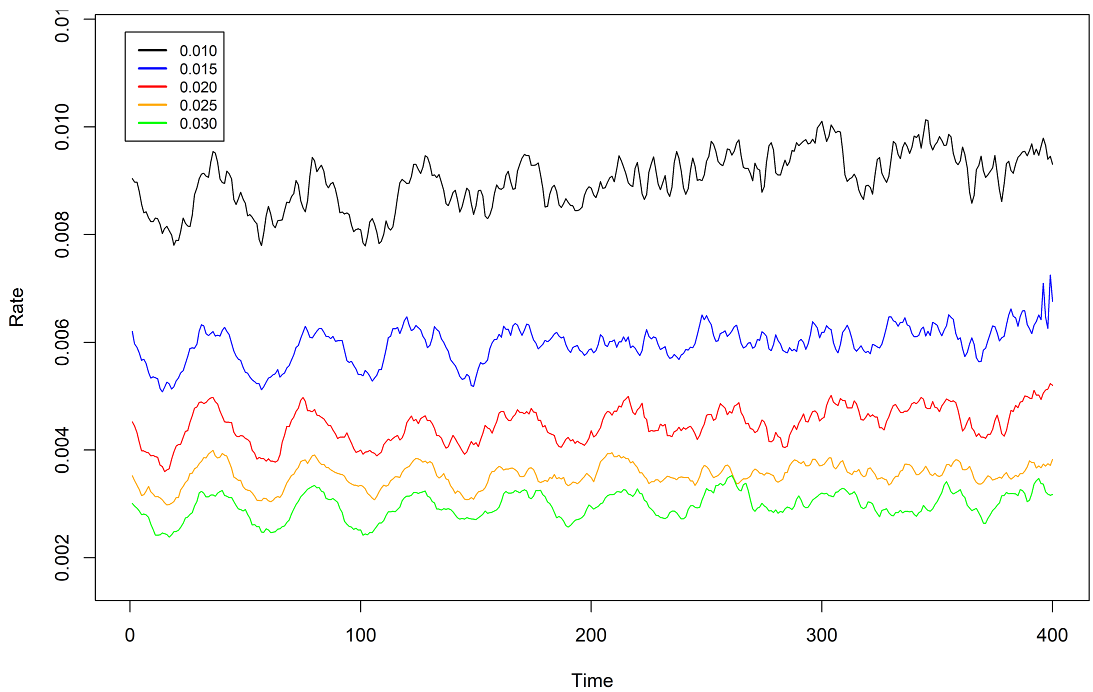
[5]Further research would be required to develop a two-country model, however it is out of the

Figure 4.4: Inflation Targets - CPI Annual Inflation Volatility



(a) Source: Author's elaboration. 100 simulations MonteCarlo distribution of the CPI annual inflation volatility for different inflation targets. Bar: medians. Box: 2nd and 3rd quartiles. Whiskers: minimum and maximum values. Points: outliers.

Figure 4.5: Inflation Targets - Quarterly Basic Interest Rate

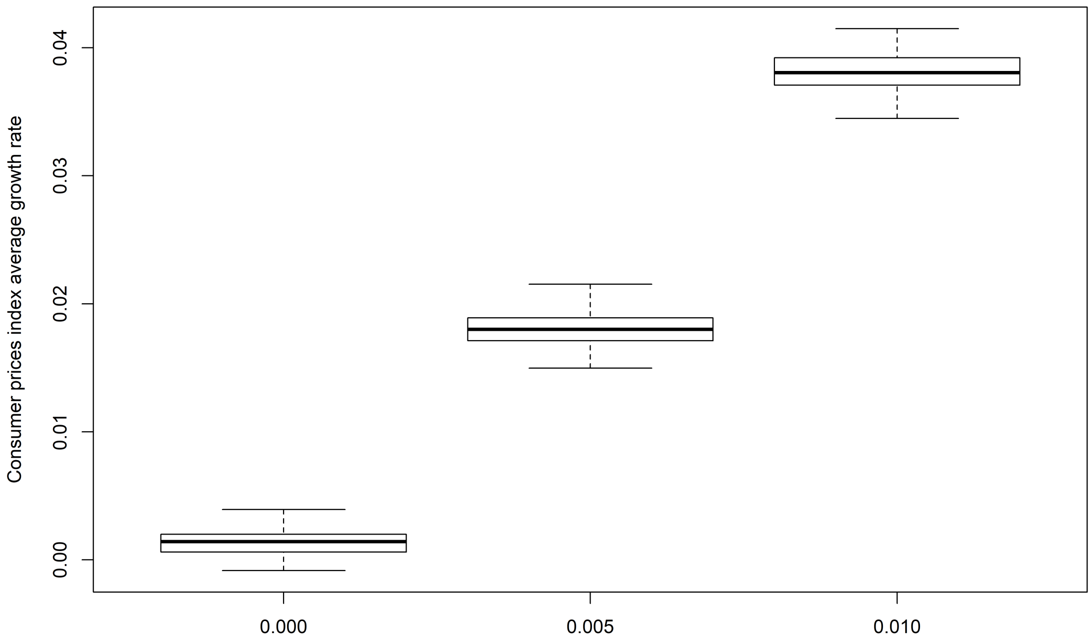


Source: Author's elaboration. 100 simulations MonteCarlo average of the quarterly basic interest rate for different inflation targets.

scope of this thesis due to space and time limitations.

should check how the exogenous growth rate we set for the external prices affect domestic inflation. External prices affect domestic prices in two ways: first, firms consider the reference price weighted by the external price when setting their own prices, and second, a share of inputs is imported, so the external price of inputs will affect the cost structure. To test how domestic inflation is affected by external inflation, we simulate a set of values for the external price growth. In this experiment we suppose that all three sectors' external prices grow at the same rate, although their initial and further levels are different. Figure 4.6 plots the MonteCarlo distributions.

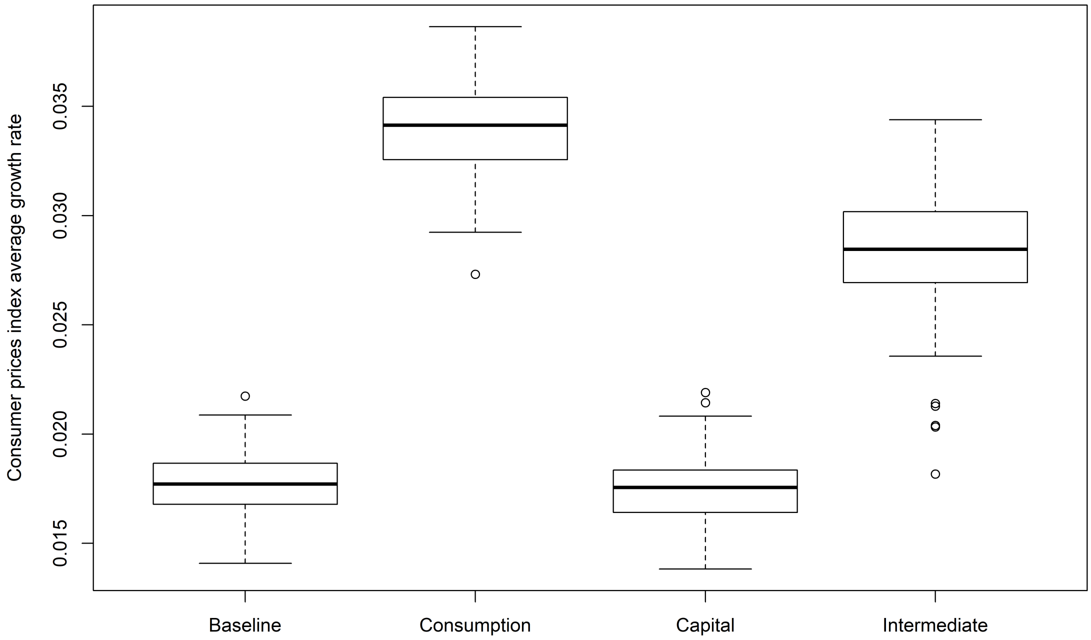
Figure 4.6: External Prices Growth Rate - CPI Annual Inflation Rate



Source: Author's elaboration. 100 simulations MonteCarlo distribution of the CPI annual inflation rate for different external prices growth rates. Bar: medians. Box: 2nd and 3rd quartiles. Whiskers: minimum and maximum values. Points: outliers.

As our model accounts for the multisectoral structure, we can try to identify which sector's external price has more impact on the CPI inflation. Instead of increasing the exogenous growth rate of all sectoral external prices at the same time, we will increase one sector's price at a time, comparing it with the baseline case. Figures 4.7 and 4.8 plot the results for the CPI inflation rate and volatility. As expected, the consumption sector external price affects the CPI inflation via the reference price for domestic consumption firms, and via the CPI index definition, an average between domestic consumption goods price and the external consumption goods price, in domestic currency, weighted by the average propensity to import of the income classes. The external price of inputs is also relevant, since consumption good firms have a propensity to import a share of inputs, and this affects the unit variable cost of domestic consumption goods. The impact on the average CPI inflation is lower than the external consumption goods price, but the CPI volatility is higher. The price of external capital goods has little to no effect on the CPI inflation.

Figure 4.7: Sectoral External Prices Growth Rate - CPI Annual Inflation Rate

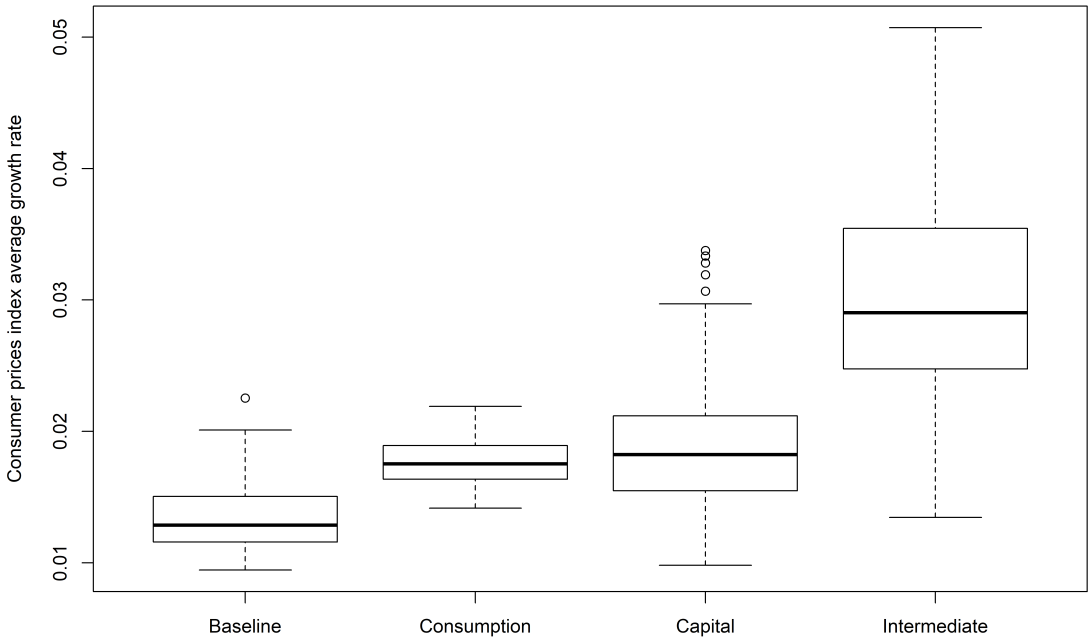


Source: Author's elaboration. 100 simulations MonteCarlo distribution of the CPI annual inflation rate for higher growth rate of each sector's external prices. Bar: medians. Box: 2nd and 3rd quartiles. Whiskers: minimum and maximum values. Points: outliers.

If the relevance of the external price of inputs was already shown on the consumer price index, it would become even more important as we examine the overall price index of the economy, the GDP deflator, as seen in Figure 4.9.

While the overall level of inflation strongly depends on the external inflation, for a given exogenous growth rate of external prices, several domestic factors will determine how domestic inflation behaves. The number of variables and parameters related to the cost and price structures are more than a handful, so we will resort to a sensitivity analysis strategy.

Figure 4.8: Sectoral External Prices Growth Rate - CPI Annual Inflation Volatility



Source: Author's elaboration. 100 simulations MonteCarlo distribution of the CPI annual inflation volatility for higher growth rate of each sector's external prices. Bar: medians. Box: 2nd and 3rd quartiles. Whiskers: minimum and maximum values. Points: outliers.

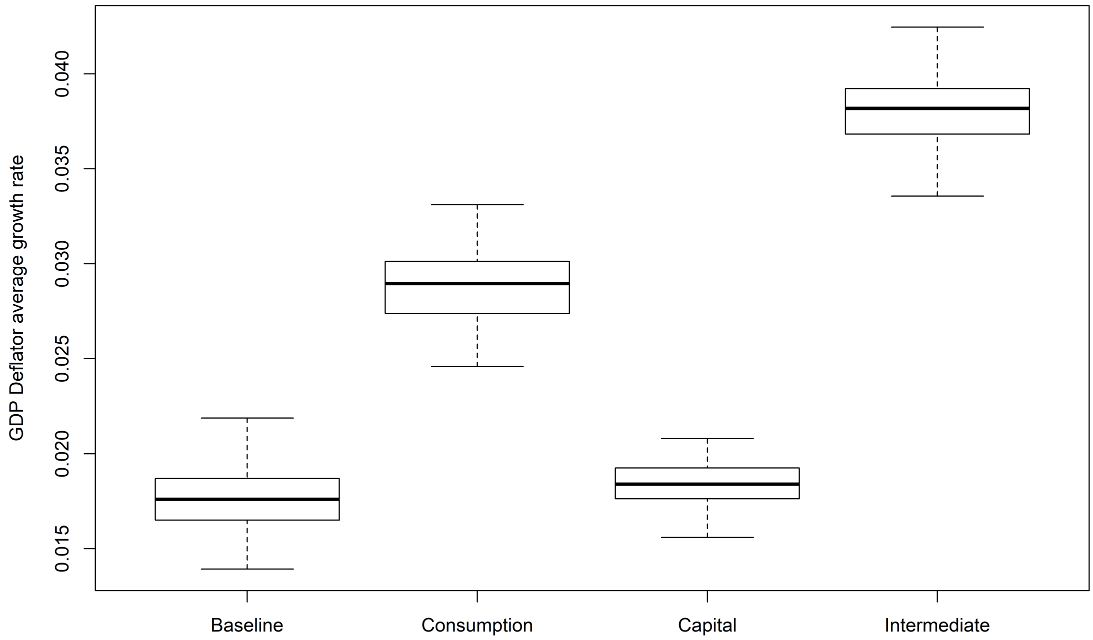
4.3 Structural Factors of Inflation: A Sensitivity Analysis

4.3.1 On Sensitivity Analysis

Sensitivity analysis aims at "studying how uncertainty in the output of a model (numerical or otherwise) can be apportioned to different sources of uncertainty in the model input" (Saltelli et al. 2008). In our case, the inputs are parameters and initial values, given the model's structure and equations, although functional forms and different model specifications are also model inputs, and could also be subjected to sensitivity analysis. In general, the analysis process consists of three steps: (i) sampling (or Design of Experiments), (ii) meta-model estimating, and (iii) variance decomposition.

Formally, following Salle and Yıldızoğlu (2014), let $x_1, x_2, ...x_k$ be the set of parameters or inputs of the model. Each parameter can vary in an interval $[x_{min}, x_{max}]$, therefore the full parametric space of the model is a set D, a k-dimensional space of the variation interval of k parameters. An experimental point is a vector $x_i^* = (x_{1,i}, x_{2,i}, ...x_{k,i}) \in D$. Our baseline initial configuration is an experimental point, such as the different configurations we test. As it is almost impossible to test the

Figure 4.9: Sectoral External Prices Growth Rate - GDP Deflator Annual Inflation Rate



Source: Author's elaboration. 100 simulations MonteCarlo distribution of the GDP deflator annual inflation rate for higher growth rate of each sector's external prices. Bar: medians. Box: 2nd and 3rd quartiles. Whiskers: minimum and maximum values. Points: outliers.

entire parametric space to infer how much uncertainty in the results is apportioned to each input, the usual first step of any sensitivity analysis is a sampling process or Design of Experiments. It consists of choosing n experimental points and therefore a n x k matrix X to build a sample and estimate the impact of each input in the true model. An efficient Design of Experiments should select the minimum n number of experimental points in other to efficiently estimate the impact of a factor in a general unexplored experimental point, and reduce the computational cost of this process. There are many sampling methods, and they are strongly correlated to the choice of the meta-model estimator.

Just to exemplify, we can combine OLS estimators with the MonteCarlo Exploration, for example, a simple but costly Design of Experiments approach. This method simply lets each parameter vary randomly in its domain, and it runs enough simulations to generate significant data to perform the OLS. One can easily see that if the parametric space D is large enough in any or both dimensions, a huge number of simulations is necessary, and this might be time-costly for large models which can take minutes or even hours to run a single simulation. Another possible sampling method is the so-called Classical Design of Experiments, in which only the interval limits of each input are tested. As Salle and Yıldızoğlu (2014) state, this approach is not suitable if the response is irregular over the domain, and it should be used only if the response is expected to be smooth on the entire domain. However, this method is useful for ranking the relative influence of inputs, so it could be useful as a screening method. There are other sampling methods.

We can perform a more efficient estimating method to measure the impact of each parameter in the model output: a Sobol variance decomposition using a Kriging meta-model estimator. The Sobol variance decomposition is a global sensitivity analysis method consisting of the decomposition model output variance into fractions, according to the variances of parameters selected for analysis, better dealing with non-linearities and non-additive interactions than traditional local sensitivity methods. It allows to disentangle and to identify both direct and interaction quantitative effects of the parameters on chosen outputs (Dosi et al. 2017b). However, due to the high computational power needed to implement such analysis in the original model, it is much more suitable to use a meta-model estimator, such as Kriging, proposed by Salle and Yıldızoğlu (2014). The Kriging method is a combination of a specific Design of Experiment using a Near Orthogonal Latin Hypercube (NOLH) and an appropriate estimated meta-model related to the specific sampling method.

The Kriging estimator is a spatial interpolation estimator of maximum likelihood, and under Gaussian assumptions it provides the best linear unbiased estimator for the response of complex, non-linear computer simulation models[6]. As it is a spatial interpolation, it adjusts the weight of the estimator giving more importance to the sampled points closer to the non-sampled experimental point in the analysis. Therefore, a spatially uniform sampling method is necessary, such as Latin Hypercubes, and the classical approach for instance is not recommended. Latin Hypercubes are not normally orthogonal, and some pairs of points can be correlated, possibly creating multicollinearity issues in the meta-model. NOLHs have already been proved as a highly efficient spatial sampling method, reducing the possible multicollinearity problem and using a low number of experimental points for a considerable number of inputs. For instance, for a number of inputs lower than 7, only 17 experimental points are needed. Therefore, using a NOLH sampling method and a Kriging meta-model estimating method, we can perform a Sobol variance decomposition, and precisely infer the response surface of our main output for the entire interval of our critical inputs, including interaction effects.

The first step involves the selection of adequate trend and correlation functions. To choose the right model, an evaluation based on in-sample and out-of-sample validation, as suggested by Salle and Yıldızoğlu (2014) is done. Q2 prediction coefficient evaluates the internal validation, whereas Root Mean Square Error (RMSE) mea-

[6]See Salle and Yıldızoğlu (2014) for a more precise formalized explanation.

sures the external efficiency. We can identify the individual and interaction effects of each parameter on the variance of the output variable, using the Sobol variance decomposition on the estimated meta-model.

4.3.2 Inflation Parameters

Using the methodology just proposed, we will explore the most relevant parameters which define prices and inflation in the model. The reduced parametric space to be tested is described in Table 4.5. For this experiment, we must make a simplifying assumption that the same value of each parameter will be used for all sectors. In normal conditions, we could set different values for different sectors, however, even in the minimum model structure of three sectors, one of each type, the number of possible combinations increases exponentially, and it would require much more time and computational power which we do not possess now. A further sensitivity analysis for different values among sectors will be left for future research. As we have already identified that external inflation is the main responsible for the average level of domestic inflation, we are interested in analyzing the domestic conditions which can amplify or reduce domestic inflation for a given growth rate of external prices.

Table 4.5: MMM Model - Inflation Related Parameters

Parameter	Description	Baseline	Min.	Max.
$\epsilon_j^{p,in}$	Imported inputs price elasticity	0	0	1
θ_j^x	External price weight	1	0	1
θ_j	Price strategy weight	0.5	0.1	0.9
$\xi_{j,0}^p$	Initial inflation passthrough	0.8	0	1
$\xi_{j,0}^{phi}$	Initial productivity passthrough	0.5	0	1
ξ_j^{fc}	Financial costs passthrough	1	0	1
$\iota_j^{in,0}$	Initial propensity to import inputs	0.05	0	0.5
ψ^{er}	Exchange rate adjustment	1	0	2
φ_{cb}^{cpi}	Inflation sensitivity of the central bank	1	0	1
ϵ_j^{px}	Exports price elasticity	0.5	0	1

For this reduced parametric space, a 11x33x65 NOLH is the best fit, providing 64 experimental points with 20 simulations for each point. An external sample of 10 experimental points is randomly chosen to test the predictability of the meta-model. The best model is a gaussian correlation function with a first-order polynomial trend specification, which generates a 0.686 cross-sample Q2 predictability index and a 0.001 RMSE. Over this meta-model, we can estimate the Sobol variance decomposition index for each parameter, illustrated in Table 4.6. This table also shows the values for each parameter which minimize and maximize the meta-model output, in that case, CPI inflation.

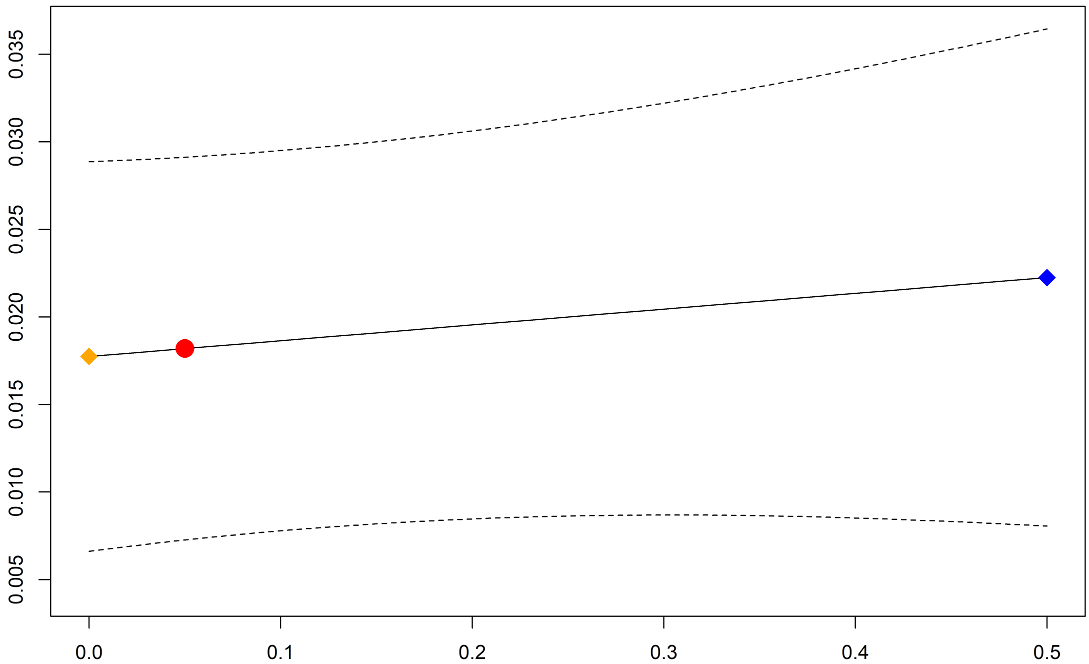
Table 4.6: Sobol Indexes and Optimization - CPI Inflation Rate

Parameter	Direct Effect	Indirect Effect	Max.	Min
$\epsilon_j^{p,in}$	0.046	0.001	0	1
θ_j^x	0.203	0.001	1	0
θ_j	0.151	0.001	0.1	0.9
ξ_j^p	0.007	0.000	1	0
ξ_j^{phi}	0.014	0.000	1	0
ξ_j^{fc}	0.000	0.000	1	0
$\iota_{j,0}^{in}$	0.570	0.002	0.5	0
ψ^{er}	0.013	0.000	0	2
φ_{cb}^{cpi}	0.000	0.000	1	0
ϵ_j^{px}	0.000	0.000	0	1

The variance decomposition shows that changes in the initial share of imported inputs in the firm's cost structure are responsible for 57% of changes in the CPI inflation for a given growth rate of external prices. Although this initial share can change during the simulations when $\epsilon_j^{p,in}$ is different from zero, effective propensity to import inputs is determined in the long-run by the initial share, and in the short-run by the real exchange rate variability. It does not mean that the effective propensity fluctuates around the initial one, because if there is a long-run trend of appreciation or depreciation of the real exchange rate, the effective propensity might change in the long run, but the weight of the initial distribution is higher than the weight of short-run fluctuations. This effect can be seen in reality: when firms have a relevant share of inputs that are imported, it is usually because they are not produced domestically, and there is no perfect substitution between domestic and imported inputs that would adjust that composition quickly with real exchange rate changes. A structural change, usually induced by policy, is needed to effectively change the composition between domestic and imported inputs, such as a process of import substitution. Figure 4.10 shows the meta-model response to the initial share of imported inputs.

The second most relevant parameter is the external price weight given by the firms when they calculate their reference price. The higher the external share in sectoral demand, the more the external price will influence the domestic price, as firms do not want to lose their external consumers. The external price weight represents the importance given by the firms to external price. If this parameter is zero, even

Figure 4.10: CPI Annual Inflation Rate Response to the Share of Imported Inputs



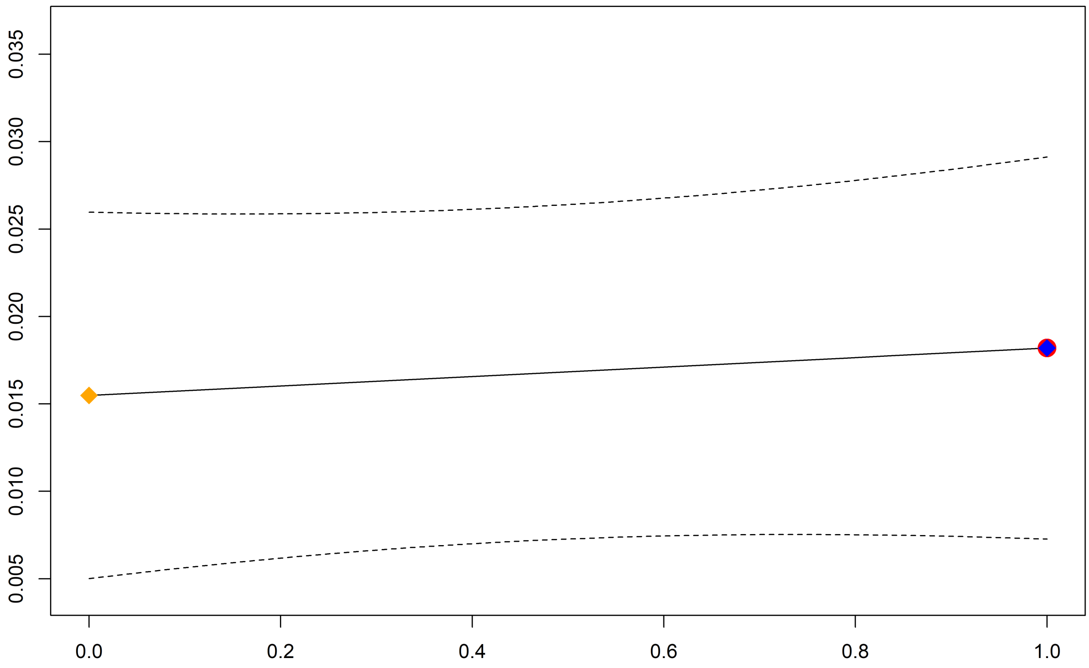
Source: Author's elaboration. Red dot: Baseline values. Blue dot: Minimum values. Yellow dot: Maximum values. Dashed lines define the 95% confidence internal.

if a big share of sectoral demand is composed of exports, firms are not considering the external price as a reference and will only look at the domestic average price. In contrast, the third relevant parameter is the reference price weight, that means, the weight given by the firms to the overall reference price (including external prices or not), which are related to the degree of monopoly in the sector, so the higher this parameter, the lower is the degree of freedom firms have to apply to their desired mark-up, and their prices do not go too far from the reference price, reducing inflation when firms gain competitiveness and desire to increase their mark-ups. Figure 4.11 shows the meta-model response to the the external price weight.

Note that the two most relevant parameters are related to the two sub-channels of the exchange rate-cost channel of monetary policy. In an economy where the external prices are relevant to the price formation of domestic firms, and/or the structural share of imported inputs is high, monetary policy could have a positive impact on the inflation level, mainly via the exchange rate-cost channel. Therefore, we plot the meta-model response surface to the combined values of these two parameters, as seen in Figure 4.12. For a given growth rate of the external prices, the combination of those two domestic structural parameters can generate an average CPI inflation rate between 1.5% and 2.2%.

Table 4.7 shows the Sobol indexes for the CPI inflation volatility. The propen-

Figure 4.11: CPI Annual Inflation Rate Response to the External Price Weight



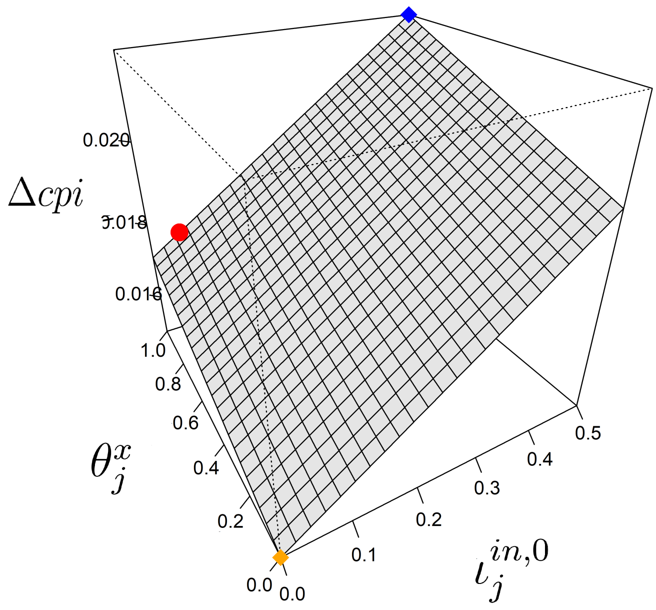
Source: Author's elaboration. Red dot: Baseline values. Blue dot: Minimum values. Yellow dot: Maximum values. Dashed lines define the 95% confidence interval.

sity to import inputs is still relevant, but now the most important is the exchange rate adjustment, a parameter that measures how the exchange rate responds to the balance of payments result, responsible for 52% of variability. The higher this parameter, the higher the exchange rate volatility. Since we know the external prices growth, the share of imported inputs, and the weight given to external prices are the most relevant factors which determine the structural level of inflation, the higher the exchange rate volatility, the higher the inflation volatility, as seen in Figure 4.13.

If the goal of monetary policy is to change the structural rate towards a desired target, it happens via the exchange rate-cost channel, but in order to make this channel work, a flexible exchange rate regime is needed, and the inflation volatility is now affected by every factor that influences the exchange rate. The monetary authority might be accepting higher inflation volatility in order to put inflation in a level different than the structural level. Figure 4.14 plots the meta-model CPI volatility response to the combined parameters.

The sensitivity analysis we implemented also works to improve robustness of our model, as it is able to generate positive, stable and volatile inflation under several parameter combinations, or structural arrangements. It also confirms that not only the average level of inflation but also its volatility are affected by several of these structural factors, which are not related to monetary policy. We have identified

Figure 4.12: CPI Annual Inflation Rate - Meta-Model Response Surface



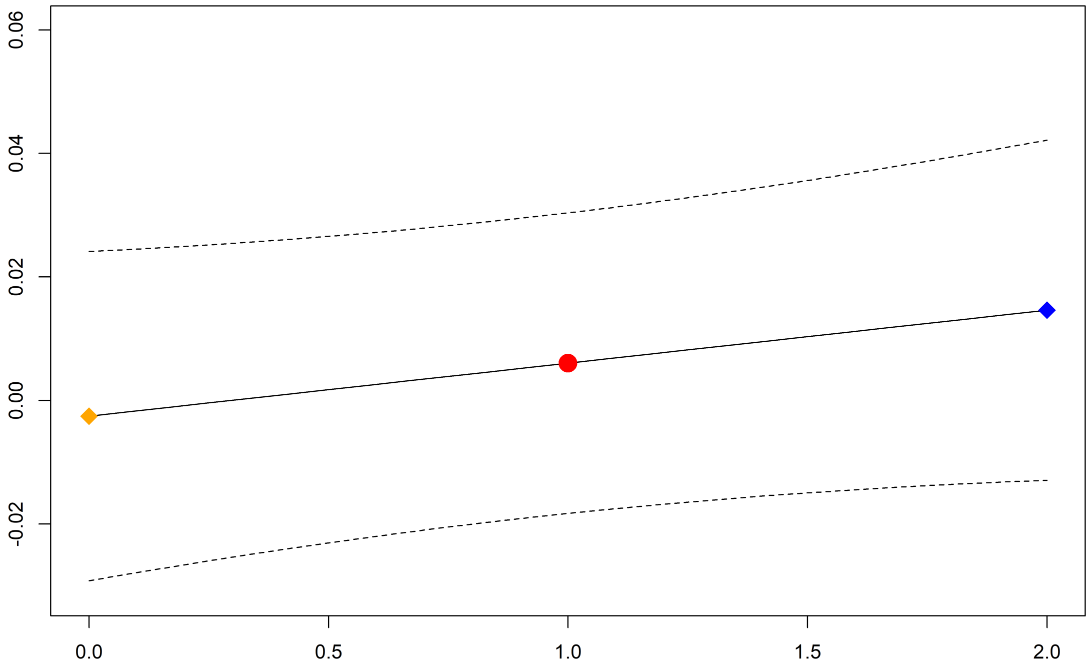
Source: Author's elaboration. Red dot: Baseline values. Blue dot: Minimum values. Yellow dot: Maximum values.

Table 4.7: Sobol Indexes and Optimization - CPI Inflation Volatility

Parameter	Direct Effect	Indirect Effect	Max.	Min
$\epsilon_j^{p,in}$	0.000	0.001	0	1
θ_j^x	0.001	0.001	0	1
θ_j	0.150	0.001	0.9	0.1
ξ_j^p	0.018	0.001	0	1
ξ_j^{phi}	0.049	0.001	0	1
ξ_j^{fc}	0.016	0.001	1	0
$\iota_{j,0}^{in}$	0.215	0.001	0.5	0
ψ^{er}	0.525	0.001	2	0
φ_{cb}^{cpi}	0.000	0.001	1	0
ϵ_j^{px}	0.025	0.001	0	1

that the external inflation can strongly affect the domestic inflation level, but the mechanisms through which the external price affects domestic price, that means the share of imported inputs, the relevant weight given by the firms to external price, and, implicitly in the last one, the share of exports in sectoral total demand,

Figure 4.13: CPI Annual Inflation Volatility Response to the Exchange Rate Volatility



Source: Author's elaboration. Red dot: Baseline values. Blue dot: Minimum values. Yellow dot: Maximum values. Dashed lines define the 95% confidence interval.

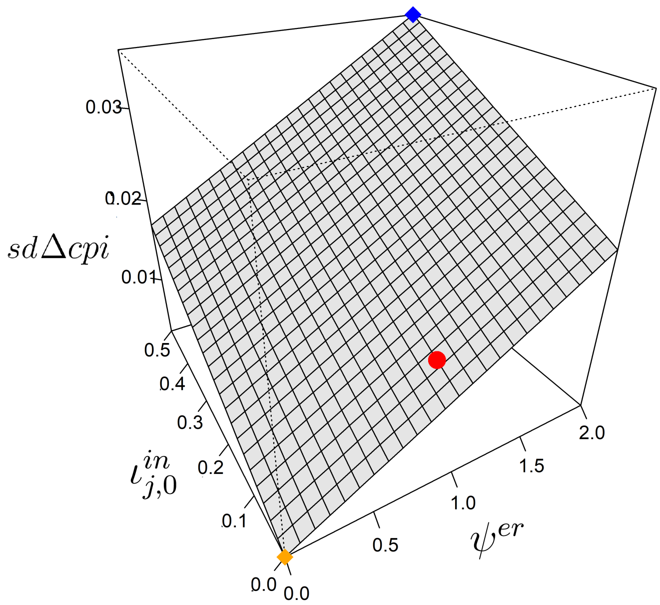
explain how the domestic inflation will react for given external inflation. Moreover, the exchange rate volatility, and thus the exchange rate policy, in combination with the monetary policy, can affect how volatile the inflation will be. We show that, if monetary policy could affect inflation, it would probably be via the exchange rate-cost channel. However, we should investigate the relevance of the other transmission mechanisms of monetary policy.

4.4 Transmission Mechanisms of Monetary Policy in the Model

The baseline simulation of our model includes several traditional and alternative transmission channels of monetary policy. Some traditional channels, which are more questionable by heterodox theories, such as the asset prices channel[7] and the expectations channel, are absent here, so not all channels illustrated in Figure 1.2 are present. Let us explicitly show the equations that capture each channel, and

[7] Although we have introduced the financial sector, as we have already discussed, it is a simple minimal representation of the financial sector, consisting basically of the banking sector. Assets are deposits and loans only. Stocks, corporate bonds, and even durable assets such as housing are not modeled.

Figure 4.14: CPI Annual Inflation Volatility - Meta-Model Response Surface



Source: Author's elaboration. Red dot: Baseline values. Blue dot: Minimum values. Yellow dot: Maximum values.

which parameters and variables modulate their effects.

Interest Rate Channel

As seen in Equation 3.5.10.5, the higher the basic interest rate, and consequently the firm's specific interest rate, the lower will be the desired replacement investment. As the transmission from the basic interest rate to base bank's interest rate (Equations 3.5.1.3, 3.5.1.4) and to firm's specific interest rate is present (Equations 3.5.1.5, 3.5.1.6), when there is an increase in the basic interest rate we could expect a reduction in the desired investment.

Balance Sheet Channel

The interest rate channel is not the only channel through which the basic interest rate can affect effective investment in the model. While an increase in the basic interest rate might affect investment decisions, decisions could be constrained by credit rationing and the balance sheet channel as well. However, this effect is more delayed, since the cost of current loans, with fixed interest rates, does not increase immediately after an increase in the basic interest rate. But if firms assume new loans, for these new loans, the effective interest rate will be higher, increasing firms' financial obligation and reducing their capability to retain profits and generate internal funds (Equation 3.5.11.1a) for future investments, thus relying on external finance and probably increasing their debt rate. Note that in equation 3.5.8.5, the interest rate on current loans, to be subtracted from gross profits, is fixed when the loan is taken.

An increase in a firm's debt rate caused by a reduction in net profits and in retained profits will not affect investment, unless the firm's debt rate reaches the maximum level (Equation 3.5.11.4). If that is the case, investment decisions, probably already reduced by the interest rate channel, could be constrained by credit availability, and effective investment could be even lower.

There is also a non-linearity that links both channels: the firm's specific interest rate to be paid in future loans, which is taken into consideration in the replacement investment decisions, is adjusted by a risk premium that depends on the firm's average past debt rate (Equations 3.5.1.5, 3.5.1.6). So, a higher interest rate might lead to an increase in the firm's indebtedness, what would lead to an even higher interest rate in the future. This seems a spiral, a strong pro-cyclical movement. Moreover, the indebtedness of the firm will deteriorate even further if the investment is effectively constrained, as the physical capital could be reduced for a given stock of loans. The relationship between these two channels is the most obscure effect of monetary policy on investment, as it depends on the current state and conditions of each individual firm in the micro-level, it has strong delays if the interest rate on loans is pre-fixed, and there is a clear non-linearity.

The Inverse Bank Lending Channel

As pointed out by several empirical studies, the correlation between the basic interest rate and the bank profits, and consequently the banks' supply of loans, is positive, contrary to what the traditional bank lending channel would assume. In addition, as the model has strong Keynesian roots and money is endogenous, the money multiplier story does not hold, and so the traditional bank lending channel is absent from our model. But the inverse channel is contemplated. When there is an increase in the basic interest rate, banks' base rate on loans will increase too (Equations 3.5.1.3, 3.5.1.4), leading to higher absolute profits. Moreover, banks hold public bonds in their portfolio, so, with the increased basic rate, the government will pay more interest for a given stock of bonds, again increasing banks' profits (Equation 3.5.12.3).

Bank's profits are directly related to their maximum supply of loans, as with a Basel-like regulatory rule and with the bank's voluntary decisions to maintain a buffer of own capital (Equation 3.5.12.1), the higher their absolute profits, the higher their capability to retain the desired amount of own capital in the form of accumulated net profits is (Equation 3.5.12.5).

There are two levels of credit rationing in the model: first, the individual credit rationing to firms, given by their individual credit assessment by the banks, so banks might constrain the amount of credit to one firm because of the firm's own characteristics and conditions, regardless of the bank's characteristics and conditions, and of the total amount of credit the bank can supply. This is the second credit rationing, as after all firms' individual credit assessment, banks can be constrained by their own conditions, so they should rank their clients and provide loans only to the soundest firms. The inverse bank lending acts in the second level of credit rationing, but it acts in a different direction as compared to the balance sheet channel. When there is an increase in the basic interest rate, it will deteriorate individual firm's balance sheets, and it will increase firms' individual credit rationing, but as banks are being more profitable, the total amount of credit that they can supply increases, so they might be able to provide credit to a firm that was not receiving any credit at all before, a firm that was at the end of the bank's ranking, for example. Once again, the final macro effect cannot be ascertained.

The Exchange Rate Channel

Exports and imports are influenced by monetary policy in the model, as suggested by the traditional exchange rate channel. The basic interest rate affects net capital flows and the balance of payments result (Equation 3.5.4.2), thus affecting the exchange rate (Equation 3.5.4.1a). With the delay of one time period, the exports (Equation 3.5.4.5) and imports (Equations 3.5.2.5 and 3.5.6.6) will be affected by the change in the nominal exchange. Notice however, as already pointed out in the first chapter, that the real effect actually depends on both exports and imports price-elasticities. In addition, the parameters ψ^{er} and υ_x are equally important, as the former measures how volatile is the exchange rate and the latter defines the relative size and importance of the capital account in the balance of payments.

The Exchange Rate Cost Channel

The presence and the relevance of this channel in the model were already discussed in the last section. The exchange rate is determinant in the price and in the cost structures, as seen in Equations 3.5.2.4 and 3.5.2.10. When the exchange rate depreciates, the cost of imported inputs increases, and the price of external competitors in domestic currency increases as well, leading to an increase of the firms' effective price, given the degree of monopoly.

The Interest Rate Cost Channel

The basic interest rate will also affect the cost structure directly via the financial costs. This direct channel, like the balance sheet channel, has some delay, as an increase in the basic interest rate will not affect the financial cost for existing loans, but if the firm takes new loans at an increase interest rate, and if it happens to be highly indebted, it will attempt to increase its price, given the degree of monopoly, as seen in Equation 3.5.2.6. The parameter $\xi^{fc}_{i,t}$ measures how much of the unit financial costs the firms will try to cover by increasing prices.

The Link from Demand to Prices

If we only consider the channels presented so far, both the monetary policy effect on demand and on prices are ambiguous, as expected and discussed in the first chapter. While the interest rate channel and the balance sheet channel act to reduce effective investment in face of an increase in the basic interest rate, the inverse bank lending channel works in the opposite way. The traditional exchange rate channel reinforces the first two mechanisms. The direct effect on prices is usually negative, as via the two sub-channels of the exchange rate cost mechanism, an increase in the interest rate tends to appreciate the nominal exchange rate, and to alleviate cost pressures to prices. But under high indebtedness, an increase in the interest rate might represent a cost pressure in itself, thus increasing prices. To make things even more ambiguous, aggregate demand might influence prices.

Even if our model accounts for multiple sectors, as we are using the minimal structure possible, with only three sectors, we do not assume *flexprice* markets in any of them, so the conventional assumption that prices act as an adjustment mechanism between supply and demand are absent here. In our sectors, even the intermediate one, there is no assumption of equilibrium in that sense. Demand and supply can be different, as they usually are. Firms take precautionary measures, routines, simple rules, to face unexpected demand fluctuation, such as producing to have a stock of inventories as buffer, and investing to have enough productive capacity beyond the normal or desired utilization. Even if this effect is not present in the model, demand can affect prices via the alternative mechanisms discussed in the first chapter.

We should note, however, that demand could affect prices with at least a delay of one time period, as firms produce based on expected demand, before they face their effective demand. Thus, when there is a demand increase this could impact firm's expected demand (Equation 3.5.3.1), and as firms use more productive capital goods firms, for a given stock of capital goods, a higher expected demand will lead to higher production, and therefore to the use of less productive capitals, resulting in a reduction of firm's average productivity. The lower average productivity will then increase wage costs (Equation 3.5.2.3) in the next period. As usual, cost shocks will be passed onto prices as far as the degree of monopoly allows the firm to do it. The diminishing returns inflation is contemplated here.

The final effect of demand on prices comes with variable delay, as in the beginning of the following year nominal wages are adjusted (Equation 3.5.2.1). If firm's average productivity had decreased due to the diminishing returns, for a given bargain power, wage rates could be reduced. However, none of those assumptions can be guaranteed. First, even if there is a reduction of firm's average productivity due to increased demand, what is relevant for the wage rate adjustment is the annual growth of productivity, which will depend not only on the initial productivity reduction, but also on the average productivity of the other periods, which can be influenced by other demand shocks, or even by the firm's past investment and implementation of more productive capital goods. Second, workers bargain power will also change (Equation 3.5.2.2), depending on the current sectoral conditions regarding capacity utilization and employment trajectory. As there are no labor market rigidities and fully elastic supply of labor in the model, employment is defined as firm's effective production, which depends on expected demand, over firm's average productivity. A demand shock will raise production and reduce the average productivity, implying higher employment, and therefore possibly higher workers' bargain power. Third, wage rates will grow as well because of the CPI inflation, so demand and cost shocks on the consumption sector can be transmitted to other sectors.

A demand increase, let us say, due to a basic interest rate reduction, will reduce productivity and increase costs in the immediate next time periods, raising prices, if we assume that the overall direct effect of monetary policy on demand is positive, for instance if the interest rate, the balance sheet and especially the exchange rate channel supersede the inverse bank lending channel. However, prices will not necessarily rise if the same interest rate reduction decreases financial costs more than it raises exchange rates and the input costs. Finally, the interest rate reduction will have an impact on wage rates, when they are adjusted. The new wage rate will depend on the price increase in the consumption sector, on the productivity reduction (assuming there was no capital implementation for that firm between the interest shock and the wage rate adjustment, which is probably not true for the aggregate of firms), and on the increased workers bargain power. Wage rates will probably grow more, generating more cost pressures for the firms and new attempts to increase price, perpetuating inflation for the next periods.

4.4.1 Simulations

To better understand which channels are acting or which channels are stronger than the others, we "turn off" the variables and parameters which modulate each channel specifically. For example, to turn off the interest rate channel, we leave the banks' interest rate fixed, regardless of the level of the basic interest rate, setting the parameters θ_b^{st} and θ_b^{lt} to 1, so Equations 3.5.1.3 and 3.5.1.4 will always be equal to $\overline{ir}^{st}_{fs,t-1}$ and $\overline{ir}^{lt}_{fs,t-1}$ respectively.

The following list describes the experiment:

- **S1** Same as baseline, but we fix the banks' interest rate sensitivity to the basic rate, effectively disabling the interest rate channel.
- **S2** Same as baseline, but we set the financial cost passthrough to prices to zero, even if firms are highly indebted, effectively disabling the interest-cost channel.
- **S3** Same as baseline, but we remove the regulatory policy which creates credit rationing, so bank profits will not affect financial constraints to investment, effectively disabling the inverse bank lending channel.
- **S4** Same as baseline, but we set exports and imports unsensitive to the real exchange rate, effectively disabling the traditional exchange rate channel.
- **S5** Same as baseline, but we set the weight that firms give to external price in the reference price calculation to zero, and we set the import content of inputs to zero, effectively disabling both sub-channels of the exchange rate-cost channel.

To check which channel is stronger, we calculate the difference between the relevant variables in the baseline case and in every other Simulation. Let us use the case of inflation volatility as an example. A bigger difference, especially a positive one (ratio bigger than 1), indicates a likely stronger channel. A negative difference (ratio lower than 1) indicates a channel that reduces the efficacy of monetary policy. Insignificant differences indicate channels which are not so relevant. Table 4.8 plots the comparison for 100 simulations in each case, and the p-value against the null-hypothesis where there is no difference between the cases, so the ratio would be 1.

Results cannot show a significant difference between the baseline case and S1, where the interest rate channel is disabled. As explained, as the interest rate on loans is fixed when the loan is taken, the effect of this channel has a strong delay, and it is probably mitigated by more immediate and stronger channels. Even the immediate effect on replacement investment decisions is considerably small, as the investment share on GDP is small, and the share of replacement investment on total investment is even smaller.

Table 4.8: Transmission Channels of Inflation and Monetary Policy - Comparative Results

Variable	S1	S2	S3	S4	S5
Volatility of GDP Growth	0.9368	0.8692	0.7770	1.0607	0.9538
	(0.1781)	(0.0041)	(0.0000)	(0.2421)	(0.3378)
Volatility of Capacity Utilization	0.9464	0.9026	0.7972	1.0758	0.7768
	(0.2488)	(0.0398)	(0.0000)	(0.1330)	(0.0000)
Likelihood of Crisis	0.9928	0.9951	0.9579	1.0126	0.9798
	(0.5567)	(0.7048)	(0.0015)	(0.2868)	(0.0678)
CPI Inflation	0.9949	0.9849	1.0058	1.0127	0.9317
	(0.6524)	(0.2102)	(0.6263)	(0.3093)	(0.0000)
Volatility of CPI Inflation	0.9799	0.6486	0.9220	1.2171	1.0864
	(0.5900)	(0.0000)	(0.0342)	(0.0000)	(0.1441)
Exchange Rate	1.0015	1.0042	1.0088	1.0070	0.9814
	(0.5342)	(0.1107)	(0.0011)	(0.0067)	(0.0000)
Volatility of Exchange Rate	0.9022	0.8622	0.6988	1.2258	1.2166
	(0.1618)	(0.0618)	(0.0000)	(0.0048)	(0.0190)
Basic Interest Rate	0.9910	0.9789	0.9994	1.0180	0.9333
	(0.4058)	(0.0686)	(0.9605)	(0.1226)	(0.0000)
Volatility of Basic Interest Rate	0.9769	0.7423	0.9290	1.1470	0.9933
	(0.4524)	(0.0000)	(0.0161)	(0.0000)	(0.8726)
Financial Sector Default Rate	0.9772	0.8523	0.8686	1.0332	1.3067
	(0.4690)	(0.0000)	(0.0000)	(0.3551)	(0.0000)

In contrast, the interest rate-cost channel acts against the effectiveness of the monetary policy, as in the absence of its effect the volatility of CPI inflation is reduced. This alternative channel has always been treated as a direct channel so far, which has a direct impact on prices without the intermediation of demand. However, the effect of this channel on real variables was not expected, and the reduction of GDP growth volatility appears as an emergent property. If the firms are highly indebted and attempt to gain profitability by incorporating financial costs into prices, a restrictive monetary policy could lead to not only an acceleration of inflation, but also to financial disruptions, bankrupts, and deterioration of real stability, given that without this channel the share of default loans on total loans are reduced significantly, thus constituting a perverse channel of monetary policy in both ways, real and nominal. Also, without this channel, the basic interest rate is much less volatile, corroborating the puzzling and spiraling effect which causes such instability. Under high indebtedness, a rise in the basic interest rate can contribute to increase inflation and to deepen the recession, as discussed by Sicsú, Modenesi, and Pimentel (2020).

Similarly, the inverse bank lending channel is another channel through which monetary policy can increase real instability. In the absence of a regulatory rule that forces the bank to reduce credit availability when its profitability is lowered, as in the case of a basic interest rate reduction, firms are less credit constrained, and even though the average debt rate increases slightly, firms can effectively finance their investment decisions and create profits to hold that higher level of indebtedness, without needing to go bankrupt and default on their loans. In fact, like in the case of the interest rate-cost channel, the share of defaulted loans on total loans strongly decreases. This result is in line with Dosi et al. (2015) who also find how Basel-like regulatory rules can be destabilizing. We find no difference in the inflation volatility though, but adding this effect up with the previous channel, it seems that via the financial variables, a reactive monetary policy actually increases real and nominal instabilities.

As expected, the traditional exchange rate channel has a positive impact on output stabilization, as both GDP growth and capacity utilization volatilities increase when the channel is absent. However, we can confirm that CPI inflation volatility also increases with statistical significance, mainly because exchange rate volatility increases too, as there is no response on the trade balance to changes in the exchange rate. When exports and imports are sensitive to prices, a fall in the exchange rate, occasioned or not by monetary policy, would induce a deterioration of the trade balance result, which, in turn, would slow exchange appreciation. Exactly because of that effect, monetary policy has to be even stronger to affect the exchange rate and to try to stabilize prices, and that is why we see an increased interest rate volatility in the absence of that channel as well. The relative efficacy of monetary policy to control inflation via demand, as proposed by the traditional literature, depends on the price-elasticities of the net exports, and if they are low, as argued by Padrón et al. (2015) for the Brazilian case, monetary policy can again exacerbate instability.

Finally, we see no difference in the GDP growth volatility when the exchange rate-cost channel is disabled, but there is a reduction of capacity utilization volatility showing a possible adverse effect of this channel on the real variables. However, CPI volatility decreases if the channel is active, and so does the exchange rate volatility. Moreover, there is a strong effect on the average inflation rate, but as already discussed in the last section, the clear reduction of the inflation rate in the absence of these transmission mechanisms is less due to the monetary policy and more because of the structural factors which absorb the impact of external inflation and create domestic inflation, as a consequence of the change in the structure made to cancel the effect of the channel. In this channel alone, we can see conflicting goals of monetary policy, as to reduce inflation volatility the capacity utilization volatility increases. If it is via the exchange rate cost channel that monetary policy could possibly bring domestic inflation towards the target, it does it by increasing real instability.

Our experiments allowed some transmission channels of monetary policy to be isolated, and so we could understand their individual impact on real and nominal variables. As always, further exercises should be done, as we could test if the effect of each channel changes, or if it is insensitive to different economic structures and conditions, but it is not done here due to space and time constraints. Each transmission mechanism of monetary policy is a research project on its own. Even so, all results reinforce the idea that monetary policy is erratic, that it fails to bring the inflation rate to a target different from what the structural conditions of the economy create, and if there is any channel through which it can try to move inflation towards the target, it is via the exchange rate cost channel, but in doing so, it creates nominal and real instability. It strongly relies on the flexible exchange rate regime, so the weak effectiveness of monetary policy depends on its interaction with the exchange rate policy, as the last two channels discussed depend on the exchange rate regime. By adopting another regime such as a fixed exchange rate, these two channels can be affected, and consequently the efficacy of monetary policy is affected too. Its interaction with the exchange rate policy and other policies will now be investigated.

4.5 Interaction with Fiscal and Exchange Rate Policies

We have seen how important both the traditional exchange rate and the exchange rate cost channels are for the monetary policy effectiveness, as the inflation targeting regime relies on a flexible exchange rate regime to have some impact on inflation volatility. This makes us question how monetary policy would act in other exchange rate regimes, such as a fixed exchange rate. Moreover, although not discussed directly in the analysis of the transmission mechanisms, monetary policy has an additional channel, let us say, that strongly relates with another macroeconomic policy: fiscal.

As in the baseline case, let us assume that the government follows a flexible primary surplus target rule with debt to GDP ratio limits, meaning that when government debt to GDP ratio reaches the maximum limit, the government increases the surplus target, effectively reducing primary expenses in relation to GDP. Government debt to GDP ratio can increase due to several factors, such as a worsening in government tax revenue and/or an increase in primary expenses, deteriorating government's primary result, or even an increase in the basic interest rate implying a rise in government interest payment.

So, suppose a nominal shock, an increase in external prices, increasing both the input cost for firms and the reference price, so domestic prices will rise. In face of domestic inflation, the Central Bank will raise basic interest rate, increasing government interest payment for a given amount of government debt. Assuming the primary result as constant, monetary policy reaction by itself would increase government debt and debt to GDP ratio. But, if there is a negative impact of the basic interest rate on demand, for instance via the exchange rate channel, net exports will be contracted, and aggregate demand will reduce, increasing debt to GDP ratio via the denominator. Such real contraction will lead to less tax revenue and more government expenses, not only for counter-cyclical unemployment benefits, but also because current government expenses rise in nominal terms in face of domestic inflation. The result is a worse primary result, which also increases government debt.

If government debt to GDP ratio is already in a high level, this situation could lead it to reach the maximum limit, forcing the government to contract even more its primary expenses, and starting a vicious circle of a self-defeating combination of policies. This result could in fact happen even without the basic interest rate increase, only because of the conservative fiscal rule, but with such monetary policy reaction, it aggravates the vicious circle. So, the biggest impacts of the basic rate on aggregate demand seems to be results of the macroeconomic policy combination. We then ask: are there other policy combinations that perform better than the recommendations of the NCM? To have some insights on the answer, we perform a comparative analysis using our model. Notice that such analysis is preliminary, as the focus of this thesis is the monetary policy, and further detailed investigation on exchange and fiscal policies would be required.

The following list synthesizes the scenarios, where the baseline case assumes a single mandate Taylor Rule, a flexible primary surplus target and a flexible exchange rate.

S1 Fixed basic interest rate, flexible primary surplus target and flexible exchange rate.

S2 Single mandate Taylor Rule, unconstrained fiscal policy and flexible exchange rate.

S3 Single mandate Taylor Rule, flexible primary surplus target and fixed exchange rate.

S4 Single mandate Taylor Rule, unconstrained fiscal policy and fixed exchange rate.

S5 Fixed basic interest rate, flexible primary surplus target and fixed exchange rate.

S6 Fixed basic interest rate, unconstrained fiscal policy and flexible exchange rate.

S7 Fixed basic interest rate, unconstrained fiscal policy and fixed exchange rate.

Table 4.9: Policy Mix - Comparative Results

Variable	S1	S2	S3	S4	S5	S6	S7
GDP Growth	1.0162	1.0494	1.0262	1.0665	1.0045	1.0649	1.0493
	(0.5251)	(0.0129)	(0.2836)	(0.0010)	(0.8568)	(0.0015)	(0.0159)
Volatility of GDP Growth	0.9702	0.6827	0.9652	0.6926	0.9978	0.6760	0.6740
	(0.2387)	(0.0000)	(0.1862)	(0.0000)	(0.9374)	(0.0000)	(0.0000)
Capacity Utilization	1.0034	1.0182	1.0057	1.0184	1.0015	1.0154	1.0180
	(0.3471)	(0.0000)	(0.1158)	(0.0000)	(0.6848)	(0.0000)	(0.0000)
Volatility of Capacity Utilization	0.9783	0.7413	0.9455	0.7412	0.9835	0.7547	0.7348
	(0.5553)	(0.0000)	(0.1280)	(0.0000)	(0.6611)	(0.0000)	(0.0000)
Likelihood of Crisis	0.9888	0.8507	0.9727	0.8336	0.9911	0.8331	0.8299
	(0.4072)	(0.0000)	(0.0464)	(0.0000)	(0.4913)	(0.0000)	(0.0000)
CPI Inflation	0.9920	0.9934	1.0236	1.0013	1.0206	1.0107	0.9981
	(0.5245)	(0.5990)	(0.0448)	(0.9172)	(0.0936)	(0.3882)	(0.8718)
Volatility of CPI Inflation	1.0956	1.0090	0.9744	0.9869	0.9758	1.0662	0.9628
	(0.0000)	(0.6883)	(0.2032)	(0.5508)	(0.2393)	(0.0033)	(0.0585)
Inflation	0.9964	0.9993	1.0337	1.0075	1.0291	1.0094	1.0021
	(0.7696)	(0.9568)	(0.0040)	(0.5286)	(0.0159)	(0.4223)	(0.8458)
Exchange Rate	0.9908	1.0219	1.0384	1.0384	1.0384	1.0181	1.0384
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Volatility of Exchange Rate	0.9149	0.7543	0.0000	0.0000	0.0000	0.6158	0.0000
	(0.0015)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Primary Surplus/GDP	1.2520	-9.7173	0.9493	-9.7633	1.3980	-8.7976	-8.3881
	(0.0188)	(0.0000)	(0.6368)	(0.0000)	(0.0014)	(0.0000)	(0.0000)
Government Debt/GDP	1.0101	6.9935	1.0141	7.1520	1.0125	7.7230	7.5478
	(0.1711)	(0.0000)	(0.0729)	(0.0000)	(0.1036)	(0.0000)	(0.0000)

By analyzing scenario 1 alone, where the only difference is the absence of a Taylor Rule, we see no significant difference in the real variables such as GDP growth and volatility, capacity utilization rate and volatility, and the likelihood of economic crisis. However, we find that CPI inflation volatility increases, mainly because of the decrease of the exchange rate volatility. As we have been arguing so far, the relative effectiveness of monetary policy to reduce inflation volatility depends on the exchange rate volatility. We verify this result by looking at scenarios 3 and 5, the first with Taylor Rule and fixed exchange rate and the second with fixed interest and exchange rates. We can see in both cases that the average inflation rate is higher because, with flexible rates, there is an exchange rate appreciation trend if the domestic economy grows at a slower rate than the rest of the world, in such a manner that exports grow more than imports, creating a positive trade balance that forces the average exchange rate down. For the same external prices, a higher average exchange rate in both cases results in a higher external price in domestic currency, increasing the average inflation rate. However, there is no significant difference in inflation volatility when compared with the baseline case. So, the Taylor Rule can reduce inflation volatility if and only if exchange rates are flexible, but if there is a fixed exchange rate, despite a higher average inflation rate, inflation volatility does not change whether there is a reactive monetary policy or not.

While the relationship with the exchange rate policy has a positive effect on nominal stabilization, real variables are more affected by the interaction with fiscal policy. If we look at scenario 2, which is basically the baseline but with unconstrained fiscal policy, long-run growth rates are higher, GDP and capacity utilization volatilities are lower, as the likelihood of crisis. There is no significant change in CPI and GDP deflator inflation rates nor volatility, although, with a higher domestic average growth rate and same external growth rate, the structural trade balance is lower, and the average exchange rate is higher than the baseline case. In addition, if we compare scenarios 2 and 6, the one with unconstrained fiscal policy but with a Taylor Rule, and the one with no fiscal policy restriction nor reactive monetary policy, we can see that the Taylor Rule reduces the average growth rate and increases, slightly, GDP volatility and the likelihood of crisis. As the flexible exchange rate regime is present in both cases, the Taylor Rule reduces inflation volatility regardless of the fiscal policy regime. Note that the unconstrained fiscal policy generates better real results, but with a higher debt to GDP ratio, as there is no fiscal rule to bound that indicator within some values. However, it does not impact negatively other variables as the conventional policy recommendation suggests. Instead, a higher but not explosive, government debt to GDP ratio generates better economic real results, without even compromising inflation.

Interestingly, scenario 7, as an extreme contrast to the baseline case following the NCM policy recommendations, presents the best economic prospects in all cases. Not only short-run results, nominal or real, such as inflation, GDP, and capacity volatilities and the likelihood of crisis, but also the long-run average growth rate is better, with no average inflation rate difference. These are overall and preliminary results, as different exchange rate regimes could be tested, and there are several other aspects of fiscal policy beyond the existence, or not, of a limit to government total expenditures, such as the composition of government expenses and the taxation structure. Moreover, fixing the basic interest rate is not a policy rule *per se*, as its level is a Central Bank's choice. This leads us to the same question posed by the Post-Keynesian debate discussed in the first chapter: if the basic interest rate should not be actively used as a policy instrument to stabilize the economy, what should be done with it? If it should be stationary, at what level should it be parked? Let us thus use our model to see if the alternative monetary policy rules generate better economic results.

4.6 Alternative Monetary Policy Rules

As a final exercise, we investigate if there are better alternative monetary policy rules instead of the traditional Taylor Rule. We have been testing only a single mandate Taylor Rule as described in Equation 3.5.1.1, but other policy goals can be implemented as other policy rules can be tested. So, in this section we replace the basic interest rate rule in the baseline simulation of our model to test alternative approaches, such as a dual mandate Taylor Rule, the Smithin Rule, the Pasinetti Rule and the Kansas City Rule, as presented in the first chapter.

4.6.1 Equations

Advocated by Blanchard, Dell'Ariccia, and Mauro (2010) for example and implemented by the Federal Reserve System, a dual mandate Taylor Rule pursues two policy goals, inflation target and output gap, measured in our model as the average productive capacity utilization rate[8]. This is a more general specification since a strict Taylor Rule can be derived from this dual mandate rule by simply setting capacity sensitivity as zero[9]. The same smoothing adjustment mechanism applies:

$$ir^*_{cb,t} = (1-\kappa)(ir^n_{cb} + \varphi^{cpi}_{cb}((\Delta cpi)^e_{cb,t} - (\Delta cpi)^t_{cb}) + \varphi^{pcu}_{cb}(\overline{pcu}_{t-1} - \overline{pcu}^t_{cb})) + \kappa \cdot ir^*_{cb,t-1} \tag{4.6.1.1}$$

where
$ir^*_{cb,t}$ is the effective nominal basic interest rate in period t;
κ is the interest rate smoothing parameter;
$ir^*_{cb,t-1}$ is the effective nominal basic interest rate in period t-1;
ir^n_{cb} is the nominal interest rate of the Central Bank;
$\dot{cpi}^t_{cb}$ is the Central Bank's inflation target;
$(\Delta cpi)^t_{cb}$ is the Central Bank's average capacity utilization target;
φ^{cpi}_{cb} is the Central Bank's sensitivity to inflation; and
φ^{pcu}_{cb} is the Central Bank's sensitivity to capacity utilization;
$\overline{pcu}_{t-1}$ is the average productive capacity utilization in period t-1; and
$(\Delta cpi)^e_{cb,t}$ is the Central Bank's expected annual CPI inflation in period t.

Following Smithin (2004) and Smithin (2007) proposition, real interest rates should be zero, so nominal interest rates should be adjusted every period (one quar-

[8]As we reject the potential output approach, another measure of economic activity must be taken. Heterodox models usually use the unemployment rate as a policy target, which is indeed reasonable. However, as we model a perfectly elastic supply of labor, the capacity utilization is a measure of employment of the capital stock, and consequently of labor.

[9]With two possible mandates, both deviations from targets have to be normalized to avoid scale problems. So, for this rule, the inflation deviation and the capacity deviation are fractions of their respective targets. The changes in the interest rate are also fractions of the current level.

ter in our model) by past quarterly inflation. The Smithin Rule is thus:

$$ir^*_{cb,t} = (1-\kappa)\left(\frac{cpi_{t-1} - cpi_{t-2}}{cpi_{t-2}}\right) + \kappa \cdot ir^*_{cb,t-1} \tag{4.6.1.2}$$

where
$ir^*_{cb,t}$ is the effective nominal basic interest rate in period t;
κ is the interest rate smoothing parameter;
$ir^*_{cb,t-1}$ is the effective nominal basic interest rate in period t-1;
cpi_{t-1} is the consumer price index in period t-1; and
cpi_{t-2} is the consumer price index in period t-2.

As explained by Lavoie and Seccareccia (1999), the Pasinetti Rule proposes a fair interest rate, a level of interest rate that keeps distribution unchanged in terms of hour of labor, therefore, real interest rate should grow following labor productivity growth:

$$ir^*_{cb,t} = (1-\kappa)\left(\frac{cpi_{t-1} - cpi_{t-2}}{cpi_{t-2}} + \frac{\overline{\phi}_{t-1} - \overline{\phi}_{t-2}}{\overline{\phi}_{t-2}}\right) + \kappa \cdot ir^*_{cb,t-1} \tag{4.6.1.3}$$

where
$ir^*_{cb,t}$ is the effective nominal basic interest rate in period t;
κ is the interest rate smoothing parameter;
$ir^*_{cb,t-1}$ is the effective nominal basic interest rate in period t-1;
cpi_{t-1} is the consumer price index in period t-1;
cpi_{t-2} is the consumer price index in period t-2;
$\overline{\phi}_{t-1}$ is the average labor productivity in period t-1; and
$\overline{\phi}_{t-2}$ is the average labor productivity in period t-2.

Finally, as proposed by Wray (2007), the Kansas City Rule defines that the nominal interest rate should be zero, and real interest rate might even be negative if inflation is positive. So:

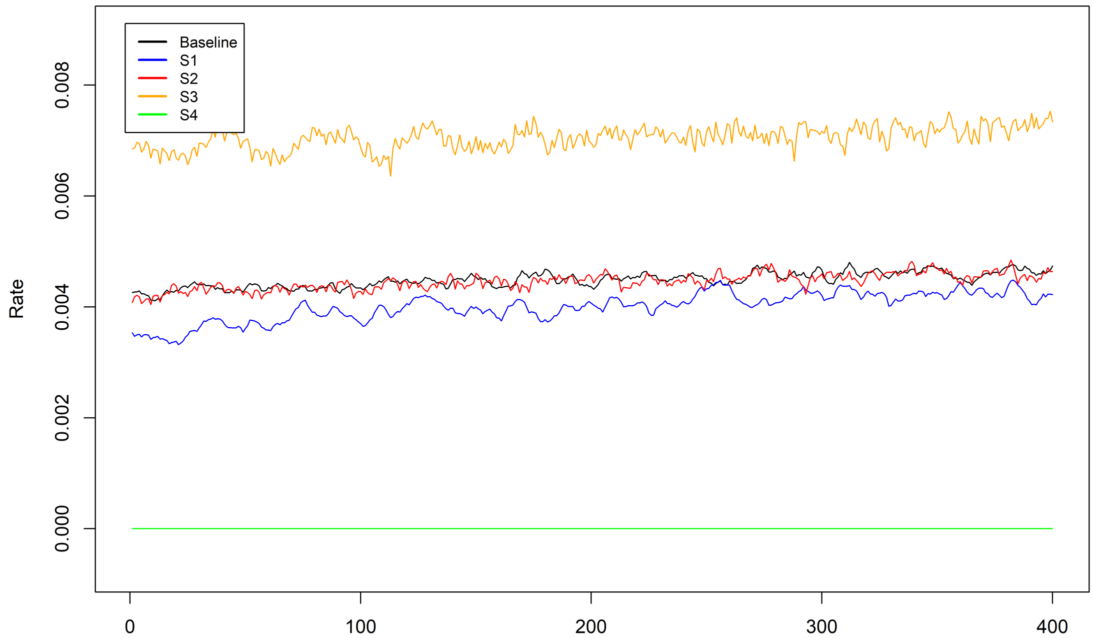
$$ir^*_{cb,t} = 0 \tag{4.6.1.4}$$

where
$ir^*_{cb,t}$ is the effective nominal basic interest rate in period t.

4.6.2 Simulations

To better isolate the effect of the monetary policy rule alone, we left the other policies as we find the best results in the previous experiments, that is, with unconstrained fiscal policy and fixed exchange rate. Further exploration to see the impact of each alternative rules combined with other fiscal and exchange rate policy are still required. So, the baseline here now describes an economy with a Single Mandate Taylor Rule, focusing on inflation, fixed exchange rate and unconstrained fiscal policy. Table 4.10 presents the comparative results and the p-value against the null-hypothesis where there is no difference between the cases, whereas Figure 4.15 plots the basic interest rate behavior under each rule.

Figure 4.15: Alternative Rules - Central Bank Basic Interest Rate



Source: Author's elaboration. MonteCarlo averages from 100 simulations of the basic interest rate set by the Central Bank.

Several insights can be obtained with the comparative results. First, the introduction of economic activity as a mandate in the Taylor Rule generates unconventional results. Instead of reducing real stability, it does increase the volatility of GDP growth, as the interest rate volatility also increases, although its average level is lower. As we saw, the traditional interest rate channel is relatively week if compared to the interest-cost channel, which we have found to create a negative impact on real stability as well. Moreover, the inverse bank lending channel is also active, whereas the only transmission channel of monetary policy to positively affect output is disabled, as we are assuming a fixed exchange rate regime. Thus, if only perverse

Table 4.10: Alternative Monetary Policy Rules - Comparative Results

Variable	Dual	Smithin	Pasinetti	Kansas
Volatility of GDP Growth	1.0391	1.0150	1.0154	0.9989
	(0.0400)	(0.4800)	(0.4535)	(0.9581)
Capacity Utilization	0.9993	0.9995	0.9998	0.9985
	(0.2299)	(0.4160)	(0.7733)	(0.0208)
Volatility of Capacity Utilization	1.0203	1.0040	1.0021	0.9896
	(0.1877)	(0.7743)	(0.8870)	(0.4759)
Likelihood of Crisis	1.0164	0.9893	0.9955	0.9873
	(0.1406)	(0.3221)	(0.6808)	(0.2209)
CPI Inflation	1.0007	1.0006	1.0006	1.0006
	(0.3823)	(0.4208)	(0.4652)	(0.3761)
Volatility of CPI Inflation	0.9963	1.0307	1.0997	0.9004
	(0.7817)	(0.0291)	(0.0000)	(0.0000)
Profit Rate	1.0000	1.0000	0.9927	1.0128
	(0.9961)	(0.9968)	(0.0002)	(0.0000)
Profit Share	0.9980	0.9999	1.0121	0.9894
	(0.0015)	(0.9215)	(0.0000)	(0.0000)
Wage Share	1.0038	1.0001	0.9774	1.0198
	(0.0015)	(0.9215)	(0.0000)	(0.0000)
Basic Interest Rate	0.8925	0.9933	1.5713	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Volatility of Basic Interest Rate	1.4547	1.1089	1.7619	0.0000
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Firms Avg. Debt Rate	0.9990	1.0022	1.0159	0.9805
	(0.7926)	(0.5541)	(0.0001)	(0.0000)
Classes Avg. Debt Rate	1.0024	0.9780	0.8164	1.1542
	(0.9124)	(0.3377)	(0.0000)	(0.0000)
Financial Sector Default Rate	0.9704	0.9861	1.0176	0.9478
	(0.1325)	(0.4908)	(0.4039)	(0.0113)
Financial Sector Demand Met	1.0016	1.0008	0.9953	0.9840
	(0.2977)	(0.6059)	(0.0064)	(0.0218)

channels are present, a volatile interest rate increases real instability, without having any effect on inflation, as the exchange rate-cost channel is also disabled.

The same occurs for the Smithin and Pasinetti Rules, as the nominal interest rate fluctuates as inflation does. Under those rules, the volatility of the basic interest rate is even higher, and it increases the volatility of inflation, confirming that any reactive function is instead destabilizing, at least nominally as there are no significant differences in GDP and capacity utilization volatilities nor the likelihood of crises. The difference between the Smithin and Pasinetti Rules is considerable. The Smithin Rule has a similar effect to the traditional Taylor Rule, except that the latter reacts to expected inflation, while the former reacts to past inflation, which increases interest volatility.

These rules, which are focused on the distributive effects, fail in their goal, as the average wage share reduces and the profit share increases under the Pasinetti Rule and there is no significant difference under the Smithin Rule. The personal distribution is also affected, as the average Gini index on income (not shown) is higher under the Pasinetti Rule. Adjusting the basic rate by productivity change in addition to the inflation increases both the level and the volatility of the nominal interest rate. The only rule that effectively stabilizes the nominal rate is the Kansas City Rule, our last case. The Kansas City Rule, as it parks the nominal basic interest rate at zero, can improve income inequality, as the wage share increases and the Gini index on income (not shown) is lower in comparison with the other rules. However, as it reduces rentism and the financial sector profits, in the presence of a regulatory rule, the banks' ability to grant loans is compromised, and the credit rationing increases, even if firms' average indebtedness and the default rate are lower.

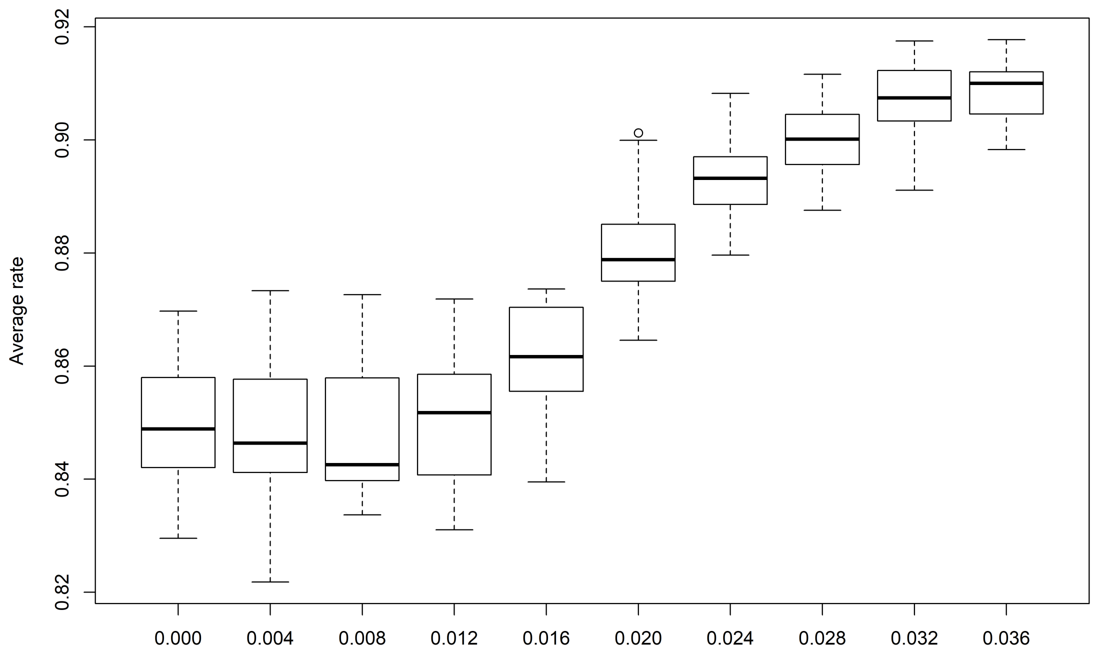
To better capture this interaction with credit granting, we explore different levels[10] of the basic interest rate to leave it stationary, instead of limiting the Kansas City approach only to a zero-level, and we see that the presence of an inverse bank lending channel created by a Basel-like regulatory rule increases instability, as lower levels of the basic interest rate, for the same regulatory rule, induce higher credit rationing (Figure 4.16), lowers effective investment and reduces real GDP growth in the long run (Figure 4.17).

To keep the same profit rate, firm's mark-ups are higher for higher levels of the interest rate (Figure 4.18), compressing the wage share (Figure 4.19), which is already reduced by the increase in financial sector profits (Figure 4.20). The worsening functional distribution affects personal inequality (Figure 4.21) and the households' indebtedness (Figure 4.22). Finally, as mark-ups and interest costs are higher, in the presence of the interest-rate cost channel, the CPI inflation rate grows when the interest rate also grows, contributing to the worsening of inequality, and creating a trade-off between growth and inflation (and inequality).

For the Kansas City Rule to work by reducing inequality and inflation, the conditions of the banking sector need to be taken into account, especially the regulatory rule which cannot be alien to the interest structure and profitability of banks. The regulatory rule should be dynamic and specific to each institutional setting, as a Minskyan approach to regulation should be (Kregel 2014), which is an argument against the "universal" rules of regulatory capital adequacy in which the same pro-

[10]As we want to test several levels, due to time and computational cost constraints, we reduce the number of simulations to 25. Increasing the number of simulations to 100, as we did so far, would give more robustness to our findings.

Figure 4.16: Interest Rate Levels - Average Credit Demand Met by Banks

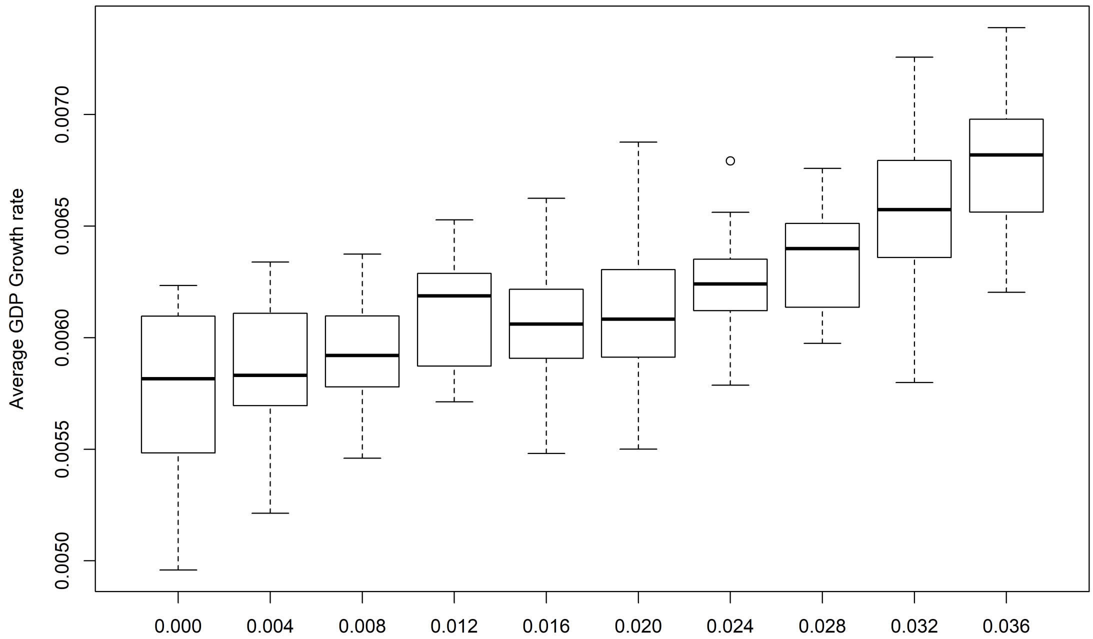


Source: Author's elaboration. 25 simulations MonteCarlo distribution of the average credit demand met by banks for different levels of the basic interest rate. Bar: medians. Box: 2nd and 3rd quartiles. Whiskers: minimum and maximum values. Points: outliers.

portion is applied to banks in more competitive and less profitable scenarios, as in Europe, and in conditions of greater concentration and profitability, as in Brazil. Despite this finding, the exploration of prudential rules and conditions in the banking sector is outside the limits of this thesis, although we have contributed to allow the future study of these points using the model presented herein.

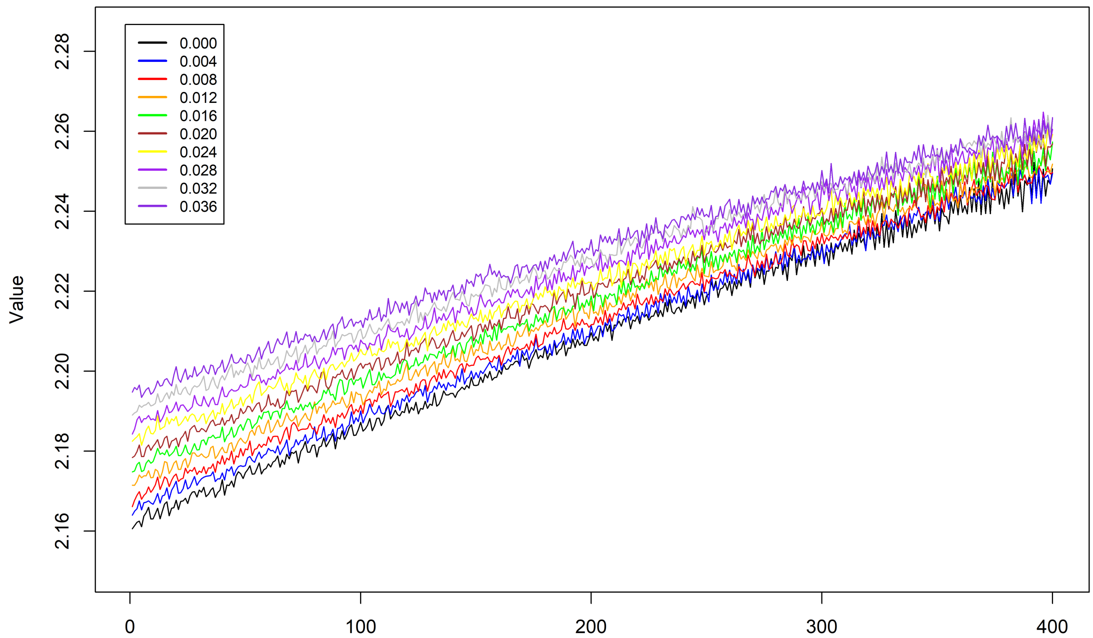
We should note that, in such policy combination, some effects of the different levels of the basic interest rate are absent, as if the basic rate is set too far apart from the external interest rate, the net capital flows will increase, but with fixed exchange rate it does not impact prices and real exports, only the levels of external debt and/or international reserves. There are also fiscal effects, as with unconstrained fiscal policy, there is a fixed real growth rate for government expenses, which can be different from the effective growth rate of GDP for different levels of the basic interest rate, possibly creating continuous government primary surplus or deficit. Further exploration of alternative fiscal strategies and exchange rate levels should be done. Moreover, the focus of this thesis is the effect of monetary policy on price and output stability, but we have theoretically recognized the distributive effects of monetary policy, as they are the focus of the alternative Post-Keynesian rules. As our model accounts for income stratification, it is suitable to investigate the functional and personal income distributions, their relationship with economic policy effectiveness,

Figure 4.17: Interest Rate Levels - Average Real GDP Growth Rate



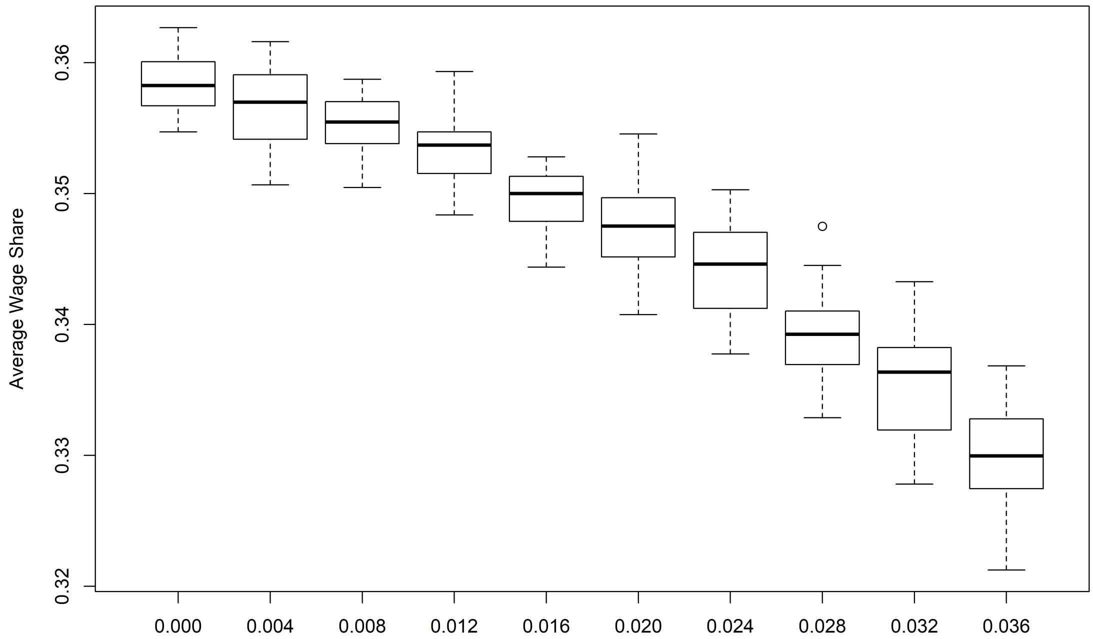
Source: Author's elaboration. 25 simulations MonteCarlo distribution of the average real GDP annual growth rate for different levels of the basic interest rate.Bar: medians. Box: 2nd and 3rd quartiles. Whiskers: minimum and maximum values. Points: outliers.

Figure 4.18: Interest Rate Levels - Average Mark-up



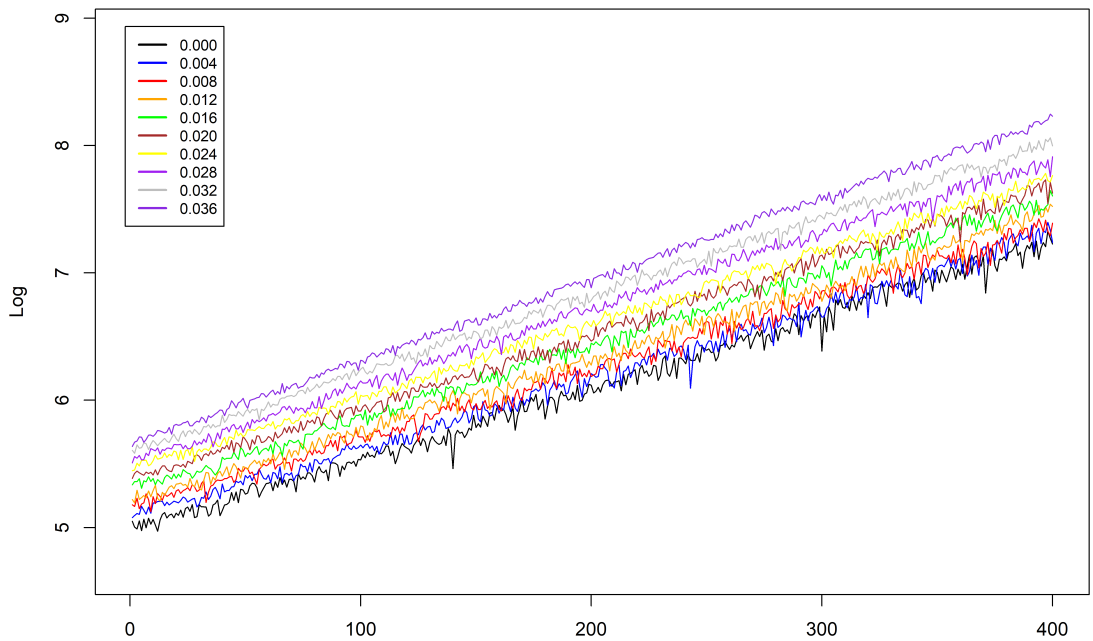
Source: Author's elaboration. MonteCarlo averages for 25 independent simulations.

Figure 4.19: Interest Rate Levels - Average Wage Share



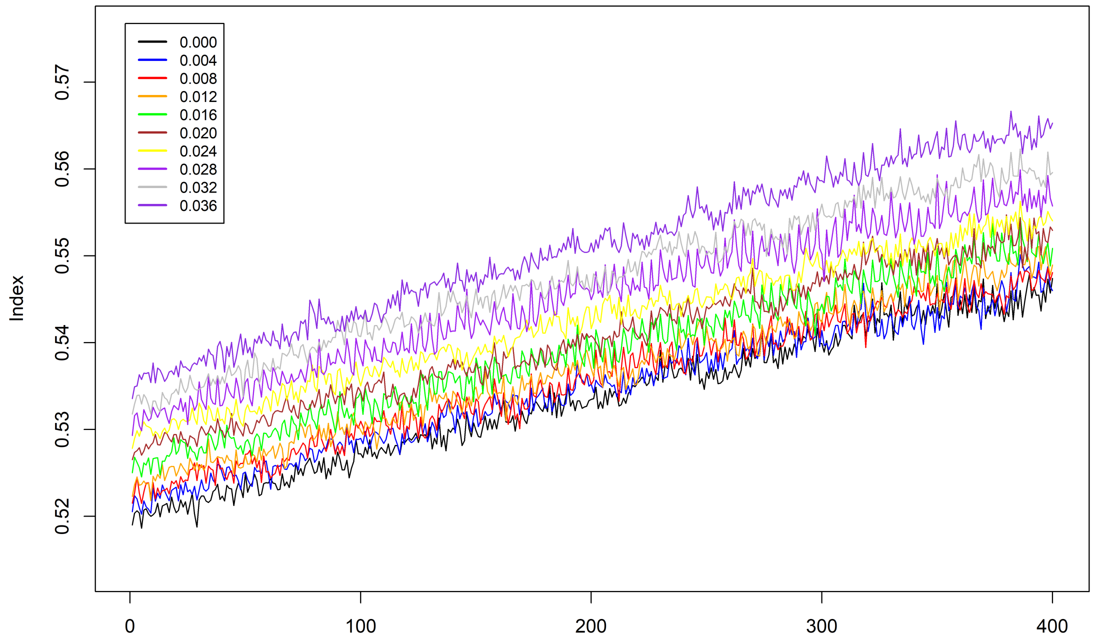
Source: Author's elaboration. 25 simulations MonteCarlo distribution of the average wage share for different levels of the basic interest rate. Bar: medians. Box: 2nd and 3rd quartiles. Whiskers: minimum and maximum values. Points: outliers.

Figure 4.20: Interest Rate Levels - Financial Sector's Profits (Series in Logs)



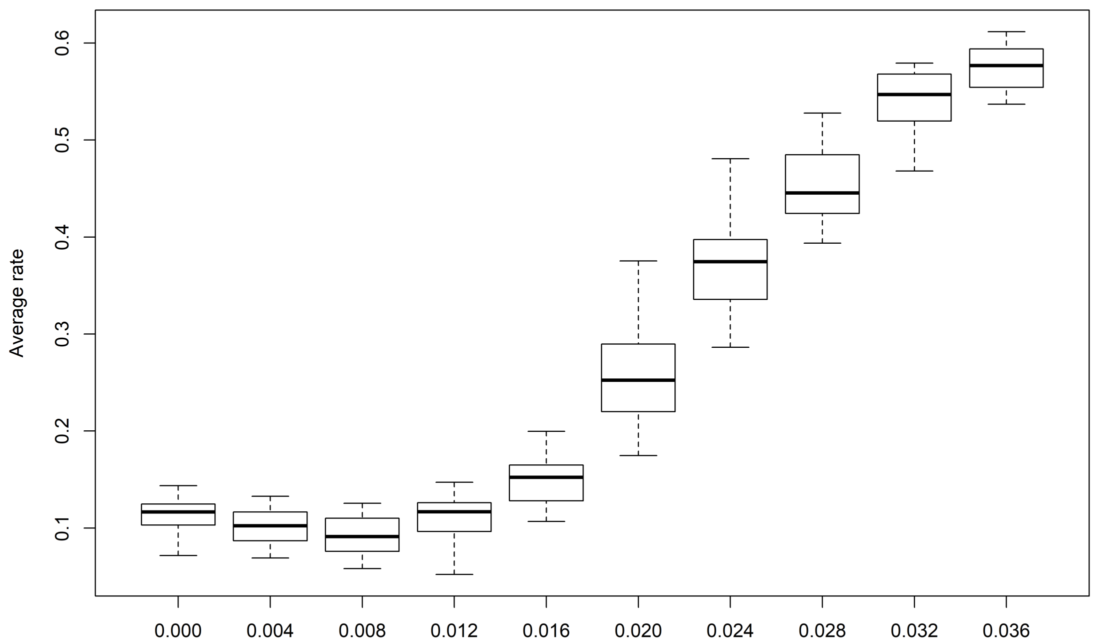
Source: Author's elaboration. MonteCarlo averages from 25 simulations of the financial sector profits in log.

Figure 4.21: Interest Rate Levels - Average Gini Index on Income



Source: Author's elaboration. MonteCarlo averages from 25 simulations of the Gini index on income.

Figure 4.22: Interest Rate Levels - Average Households' Debt Rate



Source: Author's elaboration. 25 simulations MonteCarlo distribution of the average debt rate of income classes for different levels of the basic interest rate. Bar: medians. Box: 2nd and 3rd quartiles. Whiskers: minimum and maximum values. Points: outliers.

and how distribution can be targeted by policies. This is, however, motivation for future research.

4.7 Discussion

In this chapter, after an extensive calibration procedure following stock-flow consistency norms and after validating the baseline configuration by showing a vast list of replicable stylized facts, we employed our newly presented version of the model to perform some policy experiments on monetary policy. Although the experiments are not exhaustive, we were able to gain some insights.

First, average inflation rate seems to be unsensible to arbitrary inflation target set by the Central Bank. An inflation target regime cannot set a target that is too different from the the inflation generated by the economic conditions and structure. This happens because, even if all transmission mechanisms in favor of monetary policy effectivness were acting, there is nothing in the monetary policy conduct that anchor inflation expectations and thus decisions are not based on the target set by the Central Bank. There is no credibility on the Central Bank[11].

Second, we study the structural conditions that cause inflation, especially in an open-economy with input-output structure. By employing a sensitivity analysis, we find that the initial (or structural) share of imported inputs and the weight given by the firms to external competitors' price when they set their prices are the factors responsible to generate domestic inflation for a given growth rate of external prices, which is what most affects the inflation rate, especially the external price of inputs. Interstingly, those two factos are exactly what create the exchange rate-cost channel of monetary policy.

Third, as we performed some simulations isolating each transmission channel of monetary policy in the model, we reinforce the above finding, as both the traditional and the cost channels of the exchange rate are those who act in favor of the stabilizing effect of the Taylor Rule. However, as the traditional interest rate channel has no signifficant impact and the interest rate cost channel has a much more direct effect, a perverse effect as in the case of the inverse bank lending channel, rising the basic interest rate might have some disrupting effects, especially via the financial channels, even if inflation volatility reduces via the exchange rate channel. Monetary policy is erratic and there is actually a trade-off between real and nominal stabilization.

Fourth, as monetary policy effectivness thus depends on the flexible exchange

[11]We performed preliminary experiments on Central Bank credibility, adjusting nominal wages by the inflation target instead of the past inflation. However, if credibility deteriorates cumulatively with deviations of effective inflation from the target, as there are perverse transmission mechanisms, such errors often occur and credibility is quickly lost, causing wage adjustment to be based again in past inflation.

rate regime, and there is also a strong interaction with fiscal policy, we explore unconventional policy combinations to see how monetary policy interact with them and to check if there is a strategy that produces better economic results. We find that, for real stabilization and for the lon run result, fiscal policy should be unconstrained without any negative effects on inflation. Moreover, when combined with this fiscal policy, fixed exchange and interest rate also generate the lower inflation volatility from all combinations, a policy mix that is diametrically opposed to the NCM recommendations.

Fifth, we test alternative monetary rules in combination with better fiscal and exchange policies, including some Post-Keynesian alternative rules which are concerned with the distributive effect of the interest rate. We find that any rule that makes the nominal interest rate volatile, such the single mandate Taylor Rule, a dual mandate Taylor Rule or even the Smithin and Pasinetti Rules, are destabilizing. The last two even fail to improve income distribution, as they propose. As it is the nominal rate that really matters, it is this variable that should be stationary, as supported by the Kansas City Rule, but in order for it to properly work, the Basel-like regulatory rule that creates the inverse bank lending channel must be revised. Otherwise, there will be a trade-off between real growth and inflation and inequality. We make this trade-off evident as, in our final exercise, we test several levels to park the nominal interest rate.

Conclusion

In this thesis, we tried to question the three pillars of the conventional economic thinking, regarding the role of economic stabilization and economic policies in general, with particular attention to monetary policy. The three pillars are (i) the theory; (ii) the models and methodology; and (iii) the policy recommendations.

In the first chapter, we reviewed the theoretical foundations of the NCM, which lead to the policy implication that monetary policy is fully capable of providing both nominal and real economic stability. That was the view before the GFC, consolidated after two decades of evolving economic thoughts and empirical evidence of the Great Moderation. Although the conventional literature usually identifies five or six transmission channels of monetary policy, with some debates on the intensity and/or validity of specific channels, all of them will lead to the same conclusion that there is a negative correlation between the basic interest rate and aggregate demand. Moreover, as there is the underlying assumption of perfect competition, and inflation is always explained by excess demand, the monetary authority which pursues inflation target using a reaction function, such as the Taylor Rule, will succeed to provide both price and output stability.

In addition to the empirical and theoretical questioning to each traditional transmission channel we bring some alternative mechanisms onto debate. To shed some light on these unconventional channels it is necessary to relax the simplistic but important hypothesis of perfect competition, and search for alternative theories, such as the Post-Keynesian and the Kaleckian ones. If some degree of oligopolistic competition is considered as the Kaleckian approach emphasizes, the cost structure gains more importance to price setting, and so other factors unrelated to the basic interest rate might affect prices, whereas the basic rate might affect demand and prices via different channels, turning the final result ambiguous. We highlight two channels of cost-plus inflation, what we call direct transmission mechanisms of monetary policy to price: the exchange rate-cost channel and the interest rate-cost channel. While the first works in the expected direction of the NCM, and it might be the main explanation for inflation targeting regime effectiveness in some economies such as in Brazil, the second is important to explain the well-known phenomenon of the price-puzzle, and work in the opposite direction from what the conventional Taylor

Rule expects. Moreover, based on endogenous money theory, which is present in the Post-Keynesian literature, and on strong recent empirical evidence, there might be an inverse bank lending channel instead of the traditional one, creating a positive correlation from the basic rate to demand.

By discarding the assumption of perfect competition, the traditional channels become indirect channels of monetary policy, as they affect prices, if they do it, via aggregate demand. Thus, we also discussed alternative explanations for the link from demand to prices. While the perfect competition is possible in some *flexprice* markets, in general, demand affects prices via diminishing returns and especially via distributive conflict. If there is a positive correlation from demand to prices, even if not due to perfect competition, the monetary policy channels which affect demand become indirect channels to prices. Still, with some indirect channels presenting a positive correlation with demand and others with a negative correlation, and also with some direct channels presenting positive effects on prices when others present a negative effect, we cannot ascertain *a priori* the final effect of a basic interest rate increase in real and nominal stabilization.

Moreover, while discussing alternative transmission mechanisms, we have recognized that most monetary policy analyses is done in a macro level, in an aggregate approach, abstracting heterogeneities and microeconomic aspects. When micro and sectoral factors are considered, the same channel might have different effects on different sectors of the same economy, or even on different firms of the same sector, in a way that not even the macro effect of one individual channel can be defined *a priori*. Considering the complexity involved, analytical models or models based on representative agents might distort the implications of monetary policy when rough simplifications are made. We need models which integrate micro and macro aspects and which accounts for firm-level and sectoral-level heterogeneities, which consider the complex and evolving financial structure and interrelations and the interactions of several traditional and alternative transmission mechanisms of monetary policy. Heterodox simulation models appear in recent years as a robust alternative, tackling the second pillar of the conventional economic thinking: the methodology.

The second chapter thus reviewed the methodology of recent heterodox approaches to simulation models, especially the Agent-Based and the Stock-Flow Consistent ones. AB models follow a similar mathematical instrumental framework, although theoretical assumptions vary greatly from model to model. In this framework, each basic unit, the agent, has its problem defined and its own behavior rules heterogeneously, unlike the representative utility-maximizing agent characteristic of DSGE models. This approach is widely used by Neo-Schumpeterian authors who focus more on micro issues, trying to somehow make a micro-macro integration. Such a tool allows us to analyze complex systems, characterized by micro-macro interactions, that is, macro results depending on, as well as influencing the interaction of agents at the micro level. SFC models are macro models that attempt to coherently integrate the stocks and flows of an economy. Consistency between flows and stocks is generated by a series of accounting identities derived from the transaction matrices and balance-sheets of each sector. It is noteworthy, however, that the consistency between stocks and flows is nothing more than a condition that should necessarily be met in all models to be consistent and robust.

A common critique of SFC models is that they are sectoral models, thus authors which are averse to the notion of a representative agent seek to improve the micro foundation of SFC models. It is possible to criticize some basic AB models for a lack of consistency between stocks and flows. They are, however, theoretically complementarity, as AB models are generally concerned with more productive aspects, firm's investment decisions, innovation, and technological progress, while SFC models generally focus on the financial sector, financial decisions, different assets, and real-financial relations. For these reasons there is an open research agenda which proposes the integration of the two approaches as a strong alternative to DSGE models, both methodologically and theoretically. We discuss the origin, essential elements, the basic structure, and the main literature models of those two approaches individually to identify the complementarities between them, as proposed by the integration literature.

We have found, however, that a family of heterodox models already integrated, albeit initially, these two approaches. The Multisectoral Micro-Macro model already includes elements of both types of models, and it is a robust, integrated theoretical and methodological framework, which combines foundations from Keynesian, Kaleckian and Schumpeterian approaches. But as the model was developed before the GFC, and as we have identified that most transmission mechanisms of monetary policy interact with the financial sector, we reviewed the recent AB-SFC literature in search of what the minimal financial sector structure would be, and using it as a reference, developed the financial sector in the MMM model. The review has worked not only towards that goal but also to facilitate a comparative exposition using the same symbols and notations, and thus putting all the models onto a common ground.

The minimal structure in this agenda is a credit market specification, while equities, stocks, and bonds markets, which would represent a more complete financial sector, are usually abstracted. It seems that this choice is justified in an attempt to keep models still simple, but able to capture financial dynamics and elements. The presence of at least a single bank, or an aggregate banking sector which provides loans to finance firms' decisions is unanimous. That same bank usually provides deposit accounts for the agents. In terms of firms' demand for credit, it seems a consensus to adopt a pecking order theory of investment. Therefore, in a basic

AB-SFC model, a firm's demand for credit is always the difference between desired expenses and internal funds. Firms can be credit constrained, and the individual credit supply and credit rationing mechanism seem to be the most controversial aspect of the AB-SFC modeling so far. There are several different ways through which a bank can access the creditworthiness of its clients. However, almost every model assumes that banks' total amount of credit is limited by a regulatory rule, plus some kind of individual decision regarding financial fragility. Bank's liquidity preference is expressed by the total amount of credit that a bank can provide. Finally, a basic interest rate set by the Central Bank following a Taylor Rule might be a consolidated starting point in interest setting. Moreover, it is frequently assumed that interest rate on deposits is defined by a mark-down over the basic rate, whereas the base or average interest rate on loans is determined by a mark-up over the Central Bank interest rate. However, models might differ on the level of detail and interest differentiation. The search for a minimal consensus modeling of the financial sector in the AB-SFC approach helped us develop some new formulations in the MMM model.

Thus, in the third chapter we presented what we called the Finance-Augmented MMM model, a new version of the consolidated MMM model, introducing most elements of the minimal financial sector structure in the AB-SFC literature, but considering the already existing structure of the consolidated model and its particularities. As such, we discussed the origin, theoretical roots, and main features of the model. The exposition of the model took a large part of this thesis, as it also took a large part of the research. The development of this new version contributed to a broader goal of the research in general: to turn this theoretical and methodological tool even more user-friendly and modular, so future developments could be easily implemented in the future, and the framework could be used for several other analysis and research questions, far beyond the scope of the thesis. So, as it was important to make the model easier to use, fully translated to English, freely available, and with a detailed description in the code, it was also important to make the understanding of the model as easy as possible. That is why we presented its description in detail, in several ways, and using the same symbols and notations used in the second chapter, to facilitate a comparative approach.

The model is calibrated following stock and flow consistency rules in order to avoid any unbalance and forced trend in the initial configuration, as we employ a calibration procedure proposed by the AB-SFC agenda. Even though the starting point is a non-growth steady state condition, the model is able to generate endogenous growth and cycles when the dynamic elements begin and start interacting. We show that the model replicates a considerable list of stylized facts on both growth and cycles, as it already did in its consolidated version, but we were able to replicate some additional stylized facts on financial variables, in line with several empirical evidence, validating our version as a robust representation of a theoretical economy. The baseline configuration of the model also generates a volatile but stable CPI inflation rate, on average around 1.8% annually. We verified, however, that this result is insensitive to the inflation target set by the Central Bank, as we begin our simulation experiments.

In an open economy, where firms operate under oligopolistic competition, and prices are set following a mark-up rule over unit variable costs, the cost structure and the sectoral competitive conditions are determinant to explain domestic inflation, which also depends on the external inflation. The average CPI inflation rate is strongly dependent on the external prices, especially the price of consumption goods, which has a direct effect on the households' consumption basket, but also the price of intermediate goods, as a share of inputs used in production is imported. This share is the main structural factor which generates domestic inflation for a given external inflation. The higher the structural share of imported inputs on the productive structure, the higher the impact of external prices on domestic inflation. The sensitivity analysis procedure we implemented showed that effect. When compared to the structural conditions of the economy, the monetary policy has insignificant effects on the average inflation rate, so the monetary authority cannot force inflation towards a target which is incompatible with the structural condition of the economy.

As we analyze the transmission mechanisms of monetary policy, these findings become even more evident. We find that the traditional exchange rate channel is the strongest transmission mechanism from the basic interest rate to demand, acting in the expected direction of the Taylor Rule, but the exchange-rate cost channel has a considerable negative effect on inflation volatility. So, simultaneous goals of nominal and real stability are incompatible if they are all in the shoulders of the monetary policy. These transmission mechanisms rely on the exchange rate flexibility, and so does the relative efficacy of monetary policy. The other channels are less potent, especially the traditional interest rate channel, as its main impact is on the modernization investment, which is a small share of total investment, which in turn is a small share of GDP. Combining the small weight with the its delay, as it impacts only new loans and will effectivelly impact investment only if firms are effectivelly credit constrained. If that is the case, however, the basic rate increase has a much more immediate impact as it is passed onto prices as a cost. The interest-cost channel is active, and it works against monetary policy effectiveness, corroborating the vast evidence of the so-called price-puzzle.

The monetary policy effect in an open economy strongly depends on its interaction with the exchange rate regime, but the basic interest rate has a strong interaction with fiscal policy as well. Therefore, we tested several policy combinations, although preliminarily, confirming our findings and showing that unconstrained fiscal policy is much more relevant to mitigate real instability than monetary policy, even in flexible exchange rate regimes, without compromising inflation. Policymakers could improve economic performance, even in the long-run and especially in face of a deep recession, if budget constraints and limits on public indebtedness were relaxed, and alternative proposals to the Taylor Rule were thought out, taking conventional monetary policy out of its position as the main or the only viable policy.

As monetary policy is too erratic in the presence of perverse transmission channels, and less effective than fiscal policy in reducing real stability, we investigated alternative monetary rules, especially considering the distributive effects of interest rates. The Taylor Rule, whether single or dual mandate, is destabilizing. Likewise, the Smithin and Pasinetti's Rules also act in this sense, as they condition the fluctuations of the nominal basic rate to inflation, which can create puzzling and spiralling effects. As argued by Wray (2007), the nominal rate is the relevant variable for economic decisions and consequently for output and price stability, so that rules seeking to keep the real rate stable do not reduce economic instability. Thus, Wray's view that the nominal base rate should be parked is corroborated, but in the presence of also destabilizing prudential rules, bringing the nominal interest rate level to zero slows down economic growth through the channel of banking profitability and credit rationing to investment, despite contributing to the reduction of inflation and income inequalities, both functional and personal. Not only must fiscal and exchange policies be thought out in conjunction with the monetary policy, but prudential regulation is a relevant factor and must be dynamic, following a Minskyan approach, to prevent a Kansas City-type monetary rule from creating a trade-off between economic growth and inflation and inequality.

Our simulation results are far from being exhaustive or definitive, as we ended this thesis with even more questions than when we started. However, as it was the objective of this work to question the theoretical foundations and methodological approaches that guide the policy recommendations of the New Consensus, we believe that we have successfully achieved this goal by presenting and enhancing a model that coherently integrates Keynesian, Kaleckian and Neo-Schumpeterian theories, and constitutes part of an emerging methodological agenda which proposes the combination of Agent-Based and Stock-Flow Consistent methodologies as an alternative to DSGE models. With such tool in hands, a solid way is built for the path forward, to further deepen and improve policy analysis.

We can therefore glimpse the horizon of future work. As the structure of the model is multisectorial, the composition between the sectors should be better explored, and the sectoral technical parameters should be changed to better understand the impact of the same policy on different productive structures. Still, regarding the particular focus of this work, each transmission channel can also be explored individually to capture the importance of heterogeneity, possible asymmetries, and the relative importance of conditions and factors which modulate the intensity and the effectiveness of each channel. Finally, the other economic policies deserve equal attention and thoroughness.

The role of fiscal policy, which was initially discussed in Dweck, Vianna, and Cruz Barbosa (2020), can be further examined by experimenting with different compositions of the public budget, by dynamically measuring the value of the fiscal multiplier, and by studying different taxation structures as well. The role of exchange rate policy and the external sector should also be explored, but it would require additional implementations in the current version of the model presented herein, as the external sector is considerably simplified. Refinements in line with Reif (2006) and Busato (2010) would not only fulfil this role, but would further integrate different versions and structures of the model too. Alternative prudential rules should also be investigated under different financial sector structures, as we found that regulation has a strong interaction with monetary policy and worked to introduce the financial elements in the model. To end up, taking advantage of the income classes structure present in the model, the role of income distribution and inequality in the effectiveness of all the aforementioned policies, individually and combined, is an extremely relevant topic, as well as the impact of these policies on distributive change and on the reduction of inequalities, which have real economic consequences, in addition to the obvious social ones.

While the road ahead is long and wide, we can conclude this work with at least one powerful insight. Economic policy is a choice. When policymakers give such importance to monetary policy in the stabilization role and relegate fiscal policy to the background, this is a choice. A choice that is supported by specific models and based on specific theories. The limits of the theories and of the methodology lead to a policy choice which might not generate the best economic results in terms of stability, whereas under the light of alternative approaches that do not impose reductionism and distortions to the economic object, the power of usually relegated policies becomes more evident, as the omnipotence of monetary policy is questioned. In fact, as the effects of monetary policy are much more erratic, and via some alternative transmission channels, the results could be diametrically opposed to what conventional wisdom expects, policymakers might be contributing to economic instability and deepening crisis and recessions if they employ inefficient choices, whereas more powerful strategies could be chained by austerity narratives, as an example. As it has been a decade or so of slow recovery after the GFC with constant critiques, but with no real change to conventional policy strategies, and as the economic consequences of the recent Covid-19 crisis do not present signs of quick disappearance, a new round of economic rethinking might be coming, and active fiscal incentives appear as a feasible and necessary strategy. It might be time to leave monetary policy in the background and to make new choices toward policy, methodological and theoretical alternatives.

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Appendix A

Model Comparison with the Literature

Dawid and Gatti (2018) present a remarkably interesting and extensive comparative review of the literature on macro agent based models (MABMs). Table A.1 presents a description of the simplified version of our model in the categories analyzed by the authors.

A few features and differences are not captured by this table, but it is important to compare our model with eight well-known MABM families presented in the review. The first feature not captured by Dawid and Gatti (2018), as pointed by the authors, is the timeline of events, but this is already shown in past sections and almost every main paper of the eight families of models present its own timeline. Additionally, the authors do not focus on the time discretization of the models, but this was also presented herein for our model. Finally, they do not show the network structure of the models in their comparison. However, our model does not require a network structure, as individual demand decisions are aggregated in the sectoral level and redistributed by a replicator dynamics, as already shown.

There are also some main features of the MMM model which are not captured by Dawid and Gatti (2018) categories, but they represent main differences of our model in relation to other families. The first one is the multisectoral structure, with the intermediate goods sector. Most of the stylized models use only one or two production sectors, differentiating only consumption goods and capital goods. In addition, the general specification of our model allows many sectors, as proposed by Possas (1984) and used in a sectoral level simulation model by Busato (2010) and Busato and Possas (2016). Some other models allow this kind of specification which captures sectoral relationship and endogenous demands, which are important determinants of capitalist economies (Possas 1984). Ciarli and Valente (2016), for example, create an endogenous multisectoral structure but still with the lack of intermediate goods and intersectoral production and demand relationships. Very recently, Seppecher, Salle, and Lavoie (2018) proposed a multisectoral model with 3 sectors, but the intermediate goods sector only supplies inputs to the consumption goods sector.

Another absent feature in the table is the external sector. The consolidated version of our model (Possas and Dweck 2004; Dweck 2006) already includes external sector relations, which are main determinants of growth. Reif (2006), Busato (2010) and Busato and Possas (2016) analyze external restriction in a more aggregate version of the model, whereas Dweck, Vianna, and Cruz Barbosa (2020), test different fiscal rules in response to an external shock. In the present version, the external sector is reduced, but it still played an important role in growth determination. There are other models in the literature concerned with the external sector, as Dosi, Roventini, and Russo (2019).

Table A.1: MMM Model - Description as in Dawid and Gatti 2018

Categories	**MMM Model - Simplified Version**
1. General Properties	
Stock-flow consistent?	Yes
Expectations	Firms of every sector have expectations on short-term demand, except for capital goods firms which produce based on current orders. All firms have expectations on long-term demand, for the investment decisions
Type of expectation rules	Simple extrapolative/adaptative rule
Entry of agents?	Only occur when the sector's expected sales are in a growing trajectory
Spatial structure?	No
2. Consumption Goods Market	
Producers	
Single/multiple goods?	Quality-differentiated goods
Production technology	Capital vintages with different labor productivities
Pricing rule	Effective price is a weighted average between desired price and the referece price. Desired mark-ups (desired price) evolving based on firms' market share, technological progress and product differentiation;
Quantity choice	Expected demand plus desired inventories variation

Physical investment	Investment is divided in three parts: replacement due to physical depreciation, expansion due to expected demand and technological replacement based on a payback rule
Households	
Consumption budget	Disposable income, deposits and loans
Purchasing decision	Induced consumption depends on each class' average past income, and autonomous consumption of each class increases with average quality
Interaction Protocol	Replicator dynamics. Market shares determined by prices, quality and delivery delay
3. Capital Goods Market	
Capital Goods Producers	
Differentiated physical capital?	Multiple vintages with different labor productivities
Technological change	Firms in every sector update their possible vintage through innovation and imitation. Innovation is implemented by acquisition of CaG
Pricing rule	Same as in the Consumption-goods market
Interaction Protocol	Replicator dynamics. Production based on received orders, limited to productive capacity; delivered after one investment period
Capital Goods Demand[1]	Orders to CaG sector depend on firms decisions to invest, which is divided in three parts: replacement due to physical depreciation, expansion due to expected demand and technological replacement based on a payback rule
4. Labor Market	
Firms	
Labor demand	All firms demand labor based on effective production and productivity
Wage offers	Firm-specific nominal wage, adjusted over time based on firm's average productivity growth and inflation

[1]This category is not present in the original table presented by Dawid and Gatti (2018) but we added it to our table since investment decisions and therefore capital goods demand is one of the most important part of our model and of every economy.

Workers	
Differentiated workers?	No
Labor supply	Unlimited labor supply
Reservation wage	Not applicable
Interaction Protocol	No explicit interaction protocol
5. Credit Market	
Firms	
Demand for external financing	Liquidity needs which cannot be financed internally from the own funds and liquid assets, limited to a maximum indebtedness. Firms also keep a buffer of liquid assets, proportional to capital stock
External financing options	Only bank credit
Bankruptcy rule	If the firm's level of indebtedness is higher than desired and grows for a sequence of periods
Banks	
Credit supply	Regulatory rule and bank's sensitivities limit the bank's total amount of credit supply, in addition to firm-specific credit rationing
Interest rate	Firm-specific spread over bank's base rate, based on past indebtedness
Regulatory constraints	Basel-type regulatory rule
Bank exit	Not applicable
Interaction protocol	None
6. Stock Market/Financial Management	
Firms	
Dividend payout	No dividends. Firms have a fixed profit distribution rate on net profits, after interest and tax payments
Households	
Financial investment	Income classes can save money and have financial assets, and get loans to spend more than its income
Interaction protocol	Replicator dynamics. Market shares determined by interest rates, credit rationing and defaulted loans

7. Policy Makers	
Government	
Fiscal measures	Public wages, unemployment benefits and government direct demand to sectors
Balanced budget?	Balanced budget, with possible surplus target
Central Bank	
CB interest rate	Single mandate Taylor Rule

Appendix B

Calibration Solution

In this Appendix, we show how initial values are determined based on the exogenous (pre steady-state in Caiani et al. (2016) terms) parameters. Some other parameters are also exogenous, but they are not used in the initial state calculations. They are used only during the simulations runs (free parameters, in Caiani et al. (2016) terms).

One of the most distinctive features of our model, in comparison with the majority of the AB-SFC literature, is the use of different lags in several decision instances: while firms calculate expected demand and effective production every time (production) period, investment decisions, as an example, are calculated with a more sparce gap (Γ periods, with $\Gamma = 4$ in the baseline scenario). To avoid synchronization and unrealistic peaks, not all firms decide their investment expenses at the same time. In fact, we divide the initial firms equally. To illustrate it, let us suppose that for a generic sector j, the investment frequency is four production periods, and there are 20 firms in this sector, so five firms will make their investment decisions in the first time step, another five in the second, five more in the third and the last five in the fourth time period. In the fifth time period, the first five firms will make their investment decisions again, as four production periods have passed since the last period they calculated investment expenses.

Once we know each firm that will invest in each period, we must define how many capital goods will physically depreciate for each firm at each investment period for the firm, ideally one, the minimal number possible[1], effectively creating a regular depreciation chronogram for the first capital goods of the first firms. This will help us stabilize the initial demand for capital goods: as we have no expansion or replacement investment, the only capital demand by the firms is to replace those capital goods which physically depreciated. It is easy to see that the initial real

[1] Although this is a model parameter, we will define it as one, and exploration over other values will not be done here.

capital demand by the firms in the model will be:

$$INV_0 = p_{k,0} \sum_{j=1}^{N} \frac{F_{j,0}}{\Gamma_j} \tag{B.1}$$

where
INV_0 is the initial nominal (private) investment (endogenous);
$p_{k,0}$ is initial price of the capital sector k (exogenous);
N is the number of sectors (exogenous);
$F_{j,0}$ is the initial number of firms of sector j (exogenous); and
Γ_j is the investment frequency of sector j (exogenous).

Now that we know the initial demand of the capital goods sector, defined by the aggregate depreciation, the initial scale of the model will be determined. We define the initial shares of GDP, and this can be calibrated by educated guesses or by empirical data: the private investment share of GDP, the government share of GDP, the exports share of GDP, and endogenously, (iv) the private consumption share of GDP. Private investment was just calculated by exogenously defined parameter, therefore, we can define the initial level of nominal GDP, and subsequently the initial amount of government expenses and nominal exports, multiplying the initial GDP by (ii) and (iii). The Government and the External Sector are the exogenous blocks of our model, whereas consumption is endogenous, as in most cases in real economies, and that is why the consumption share of GDP is determined endogenously. Users can also use those parameters to calibrate our model to represent economies where the government size is bigger or smaller, or even calibrate for an economy more or less open to the external sector.

$$GDP_0 = \frac{INV_0}{\Theta_{k,0}} \tag{B.2}$$

$$EXP_0 = GDP_0 \cdot \Theta_{x,0} \tag{B.3}$$

$$GOV_0 = GDP_0 \cdot \Theta_{g,0} \tag{B.4}$$

$$CON_0 - IMP_0 = GDP_0(1 - \Theta_{k,0} - \Theta_{x,0} - \Theta_{g,0}) \tag{B.5}$$

where
GDP_0 is the initial nominal GDP (endogenous);
EXP_0 is the initial nominal exports (endogenous);
GOV_0 is the initial nominal government expenses (endogenous);
CON_0 is the initial nominal consumption (endogenous);
IMP_0 is the initial nominal imports (endogenous);
INV_0 is the initial nominal (private) investment (endogenous);
$\Theta_{k,0}$ is the initial share of private investment over GDP (exogenous);
$\Theta_{x,0}$ is the initial share of exports over GDP (exogenous); and
$\Theta_{g,0}$ is the initial share of government expenses over GDP (exogenous).

In addition, users can also control the initial government expenses composition and the sectoral exports share, meaning that, once the nominal total government expenses are defined, we can also define the government consumption demand, intermediate goods demand and capital demand, if any. The same happens to the external sector: once total nominal exports are defined, by the sectoral exports share, we know the external consumption demand, intermediate demand, and capital demand. Government and external capital demand will sum up with private capital demand to determine the total sectoral demand of the capital good sector.

$$exp_{c,0} = \Xi_{c,0} \cdot EXP_0 \tag{B.6}$$

$$exp_{k,0} = \Xi_{k,0} \cdot EXP_0 \tag{B.7}$$

$$exp_{in,0} = EXP_0(1 - \Xi_{c,0} - \Xi_{k,0}) \tag{B.8}$$

where
$exp_{c,0}$ is the initial nominal exports of the consumption goods sector (endogenous);
$exp_{k,0}$ is the initial nominal exports of the capital goods sector (endogenous);
$exp_{in,0}$ is the initial nominal exports of the intermediate goods sector (endogenous);
EXP_0 is the initial nominal exports (endogenous);
$\Xi_{c,0}$ is the initial share of consumption exports over total exports (exogenous); and
$\Xi_{k,0}$ is the initial share of capital exports over total exports (exogenous).

$$c_{g,0} = \Phi_{c,0} \cdot GOV_0 \tag{B.9}$$

$$i_{g,0} = \Phi_{k,0} \cdot GOV_0 \tag{B.10}$$

$$inp_{g,0} = \Phi_{in,0} \cdot GOV_0 \tag{B.11}$$

$$w_{g,0} = GOV_0(1 - \Phi_{c,0} - \Phi_{k,0} - \Phi_{in,0}) \tag{B.12}$$

where
$c_{g,0}$ is the initial nominal government expenses on consumption (endogenous);
$i_{g,0}$ is the initial nominal government expenses on investment (endogenous);
$inp_{g,0}$ is the initial nominal government expenses on inputs (endogenous);
$w_{g,0}$ is the initial government wages (endogenous);
GOV_0 is the initial nominal government expenses (endogenous);
$\Phi_{c,0}$ is the initial share of consumption on government expenses (exogenous);
$\Phi_{k,0}$ is the initial share of investment on government expenses (exogenous); and
$\Phi_{in,0}$ is the initial share of inputs on government expenses (exogenous).

Following hypothesis 3, both the government and the external sector must start balanced. The initial stock of government bonds (debt) is determined exogenously, given the initial government debt rate over GDP, and since the initial Central Bank interest rate is also determined exogenously, the amount of government's interest payment is already known. For the government debt rate to be constant, initial total taxes must be equal to government primary expenses plus interest payment, and the surplus rate target must be equal to government interest payment over GDP.

$$TAX_0 = GOV_0 + ir_{cb,0} \cdot b_0^s \tag{B.13}$$

$$b_0^s = dr_{g,0} \cdot GDP_0 \tag{B.14}$$

$$st_0 = ir_{cb,0} \cdot dr_{g,0} \tag{B.15}$$

where
TAX_0 is the initial total taxes (endogenous);
GOV_0 is the initial government expenses (endogenous);
$ir_{cb,0}$ is the initial central bank basic interest rate (exogenous);
b_0^s is the initial stock of bonds, government debt (endogenous);
$dr_{g,0}$ is the initial government debt rate over GDP (exogenous);
GDP_0 is the initial nominal GDP (endogenous); and
st_0 is the initial primary surplus target (endogenous).

Similarly, the initial stock of international reserves is given by the initial reserves rate over GDP, determined exogenously, and by the initial GDP. To keep this rate constant, the balance of payments result must be zero, so total imports must be equal to total exports plus net capital flows, whereas the latter is determined by the interest rate difference and the initial GDP. The initial external income is also determined as a multiple of initial domestic GDP.

$$IMP_0 = EXP_0 + cf_0^{nt} \tag{B.16}$$

$$cf_0^{nt} = (ir_{cb,0} - ir_x)\upsilon_x \cdot GDP_0 \tag{B.17}$$

$$y_{x,0} = \eta_{x,0} \cdot GDP_0 \tag{B.18}$$

where
IMP_0 is the initial imports (endogenous);
EXP_0 is the initial exports (endogenous);
cf_0^{nt} is the initial net capital flows (endogenous);
$ir_{cb,0}$ is the initial Central Bank basic interest rate (endogenous);
ir_x is the initial external interest rate (exogenous);
υ_x is the capital flows proportion of GDP (exogenous);
$y_{x,0}$ is the initial external income (endogenous);
$\eta_{x,0}$ is the initial external income proportion of GDP (exogenous); and

GDP_0 is initial GDP (endogenous).

Total taxes are composed by indirect tax on firms and income tax on classes. Sectoral tax rates and classes' tax rate are exogenously defined, and to make sure that total taxes meet the amount obtained with those tax rates, we will use income classes as endogenous closure to the calibration, normalizing their tax rates. Sectoral indirect tax rates remain unchanged. The same happens to imports. Total imports are composed by firms input and capital imports and classes consumption imports. Classes propensity to import will be normalized to meet the total amount.

Sectoral demand of the capital goods sector is already determined, and so is the demand of the consumption sector, as we know the private consumption share of GDP, the government consumption demand and the external consumption demand, as seen in equations 3.5.7.1 and 3.5.7.3. The intermediate goods sector demand depends on the production of all firms, of all sectors, plus government and external demand. By corollary 2.3, we know the capital and consumption sectors production, and given the input technical coefficient exogenous parameters, we can define the intermediate good sector demand.

$$o_{c,0} = \frac{CON_0 + exp_{c,0} + c_{g,0}}{p_{c,0}} \tag{B.19}$$

where
$o_{c,0}$ is the initial real sectoral demand of the consumption sector c (endogenous);
CON_0 is the initial nominal domestic consumption (endogenous);
$exp_{c,0}$ is the initial nominal exports of the consumption sector (endogenous);
$c_{g,0}$ is the initial nominal government expenses on consumption (endogenous); and
$p_{c,0}$ is the initial price of the consumption sector in period t (exogenous).

$$o_{k,0} = \frac{INV_0 + exp_{k,0} + i_{g,0}}{p_{k,0}} \tag{B.20}$$

where
$o_{k,0}$ is the initial real sectoral demand of the capital sector k (endogenous);
INV_0 is the initial nominal private investment (endogenous);
$exp_{k,0}$ is the initial nominal exports of the capital sector (endogenous);
$i_{g,0}$ is the initial nominal government expenses on investment (endogenous); and
$p_{k,0}$ is the initial price of the capital sector in period t (exogenous).

$$o_{in,0} = \frac{o_{c,0} \cdot \alpha_c(1-\iota_c^{in}) + o_{k,0} \cdot \alpha_k(1-\iota_k^{in}) + \frac{(exp_{in,0}+inp_{g,0})}{p_{in,0}}}{1-\alpha_{in}(1-\iota_{in}^{in})} \tag{B.21}$$

where

$o_{in,0}$ is the initial real sectoral demand of the intermediate sector in (endogenous);
$o_{c,0}$ is the initial real sectoral demand of the consumption sector c (endogenous);
α_c is the technical coefficient of inputs of the consumption sector c (exogenous);
ι_c^{in} is the consumption sector c initial propensity to import inputs (exogenous) ;
$o_{k,0}$ is the initial real sectoral demand of the capital sector k (endogenous);
α_k is the technical coefficient of inputs of the capital sector k (exogenous);
ι_k^{in} is the capital sector k initial propensity to import inputs (exogenous);
$exp_{in,0}$ is the initial nominal exports of the intermediate goods sector (endogenous);
$inp_{g,0}$ is the initial nominal government expenses on inputs (endogenous);
$p_{in,0}$ is the initial price of the intermediate sector *in* (exogenous);
α_{in} is the technical coefficient of inputs of the intermediate sector *in* (exogenous);
ι_{in}^{in} is the intermediate sector *in* initial propensity to import inputs (exogenous).

Now it is easy to calculate sectoral variables, such as production, sales (given prices), productive capacity (given the sector capital-output ratio and desired degree of capacity utilization), sectoral stocks of loans and deposits, defined as desired ratios over nominal capital, interest paying and interest receiving, and all firm variables. One sectoral variable is defined endogenously, though: the initial nominal wage. We set prices, profit rate, tax rate, R&D revenue proportion, input technical coefficients, interest rates and productivity endogenously, so the endogenous variable is the nominal wage. Given the initial sectoral production, with the nominal wage and initial productivity, we can calculate the amount of wage payment of each sector, to be distributed to the income classes. We also already know the total amount of net profits of each sector, but the profit distribution rate is going to be determined endogenously too. So, to keep the firms' debt rate stable, in line with the government and the external sector stock-flow variables, the stock of debt must grow at a zero rate as the stock of capital will be constant for the calibration.

By corollary 2.3, sectoral production and sales are equal to sectoral demand:

$$o_{j,0} = x_{j,0} = s_{j,0} \tag{B.22}$$

where

$o_{j,0}$ is the initial real sectoral demand of sector j;
$x_{j,0}$ is the initial production of sector j; and
$s_{j,0}$ is the initial sales of sector j.

Initial sectoral stocks of capital, deposits and loans must be determined based on the initial production. Assuming that firms operate at the desired level of productive capacity, we can calculate total productive capacity, and the initial stock of capitals given sectoral capital-output ratio. Firms start with desired level of deposits, given initial liquidity preference which is a share of capital. Finally, initial debt rate is given exogenously, and once stock of capital and deposits are determined, we can define the initial stock of loans. Note that initial loans are long-term, assuming they were taken to finance the initial capital stock. There are no short-term loans in the beginning, as they are taken to cover net losses:

$$x^p_{j,0} = \frac{x_{j,0}}{pcu^d_j} \tag{B.23}$$

$$k^{s,r}_{j,0} = x^p_{j,0} \cdot \beta_j \tag{B.24}$$

$$k^{s,n}_{j,0} = k^{s,r}_{j,0} \cdot p_{k,0} \tag{B.25}$$

$$dep^s_{j,0} = k^{s,n}_{j,0} \cdot lp_{j,0} \tag{B.26}$$

$$l^s_{j,0} = (k^{s,n}_{j,0} + dep^s_{j,0}) \cdot dr_{j,0} \tag{B.27}$$

where
$x^p_{j,0}$ is the initial productive capacity of sector j (endogenous);
$x_{j,0}$ is the initial production of sector j (endogenous);
pcu^d_j is the desired capacity utilization of sector j (exogenous);
$k^{s,r}_{j,0}$ is the initial stock of (real) capital of sector j (endogenous);
β_j is the capital-output ratio of sector j (exogenous);
$k^{s,n}_{j,0}$ is the initial stock of (nominal) capital of sector j (endogenous);
$p_{k,0}$ is the initial price of the capital goods sector k (exogenous);
$dep^s_{j,0}$ is initial stock of deposits of sector j (endogenous);

$lp_{j,0}$ is the initial liquidity preference of sector j (exogenous);
$l^s_{j,0}$ is the initial stock of loans of sector j (endogenous); and
$dr_{j,0}$ is the initial debt rate of sector j (exogenous).

As initial loans are long-term, we know the amortization expenses of each sector. The goal of private investment in this no-growth steady state is to replace depreciated capital goods to keep the stock of capital constant, as demand is assumed to be constant. Therefore, to maintain the debt rate constant, the stock of loans must be constant too, so new loans must be equal to amortization expenses. New loans depend on the investment expenses and on retained profits, which will be calculated endogenously, so retained profits must be equal to investment expenses minus amortization expenses. The profits distribution rate parameter will be then determined endogenously. Profits are easily calculated as we know exogenously sectoral profit rate:

$$pr^{nt}_{j,0} = \rho_{j,0} \cdot k^{s,n}_{j,0} \tag{B.28}$$

$$pr^{ret}_{j,0} = \frac{F_{j,0}}{\Gamma_j} - \frac{l^s_{j,0}}{\Upsilon_j} \tag{B.29}$$

$$\delta_j = \frac{pr^{nt}_{j,0} - pr^{ret}_{j,0}}{pr^{nt}_{j,0}} \tag{B.30}$$

where
$pr^{nt}_{j,0}$ is the initial net profits of sector j (endogenous);
$\rho_{j,0}$ is the initial profit rate of sector j (exogenous);
$k^{s,n}_{j,0}$ is the initial stock of (nominal) capital of sector j (endogenous);
$pr^{ret}_{j,0}$ is the initial retained profits of sector j (endogenous);
$F_{j,0}$ is the initial number of firms of sector j (exogenous);
Γ_j is the investment frequency of sector j (exogenous);
$l^s_{j,0}$ is the initial stock of loans of sector j (endogenous);
Υ_j is the capital lifetime of sector j (exogenous); and
δ_j is the profits distribution rate of sector j (endogenous).

Another sectoral variable is calculated endogenously and deserves attention: the wage rate. Once we know sectoral revenue, tax rate, R&D expenses, input expenses, interest paying on stock of loans and interest receiving on stock of deposits, and sectoral net profits, the wage costs must be determined endogenously. But let us define the initial interest rate structure:

$$ir_0^{dep} = ir_{cb,0} - spr^{dep} \tag{B.31}$$

$$\overline{ir}^{st}_{fs,0} = ir_{cb,0} + spr^{st}_{fs,0} \tag{B.32}$$

$$\overline{ir}^{lt}_{fs,0} = ir_{cb,0} + spr^{lt}_{fs,0} \tag{B.33}$$

$$\overline{ir}^{lt}_{j,0} = \overline{ir}^{lt}_{fs,0} + rp^{lt}_{fs} \cdot dr_{j,0} \tag{B.34}$$

where
ir_0^{dep} is the initial interest rate on deposits (endogenous);
$ir_{cb,0}$ is the initial central bank interest rate (endogenous);
spr^{dep} is the deposits spread (exogenous);
$\overline{ir}^{st}_{fs,0}$ is the initial average short-term interest of the financial sector (endogenous);
$spr^{st}_{fs,0}$ is the initial short-term spread of the financial sector (exogenous);
$\overline{ir}^{lt}_{fs,0}$ is the initial average long-term interest of the financial sector (endogenous);
$spr^{lt}_{fs,0}$ is the initial long-term spread of the financial sector (exogenous);
$\overline{ir}^{lt}_{j,0}$ is the initial average long-term interest rate of sector j (endogenous);
rp^{lt}_{fs} is the long-term risk premium of the financial sector (exogenous); and
$dr_{j,0}$ is the initial debt rate of sector j (exogenous).

Thus, sectoral net financial gains are given by the sectoral long-term interest rate on the initial stock of loans, minus the deposits interest rate on the initial stock of deposits. Input costs are given by initial sectoral production, the input technical coefficient, initial propensity to import inputs, initial intermediate sector price and external price, and finally, the initial exchange rate:

$$inp_{j,0} = x_{j,0}(\alpha_j(1 - \iota_j^{in})p_{in,0} + \alpha_j \cdot \iota_j^{in} \cdot p^x_{in,0} \cdot er_0) \tag{B.35}$$

$$wr_{j,0} = \frac{\phi_{j,0}(re_{j,0}(1 - tr_j)(1 - \lambda_j) - inp_{j,0} - (\overline{ir}^{lt}_{j,0} \cdot l^s_{j,0} - ir^{dep}_0 \cdot dep^s_{j,0}) - pr^{nt}_{j,0})}{x_{j,0}} \tag{B.36}$$

where
$inp_{j,0}$ is the initial input expenses of sector j (endogenous);
$x_{j,0}$ is the initial production of sector j (endogenous);
α_j is the input technical coefficient of sector j (exogenous);
$p_{in,0}$ is the initial price of intermediate sector in (exogenous);
ι^{in}_j is the initial propensity to import inputs of sector j (exogenous);
$p^x_{in,0}$ is the initial external price of intermediate sector in (exogenous);
er_0 is the initial exchange rate (exogenous);
$wr_{j,0}$ is the initial wage rate of sector j (endogenous);
$\phi_{j,0}$ is the initial labor productivity of sector j (exogenous);
$re_{j,0}$ is the initial revenue of sector j (endogenous);
tr_j is the indirect tax rate of sector j (exogenous);
λ_j is the R&D revenue proportion of sector j (exogenous);
$\overline{ir}^{lt}_{j,0}$ is the initial average long-term interest rate of sector j (endogenous);
$l^s_{j,0}$ is the initial stock of loans of sector j (endogenous);
ir^{dep}_0 is the initial interest rate on deposits (endogenous);
$dep^s_{j,0}$ is initial stock of deposits of sector j (endogenous);
$pr^{nt}_{j,0}$ is the initial net profits of sector j (endogenous); and
$x_{j,0}$ is the production of sector j (endogenous).

With profit rates and wage rates of all sectors defined, we are on the way to calculate aggregate wages and profits, with the financial sector profits missing. The financial sector profits depend on the interest payment on existing stock of loans, minus the interest paid on the stock of deposits, plus government interest payment (assuming there are no defaulted loans initially). The total stock of loans is already defined, as we assume income classes do not start indebted, so we just need to sum up the stock of loans of all sectors. However, we do not know the initial stock of deposits yet, as its reasonable to assume that the income classes possess some accumulated deposits, given their marginal propensity to consume lower than one. A simple way to define the initial stock of deposits is defining a initial financial sector leverage, measured as stock of loans over stock of deposits. Then, the income classes stock of deposits will be the difference between total deposits and firms' deposits.

So, financial profits can be calculated now:

$$pr_{fs,0} = \sum_{j=1}^{N} (\overline{ir}_{j,0}^{lt} \cdot l_{j,0}^{s}) - \frac{ir_0^{dep} \cdot l_{j,0}^{s}}{lev_{fs,0}} + ir_{bc,0} \cdot b_0^s \tag{B.37}$$

where
$pr_{fs,0}$ is the initial financial sector profits (endogenous);
N is the number of sectors (exogenous);
$\overline{ir}_{j,0}^{lt}$ is the initial average long-term interest rate of sector j (endogenous);
$l_{j,0}^{s}$ is the initial stock of loans of sector j (endogenous);
ir_0^{dep} is the initial interest rate on deposits (endogenous);
$lev_{fs,0}$ is initial leverage of the financial sector (exogenous);
$ir_{cb,0}$ is the initial central bank interest rate (endogenous); and
b_0^s is the initial stock of bonds, government debt (endogenous).

Assuming all financial sector profits are distributed as all banks already start with own capital to cope with regulatory rules and own sensitivities, aggregate income is defined:

$$PR_0 = pr_{fs,0} + \sum_{j=1}^{N} pr_{j,0}^{nt} \tag{B.38}$$

$$PR_0^{dis} = pr_{fs,0} + \sum_{j=1}^{N} pr_{j,0}^{nt} \cdot \delta_j \tag{B.39}$$

$$WG_0 = w_{g,0} + \sum_{j=1}^{N} \left(wr_{j,0} \cdot \frac{x_{j,0}}{\phi_{j,0}} + \lambda_j (1 - tr_j) re_{j,0} \right) \tag{B.40}$$

where
PR_0 is the initial aggregate profits (endogenous);
N is the number of sectors (exogenous);
$pr_{j,0}^{nt}$ is the initial net profits of sector j (endogenous); and
PR_0^{dis} is the initial distributed profits (endogenous);
δ_j is the profits distribution rate of sector j (endogenous);
WG_0 is the initial aggregate wages (endogenous);
$w_{g,0}$ is the initial government wages (endogenous);
$wr_{j,0}$ is the initial wage rate of sector j (endogenous);
$x_{j,0}$ is the production of sector j (endogenous);

$\phi_{j,0}$ is the initial labor productivity of sector j (exogenous);
λ_j is the R&D revenue proportion of sector j (exogenous);
tr_j is the indirect tax rate of sector j (exogenous); and
$re_{j,0}$ is the initial revenue of sector j (endogenous).

Each class appropriates specific (exogenous) shares of distributed profits and aggregated wages. We assume there are no unemployment benefits initially, as sectoral employment is constant. Therefore, classes initial disposable (and average) income is:

$$y_{h,0}^{dp} = \omega_h \cdot WG_0 + \pi_h \cdot PR_0^{dis} \tag{B.41}$$

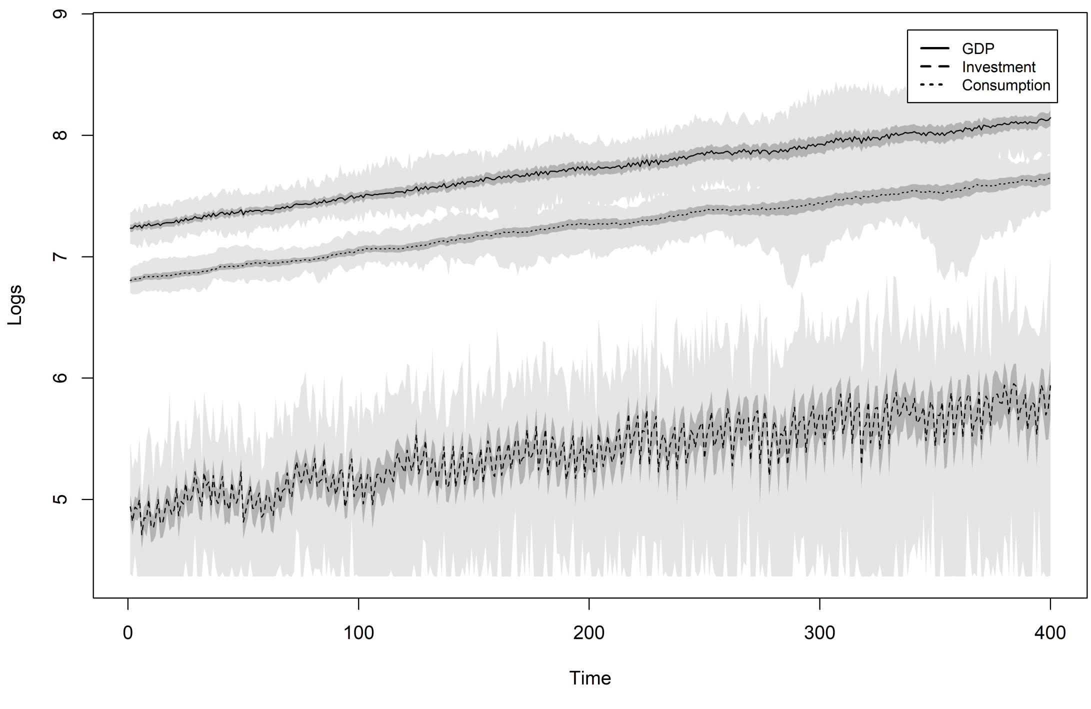
where
$y_{h,0}^{dp}$ is the class h initial nominal disposable income (and average)(endogenous);
ω_h is the class h wage appropriation (exogenous);
WG_0 is the initial aggregate wages (endogenous);
π_h is the class h profit appropriation (exogenous); and
PR_0^{dis} is the initial distributed profits (endogenous).

Appendix C

Baseline Graphics

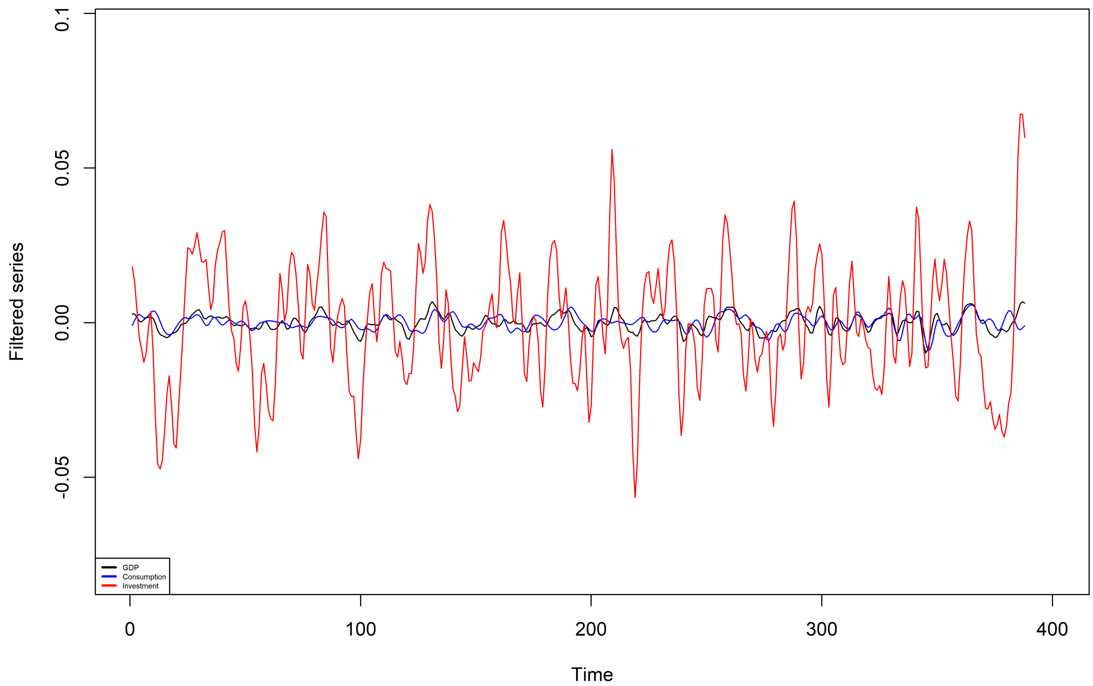
C.1 Aggregate Variables

Figure C.1: Baseline Results - GDP, Consumption and Investment (Series in Logs)



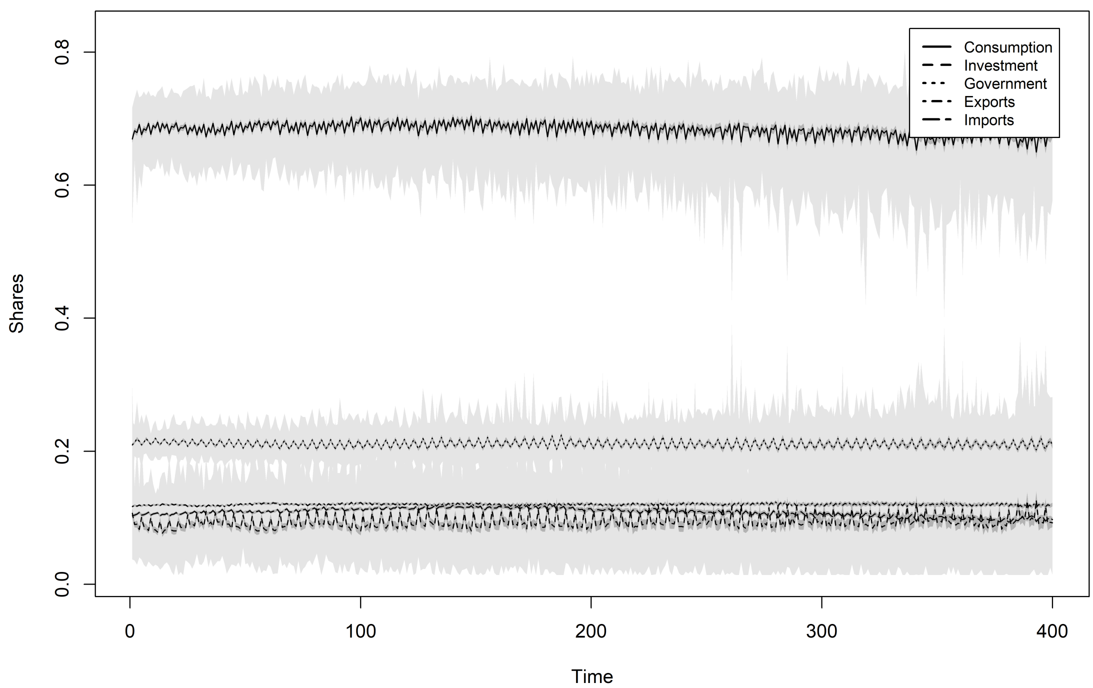
Source: Author's elaboration. MonteCarlo averages from 100 simulations of GDP, consumption and investment in log. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.2: Baseline Results - GDP, Consumption and Investment (Filtered Series)



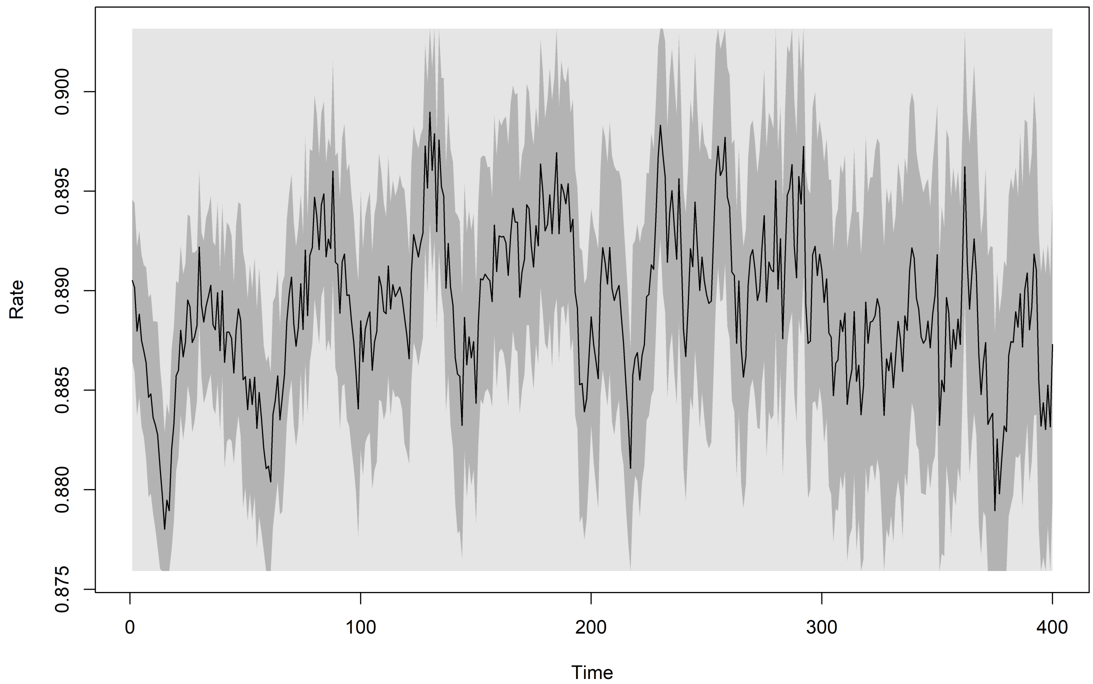
Source: Author's elaboration. Band-pass filtered series (6,32,12) of GDP, consumption and investment in log.

Figure C.3: Baseline Results - Components of Demand (Share of GDP)



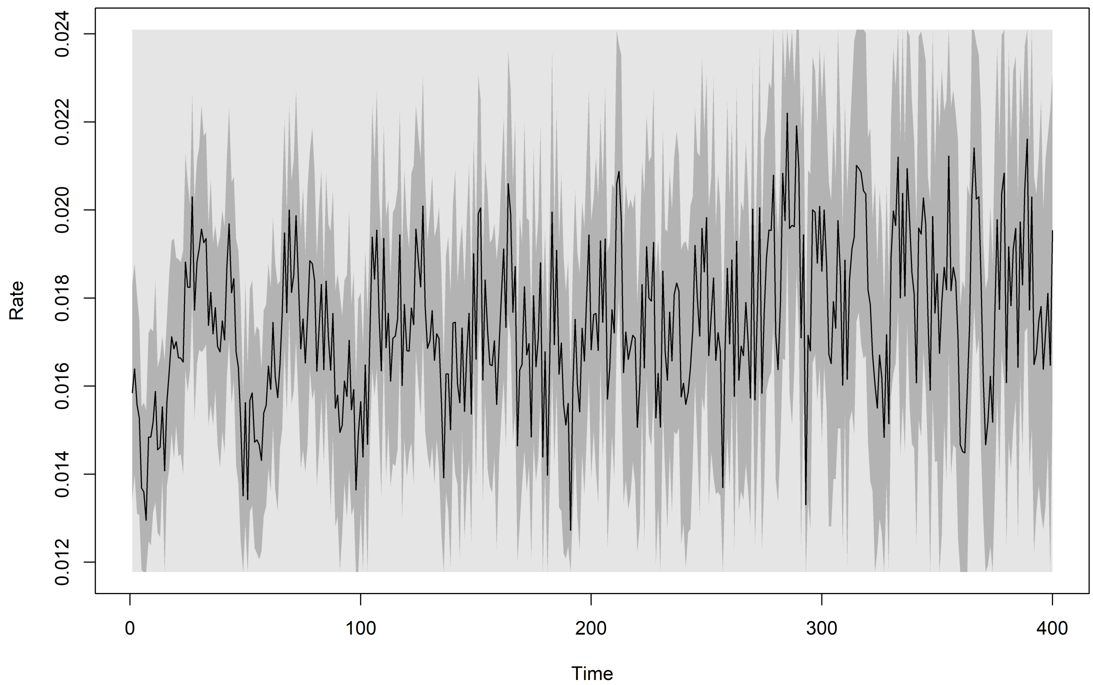
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the shares of consumption, investment, government expenses, exports and imports on GDP. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.4: Baseline Results - Productive Capacity Utilization



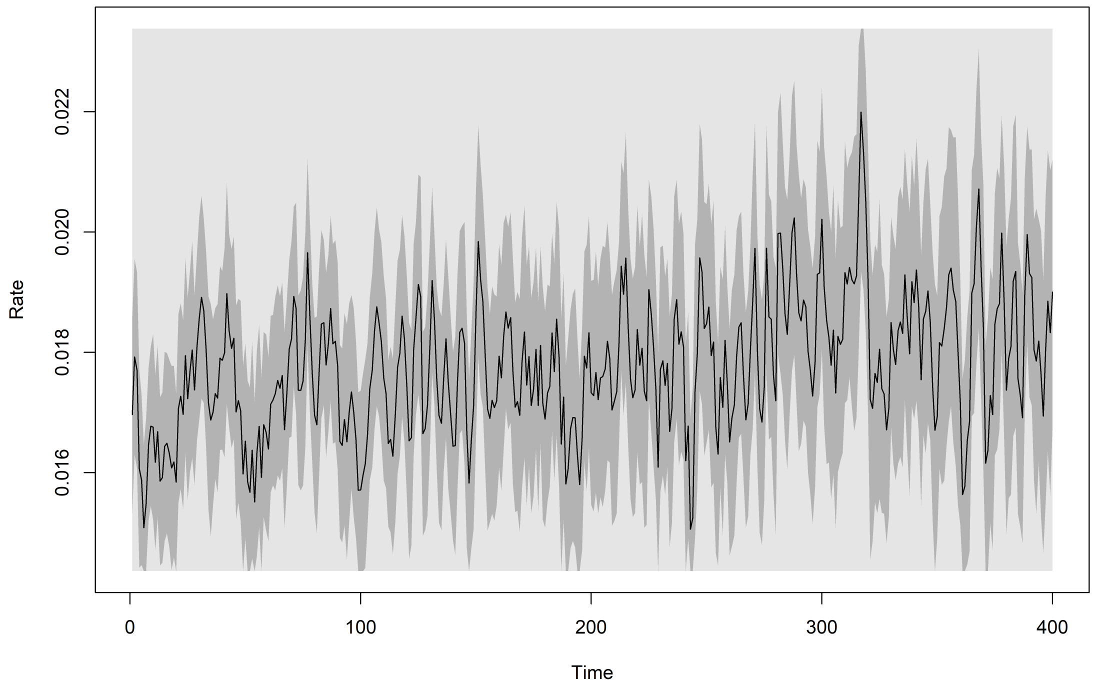
Source: Author's elaboration. MonteCarlo averages from 100 simulations of average productive capacity utilization. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.5: Baseline Results - GDP Deflator Annual Inflation



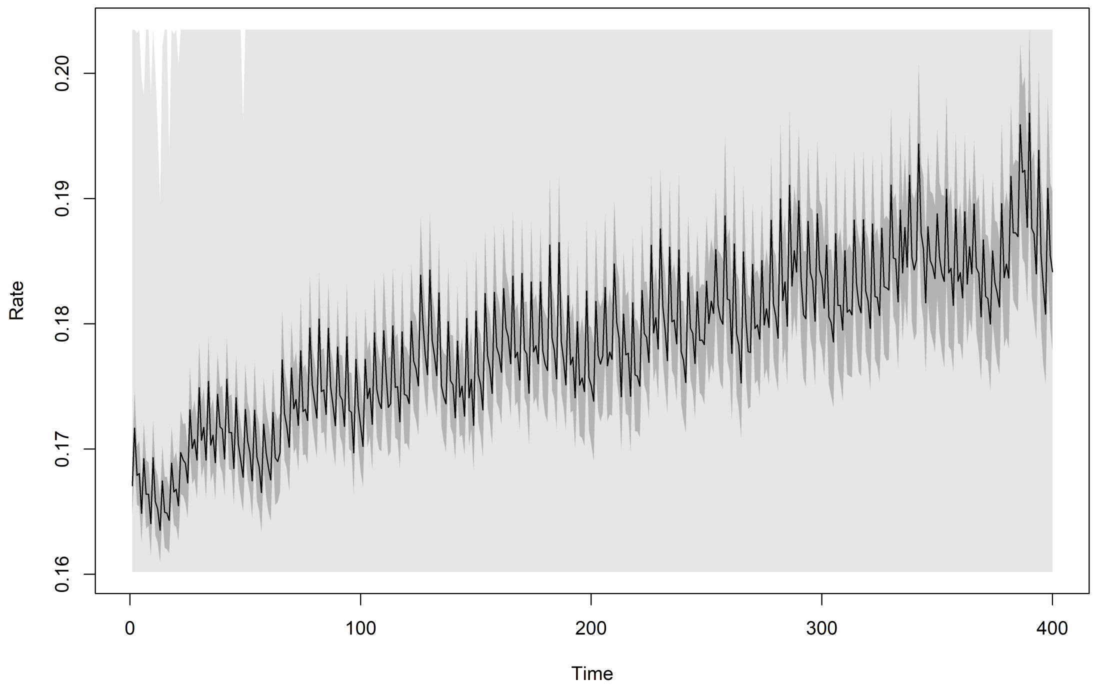
(a) Source: Author's elaboration. MonteCarlo averages from 100 simulations of GDP deflator annual inflation rate. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.6: Baseline Results - CPI Annual Inflation



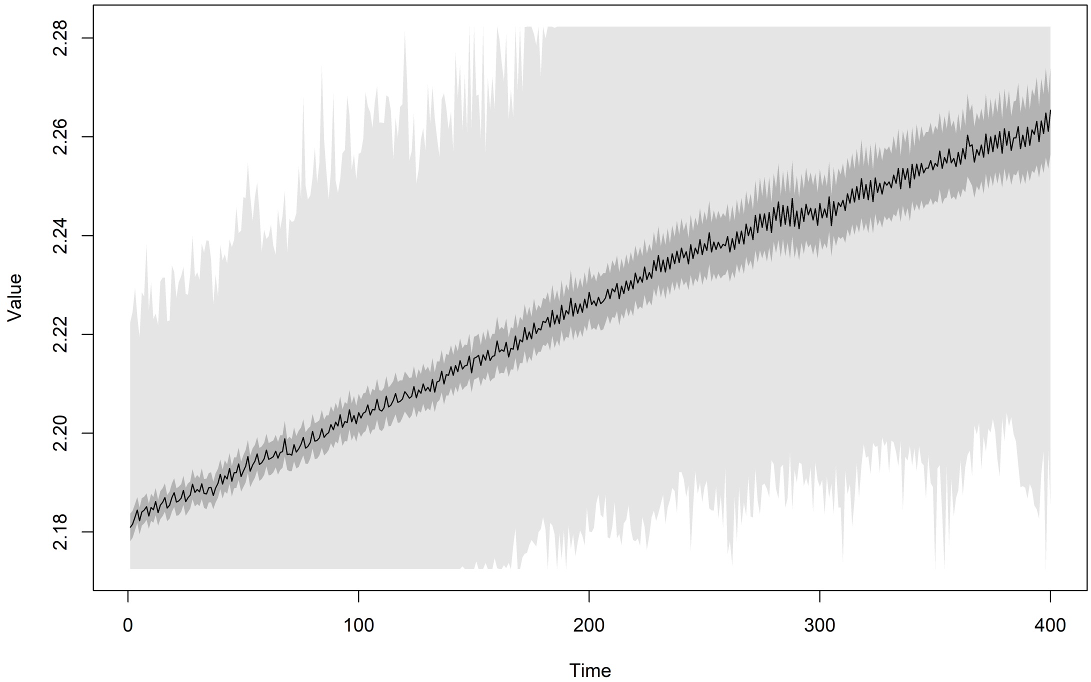
Source: Author's elaboration. MonteCarlo averages from 100 simulations of CPI annual inflation rate. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.7: Baseline Results - Average Profit Rate



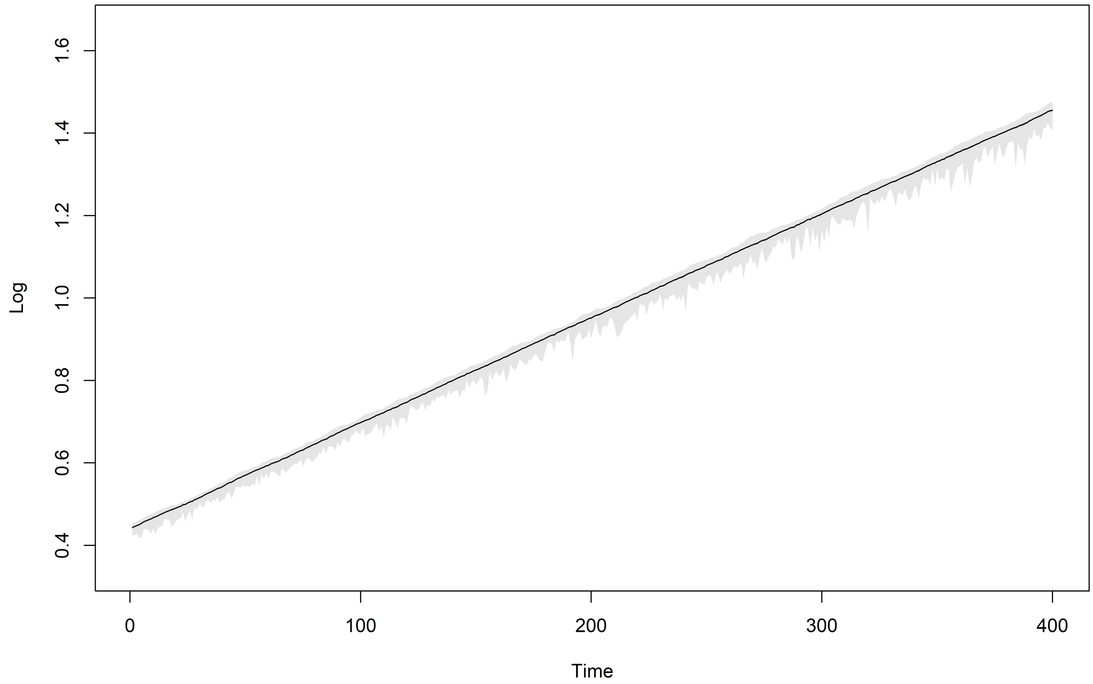
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the firms' average profit rate on capital. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.8: Baseline Results - Average Mark-up



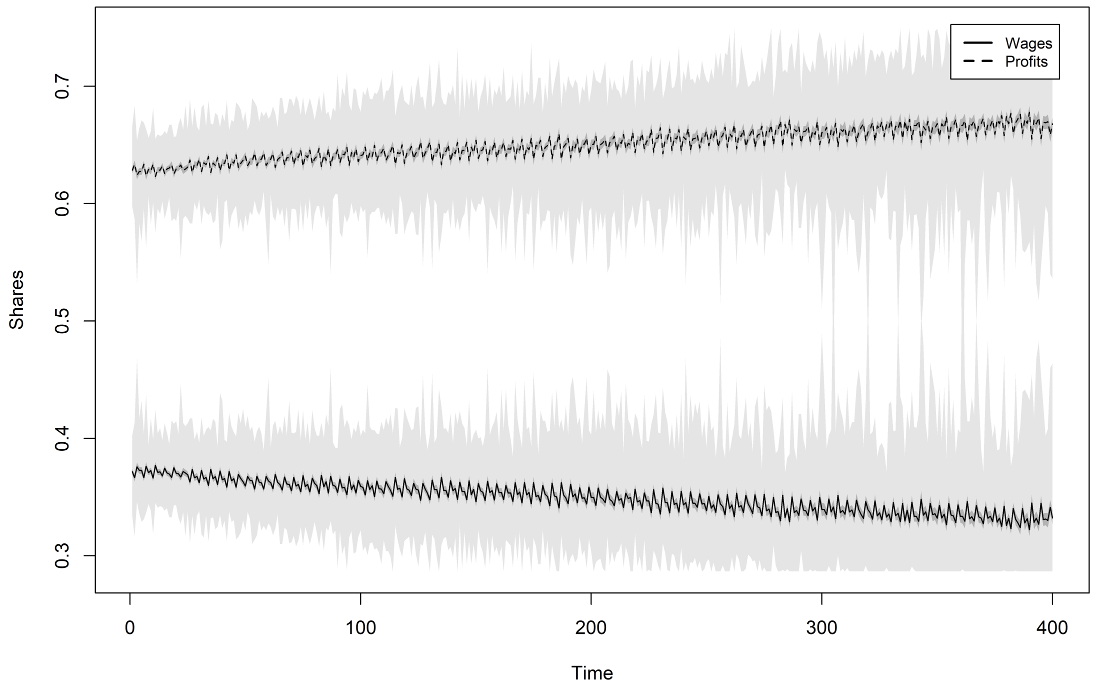
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the firms' average mark-up. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.9: Baseline Results - Average Productivity



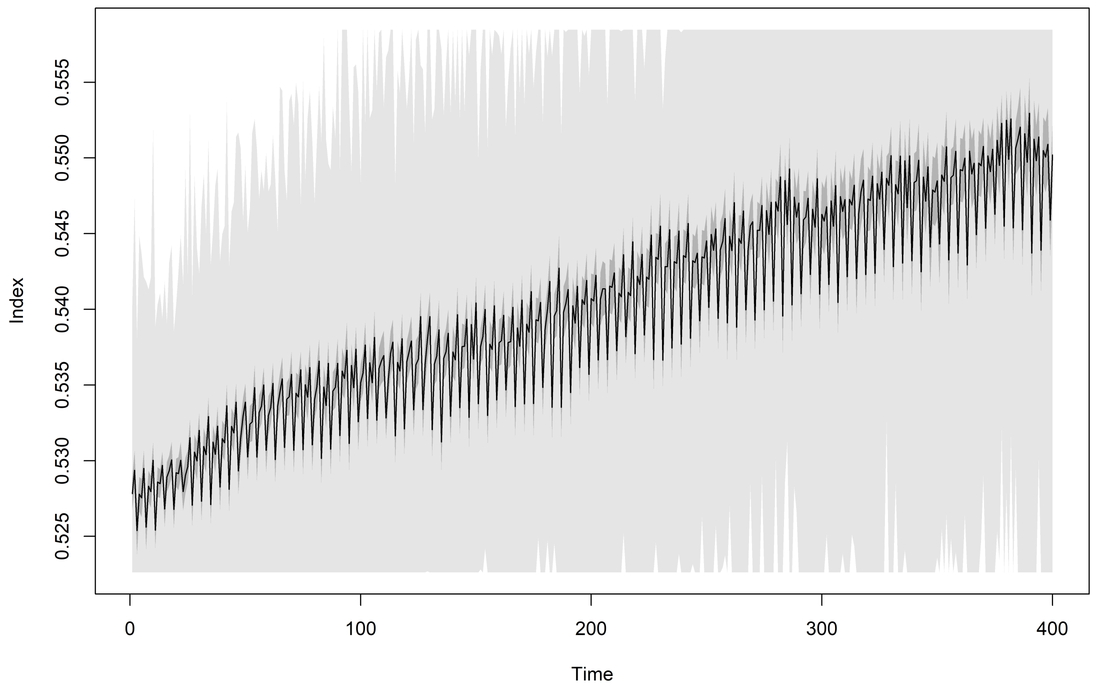
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the firms' average labor productivity in log. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.10: Baseline Results - Functional Distribution of Income



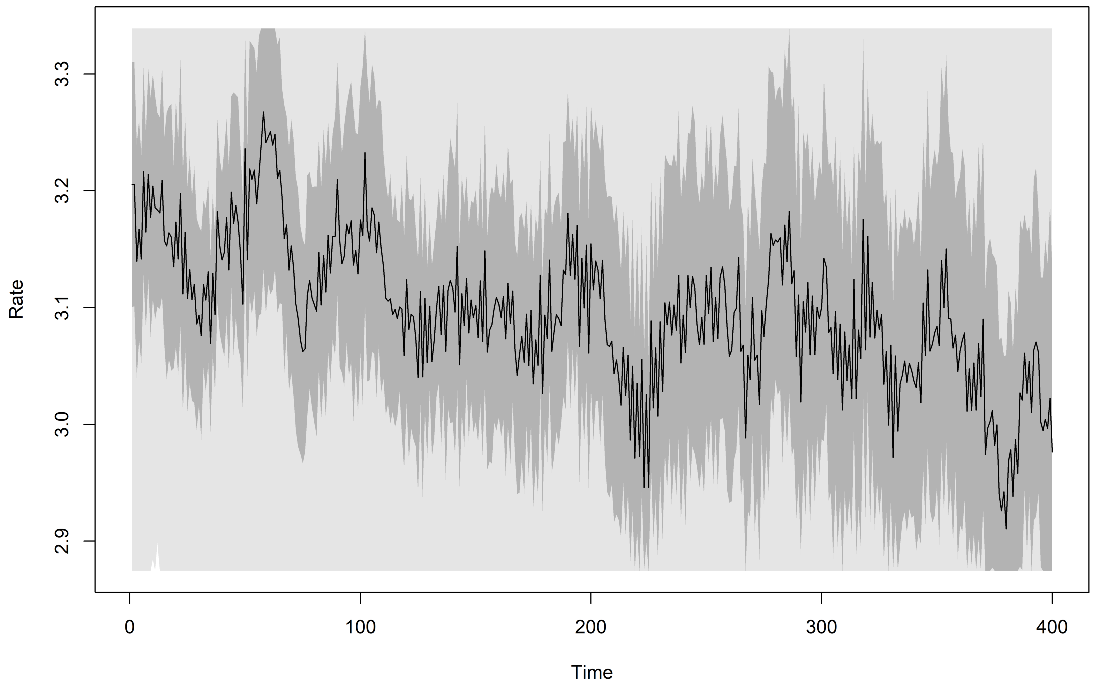
Source: Author's elaboration. MonteCarlo averages from 100 simulations of wage and profit shares on income. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.11: Baseline Results - Gini Index on Income



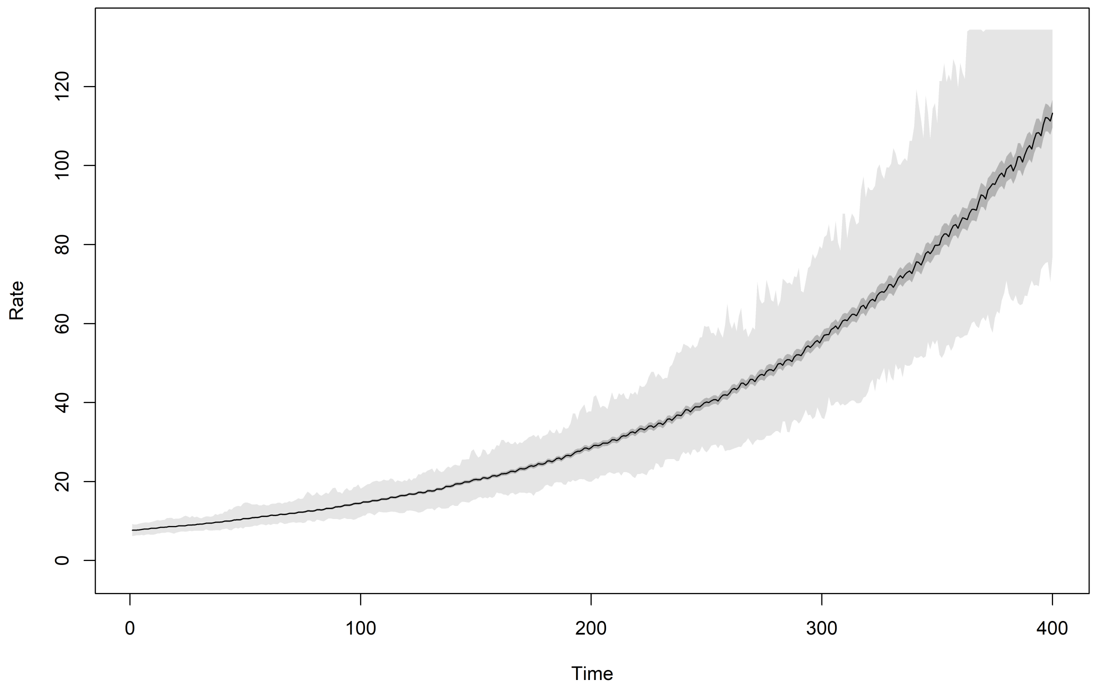
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the Gini index on income. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.12: Baseline Results - Capital Stock to GDP



Source: Author's elaboration. MonteCarlo averages from 100 simulations of the total stock of capital over GDP. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

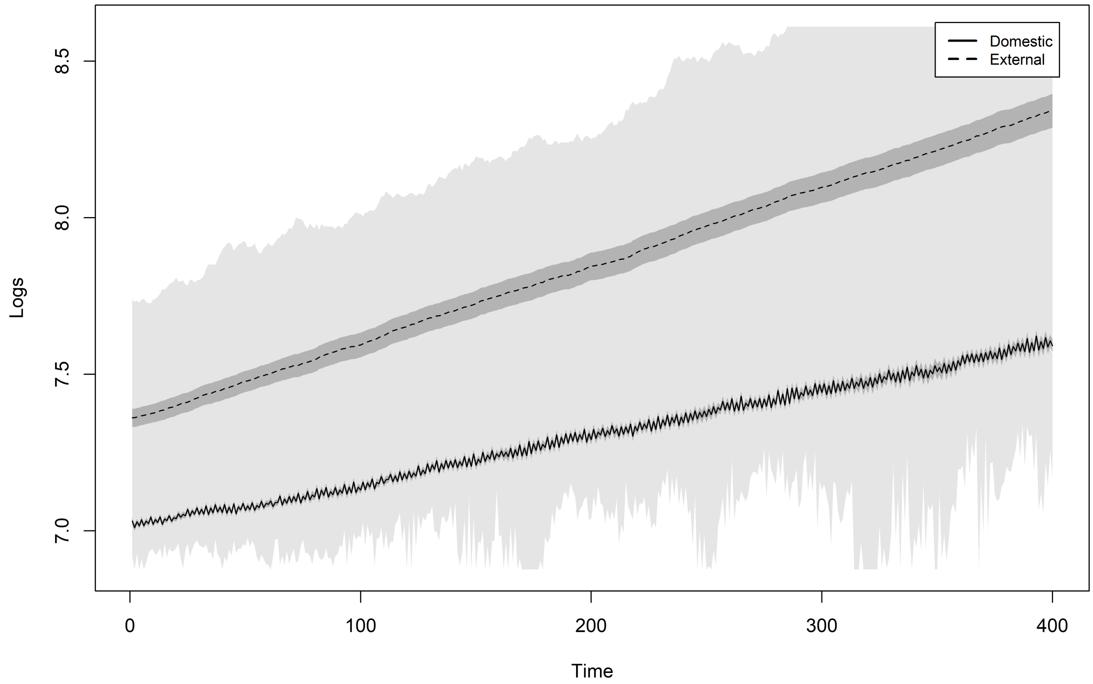
Figure C.13: Baseline Results - Capital-Labor Ratio



Source: Author's elaboration. MonteCarlo averages from 100 simulations of the aggregate capital-labor ratio. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

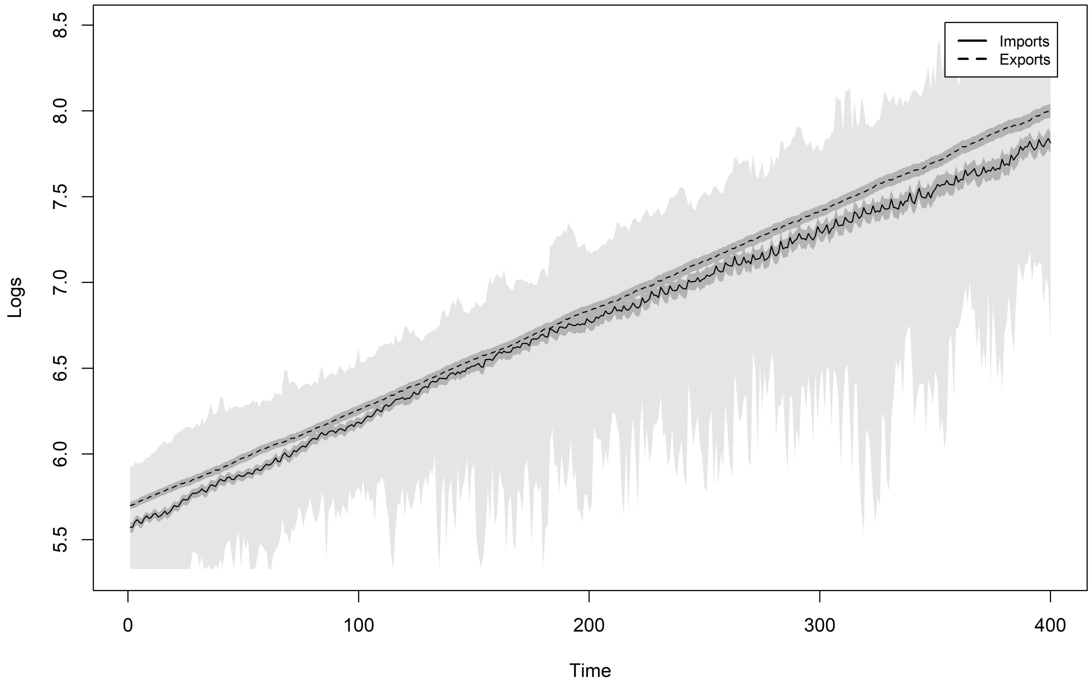
C.2 External Sector Variables

Figure C.14: Baseline Results - External and Domestic Real GDP



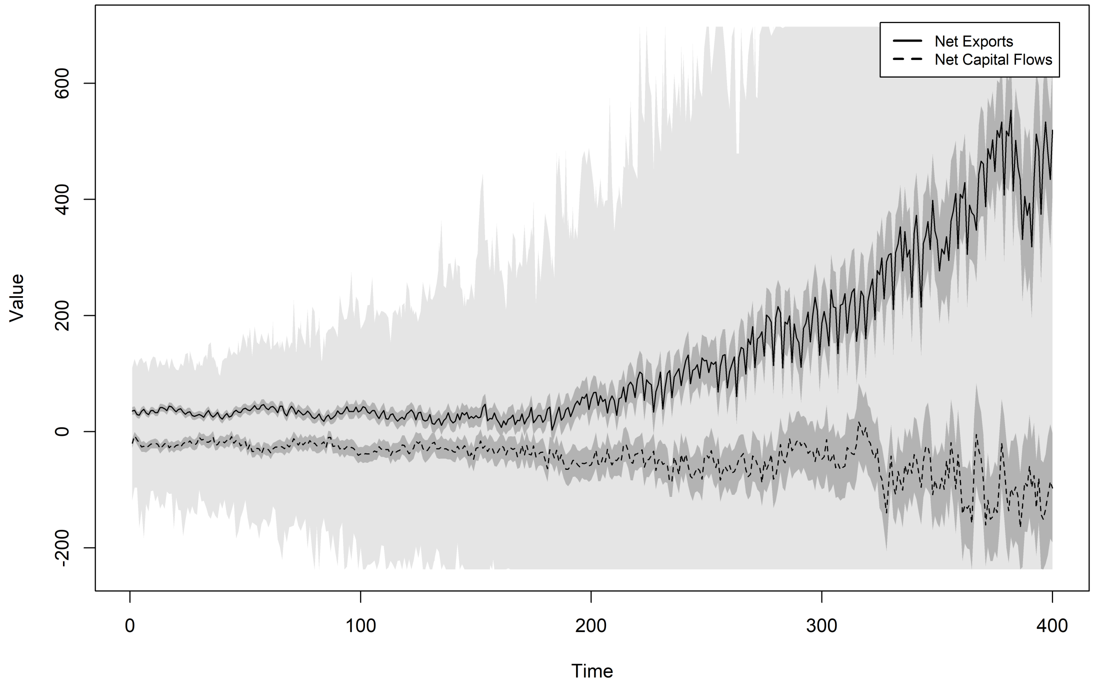
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the external and domestic real GDP in log. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.15: Baseline Results - Exports and Imports



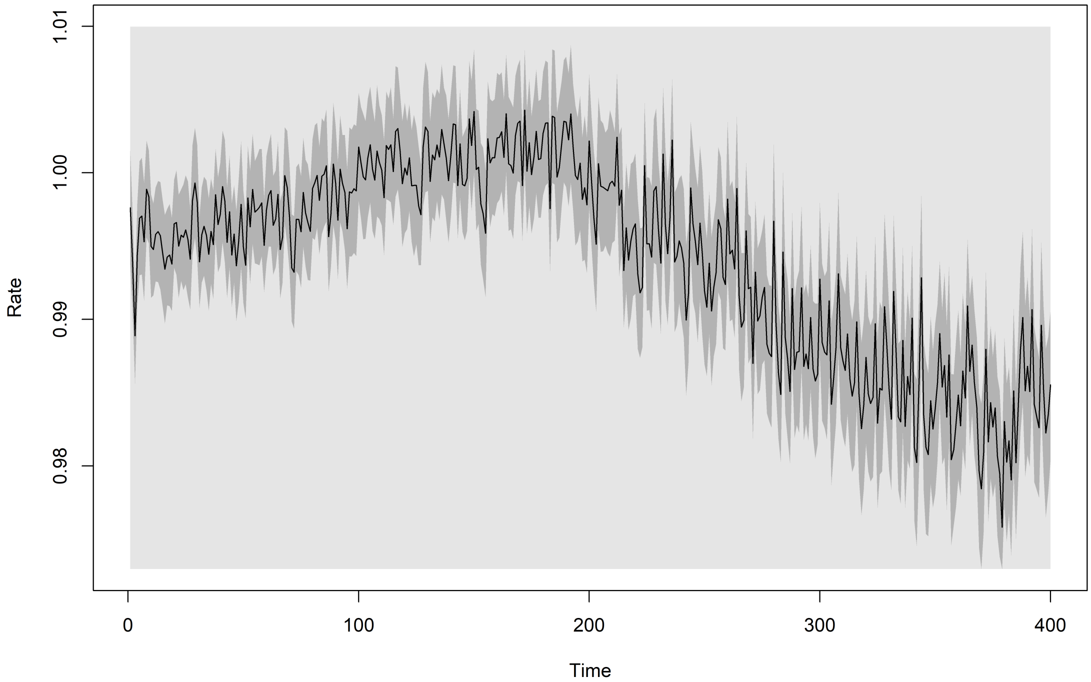
Source: Author's elaboration. MonteCarlo averages from 100 simulations of nominal exports and imports in logs. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.16: Baseline Results - Trade Balance and Capital Account



Source: Author's elaboration. MonteCarlo averages from 100 simulations of the trade balance and the capital account results. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

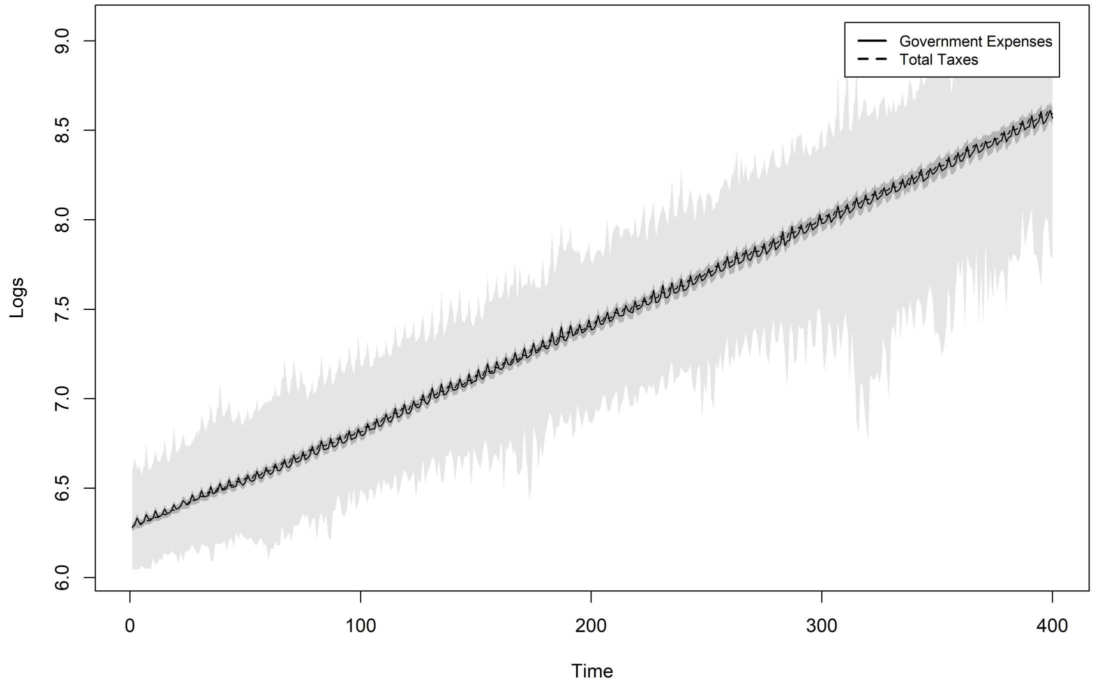
Figure C.17: Baseline Results - Exchange Rate



Source: Author's elaboration. MonteCarlo averages from 100 simulations of the nominal exchange rate. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

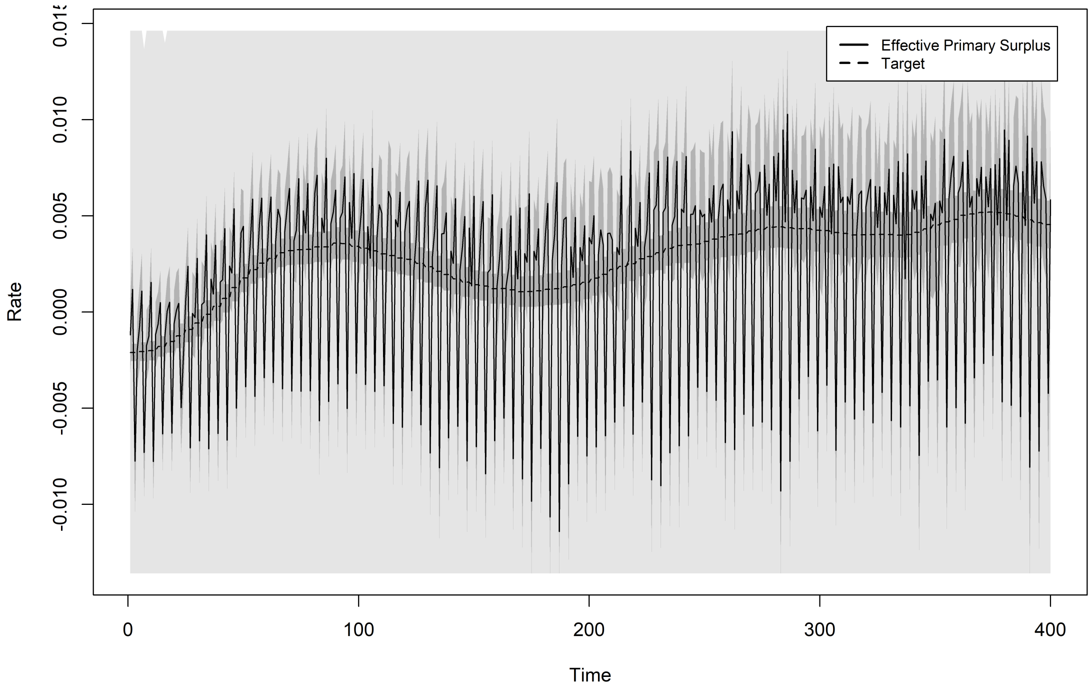
C.3 Government Variables

Figure C.18: Baseline Results - Taxes and Government Expenses



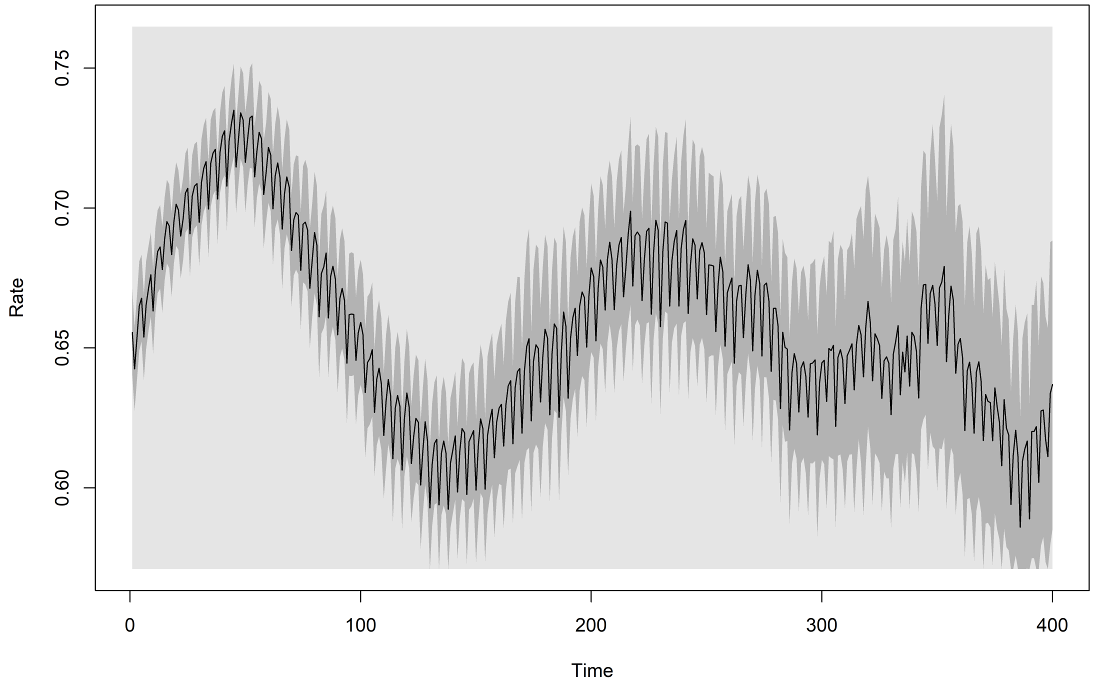
Source: Author's elaboration. MonteCarlo averages from 100 simulations of total taxes and government primary expenses in log. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.19: Baseline Results - Government Primary Result and Target



Source: Author's elaboration. MonteCarlo averages from 100 simulations of the effective and target primary result as proportion of GDP. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

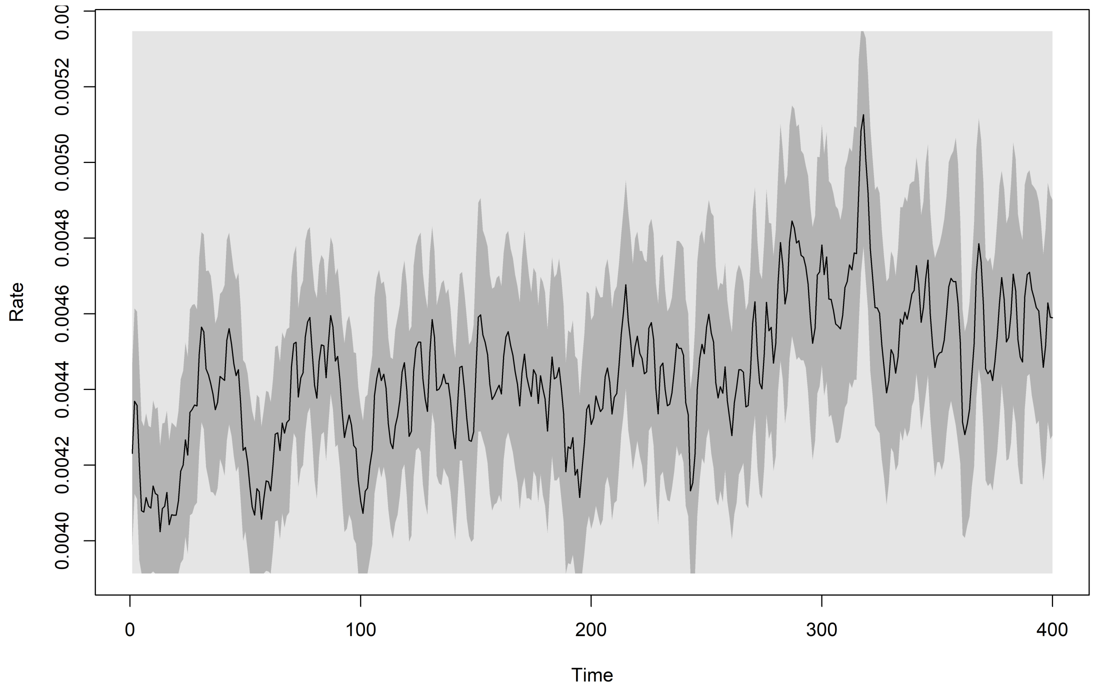
Figure C.20: Baseline Results - Government Debt to GDP Ratio



Source: Author's elaboration. MonteCarlo averages from 100 simulations of the government debt to GDP ratio. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

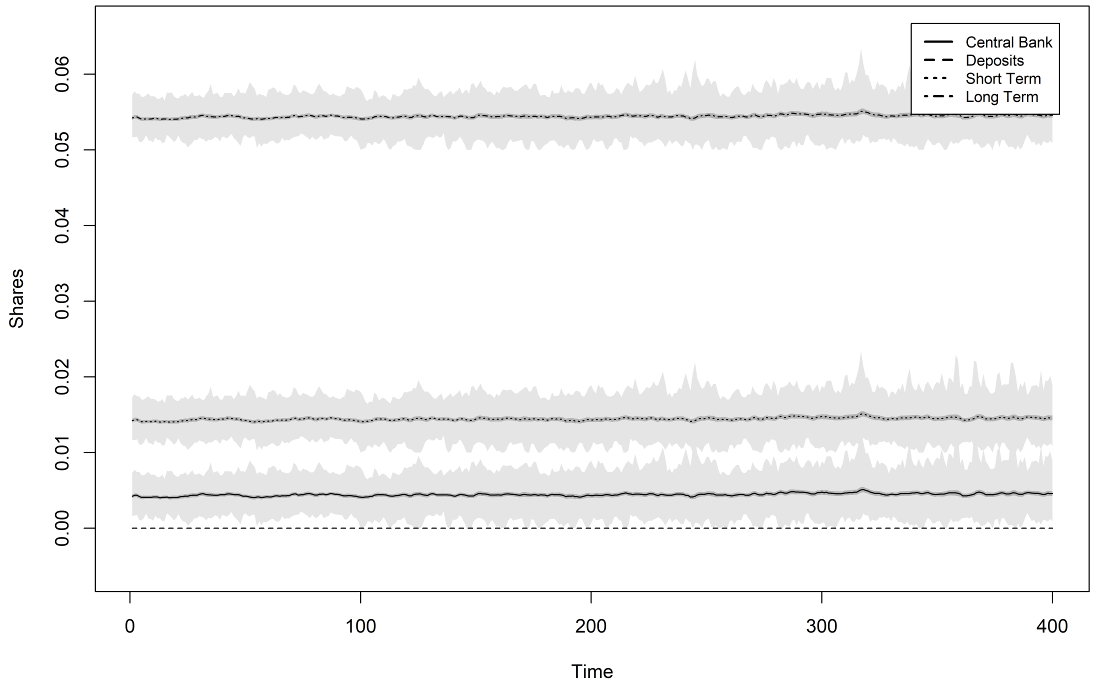
C.4 Financial Sector Variables

Figure C.21: Baseline Results - Basic Interest Rate



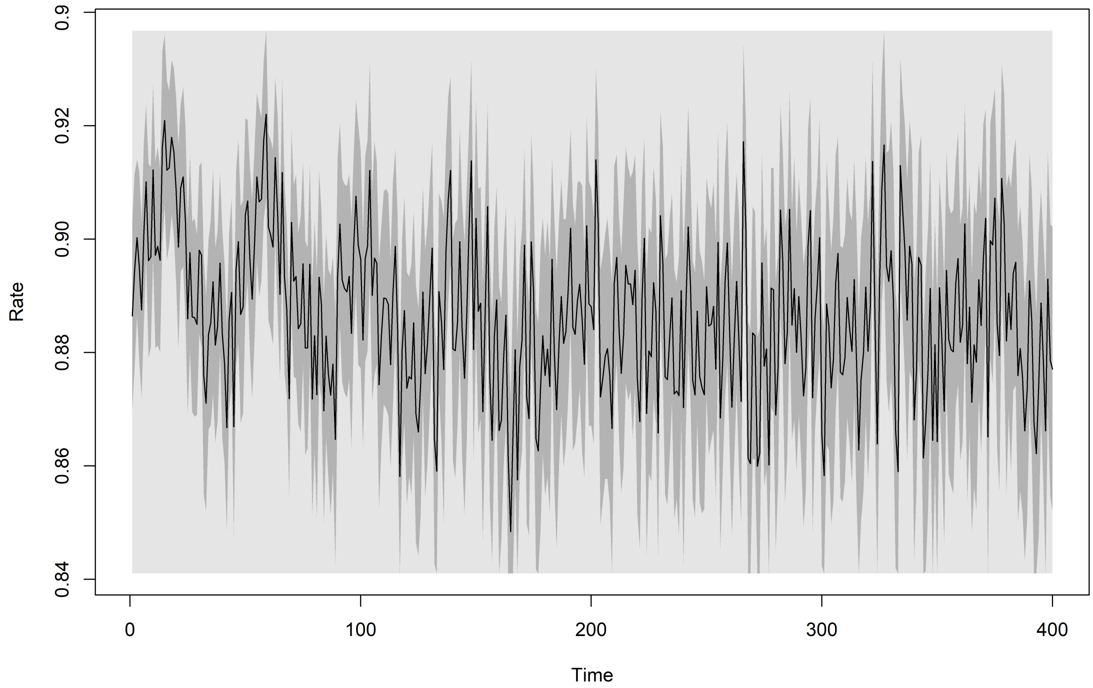
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the basic interest rate. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.22: Baseline Results - Interest Rate Structure



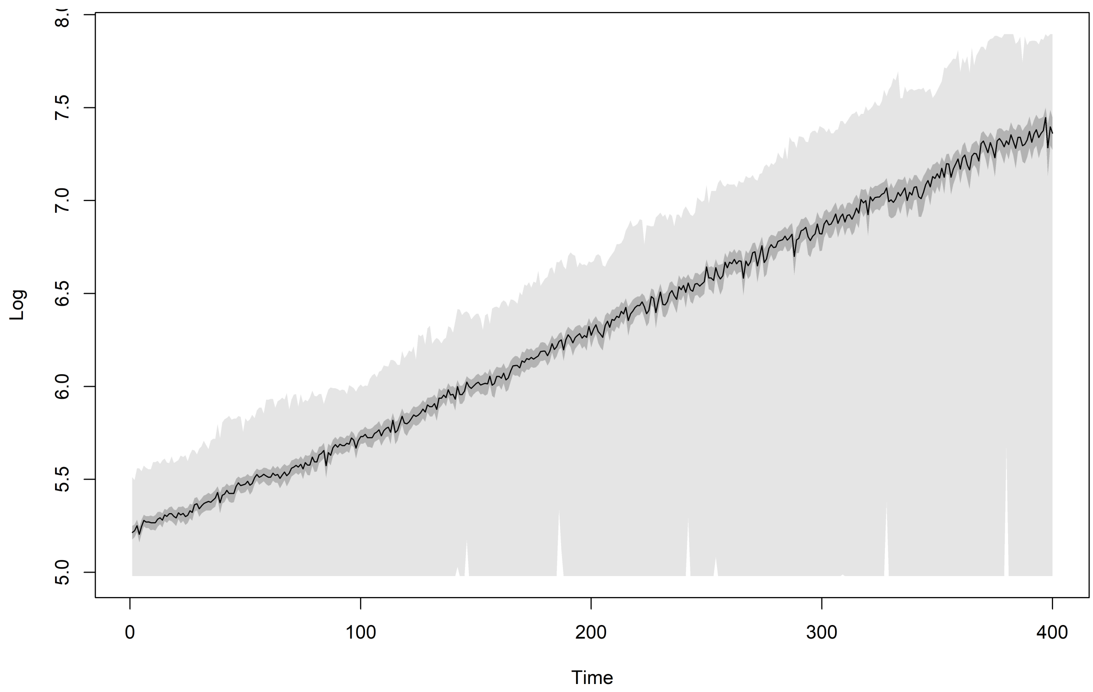
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the interest rates on deposits, on short-term loans and on long-term loans. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.23: Baseline Results - Financial Sector Demand Met (Credit Rationing)



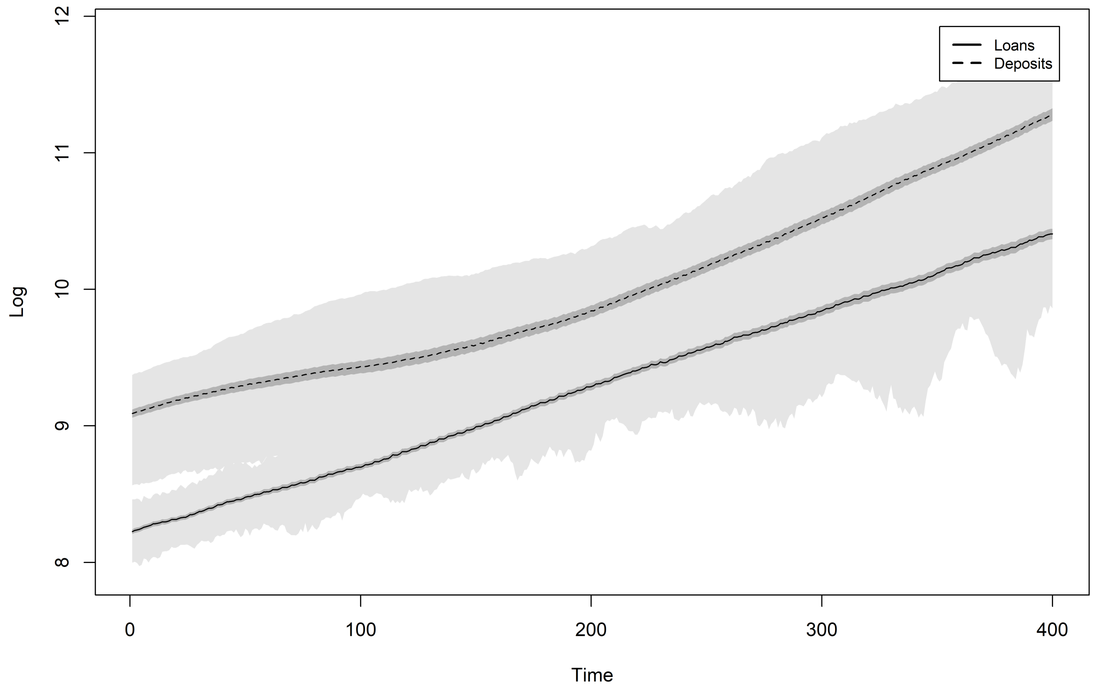
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the rate of credit demand met by the banks. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.24: Baseline Results - Financial Sector Profits



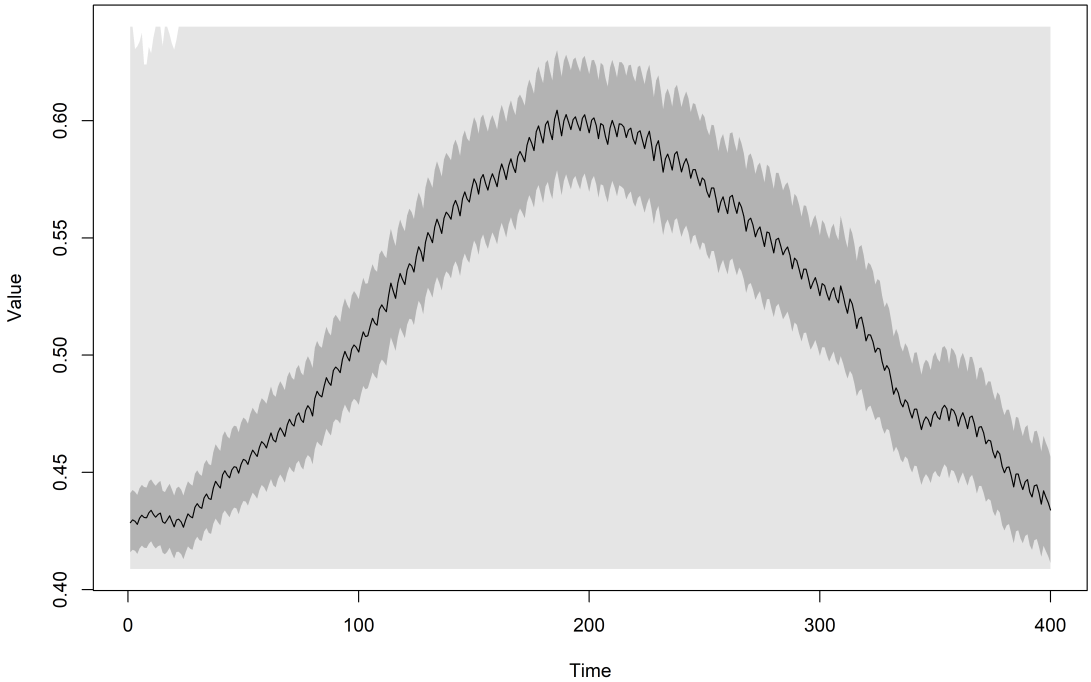
Source: Author's elaboration. MonteCarlo averages from 100 simulations of banks' profits in log. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.25: Baseline Results - Stock of Loans and Deposits



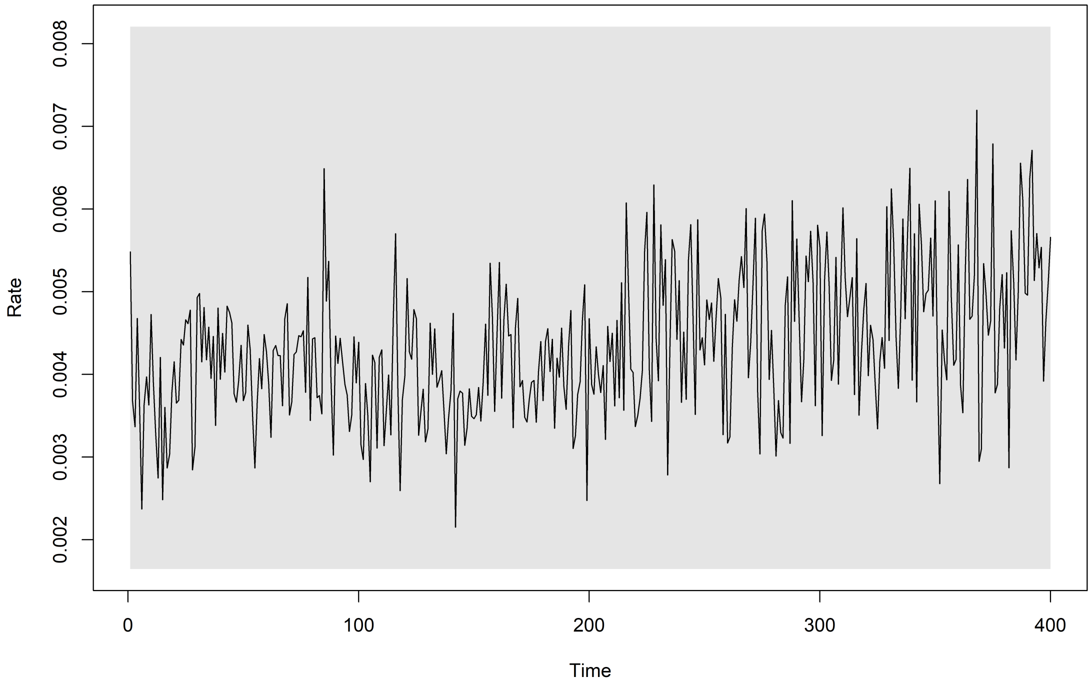
Source: Author's elaboration. MonteCarlo averages from 100 simulations of total stock of loans and total stock of deposits in log. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.26: Baseline Results - Financial Sector Leverage



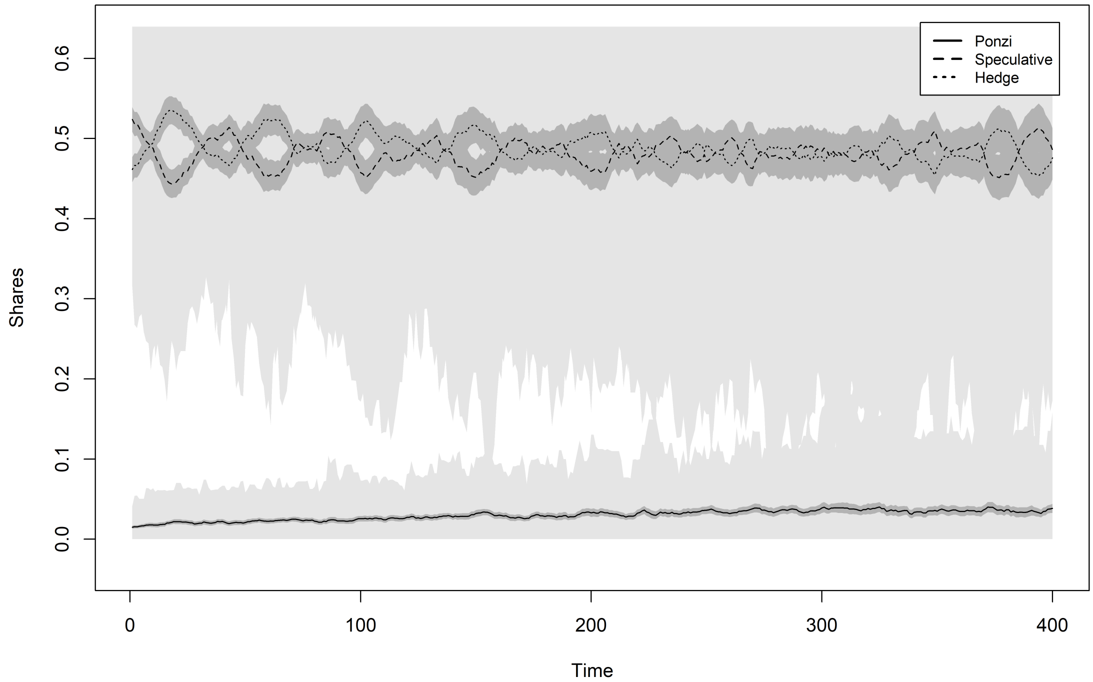
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the banks' average leverage ratio. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.27: Baseline Results - Percentage of Bankrupt Firms



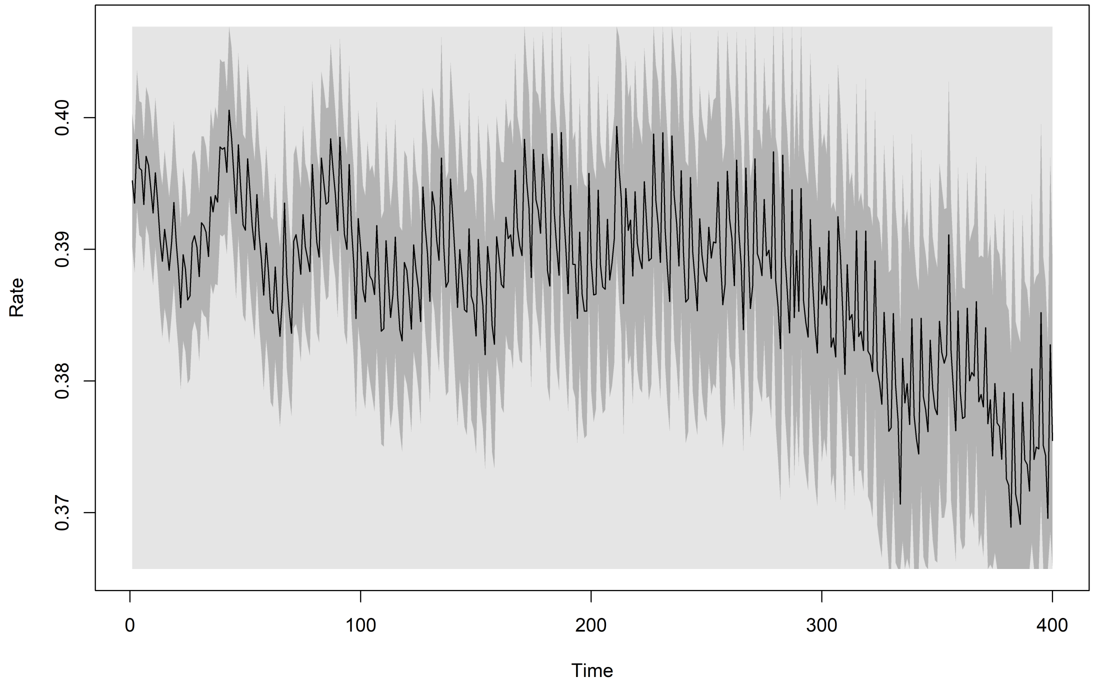
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the share of bankrupt firms over total firms. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.28: Baseline Results - Share of Firms in Minsky's Financial Positions



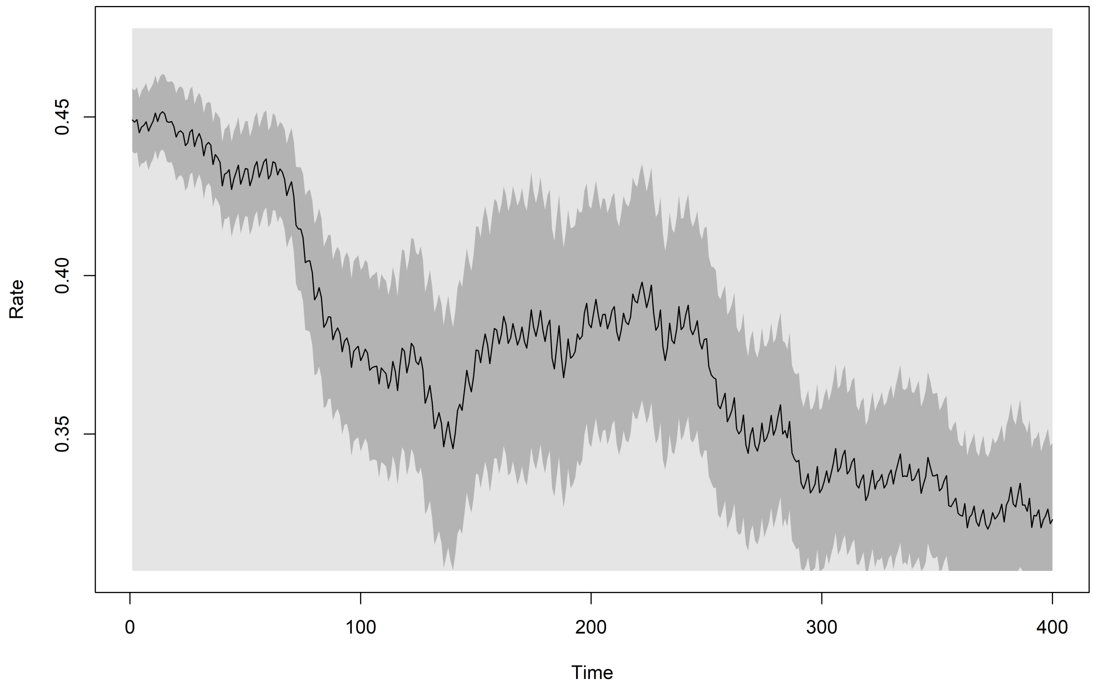
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the share of firms in Ponzi, Speculative and Hedge finance. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.29: Baseline Results - Firms Average Debt Rate



Source: Author's elaboration. MonteCarlo averages from 100 simulations of the firms' average debt rate. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

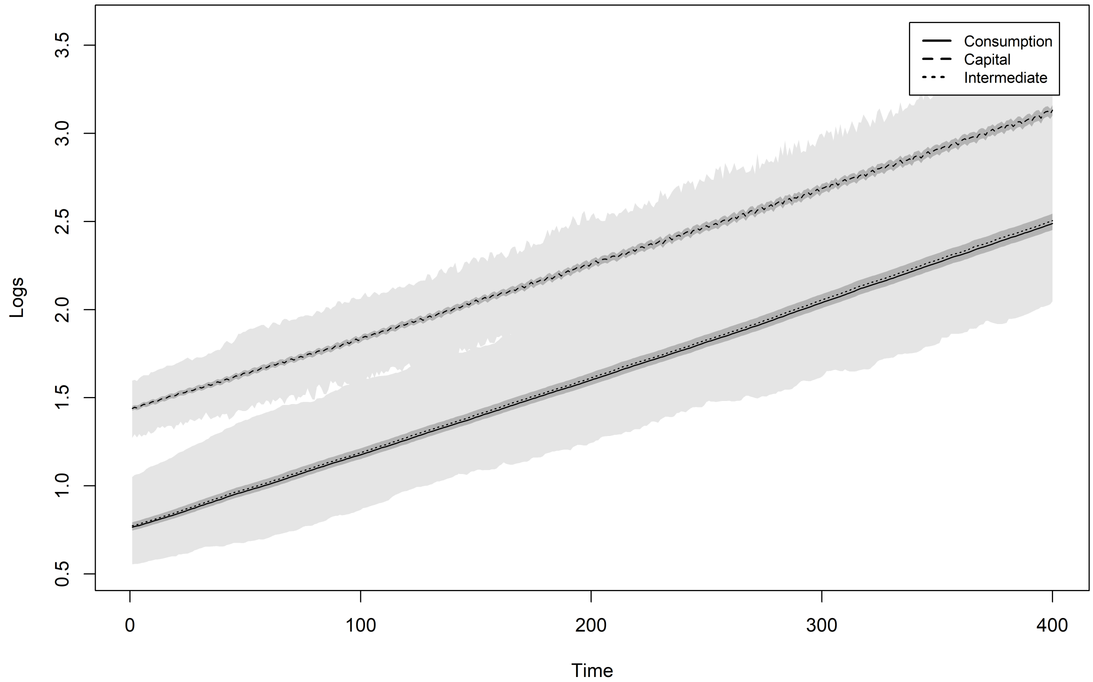
Figure C.30: Baseline Results - Households Average Debt Rate



Source: Author's elaboration. MonteCarlo averages from 100 simulations of the classes average debt rate. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

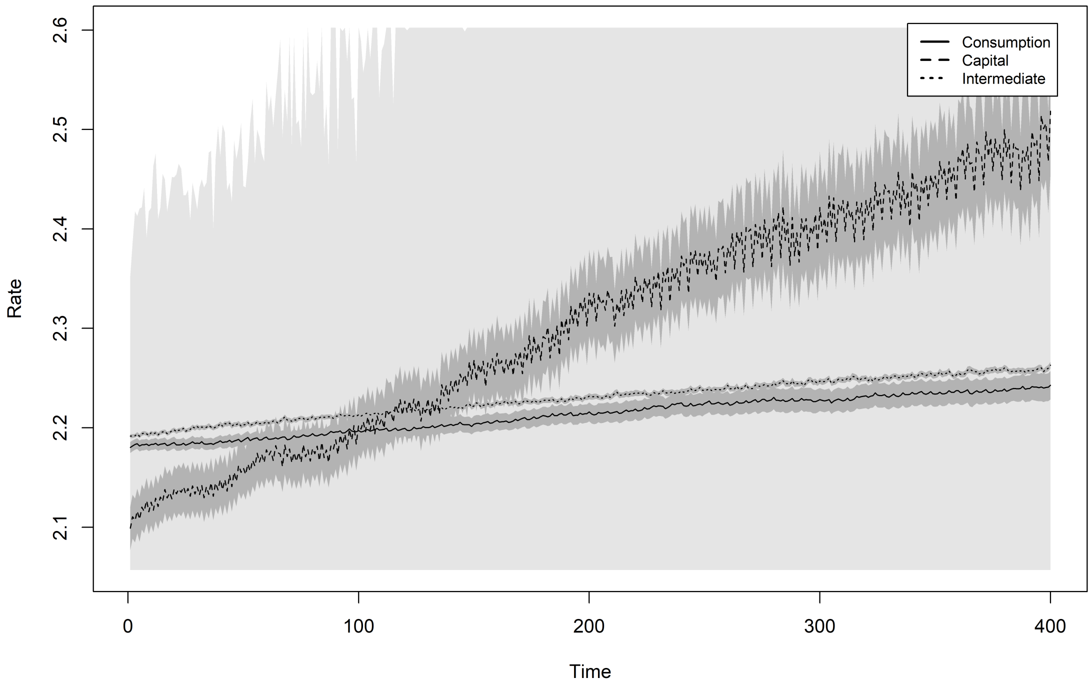
C.5 Sectoral Variables

Figure C.31: Baseline Results - Sectoral Average Price



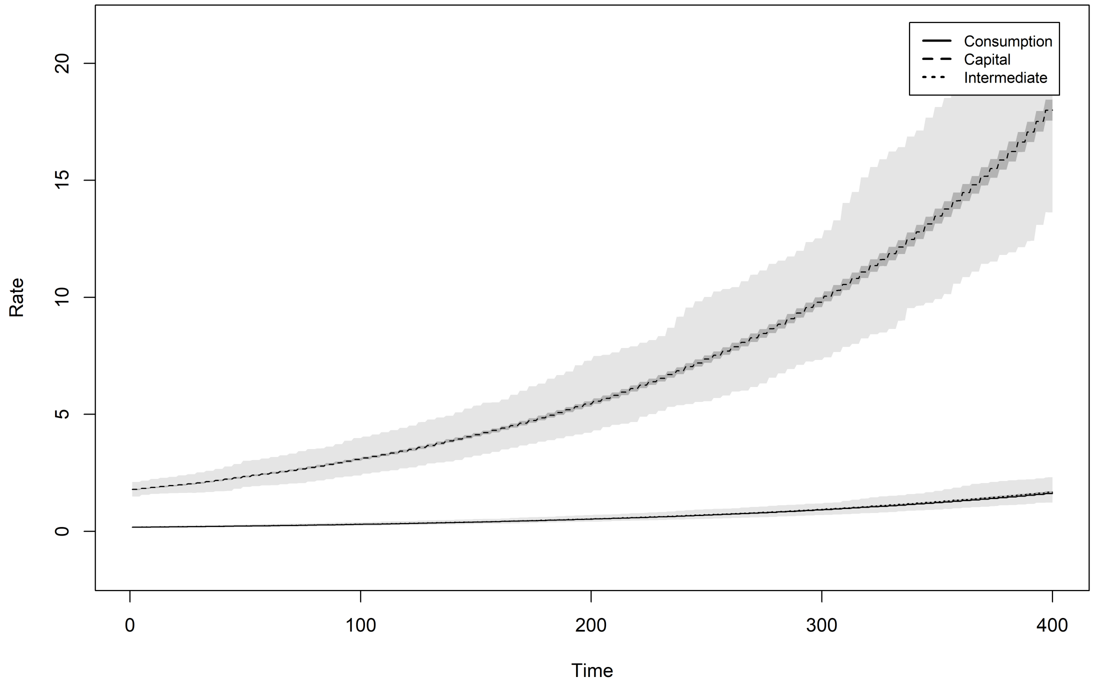
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the average price in log of the consumption, intermediate and capital sectors. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.32: Baseline Results - Sectoral Average Mark-up



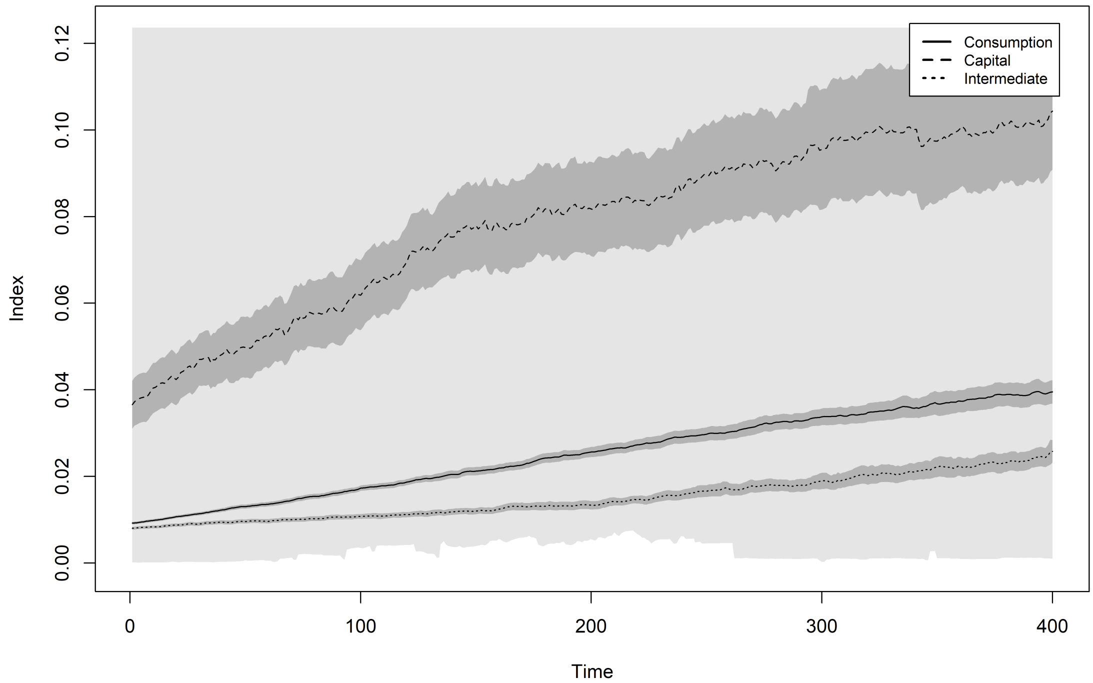
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the average mark-up of the consumption, intermediate and capital sectors. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.33: Baseline Results - Sectoral Average Wage



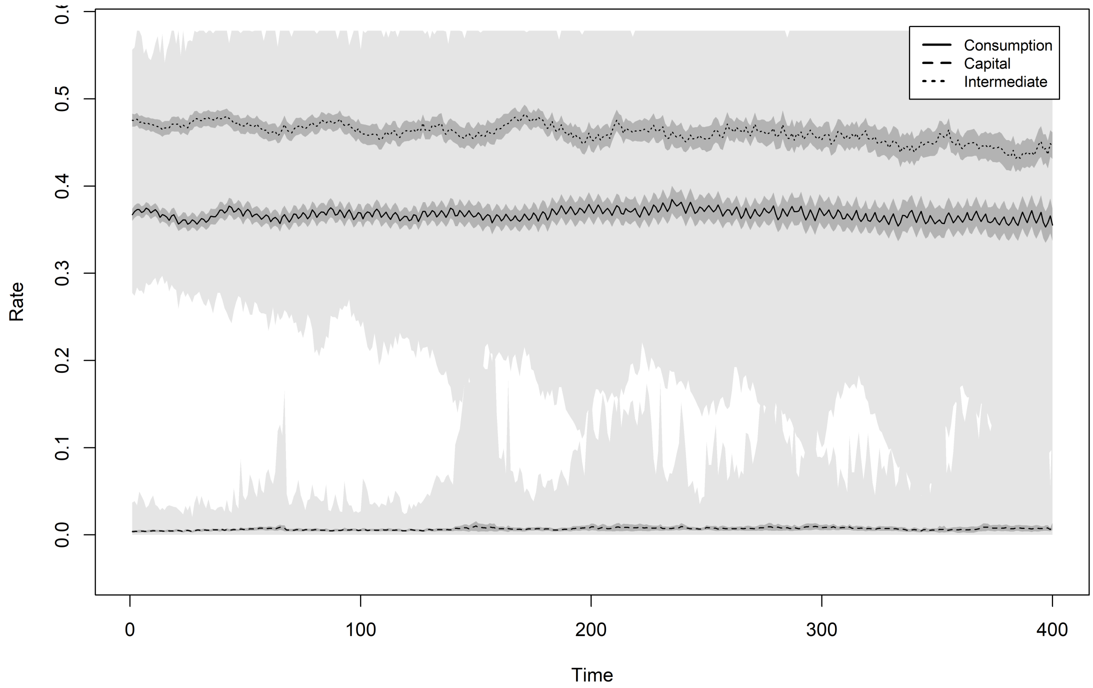
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the average nominal wage rate of the consumption, intermediate and capital sectors. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.34: Baseline Results - Sectoral Inverse HHI



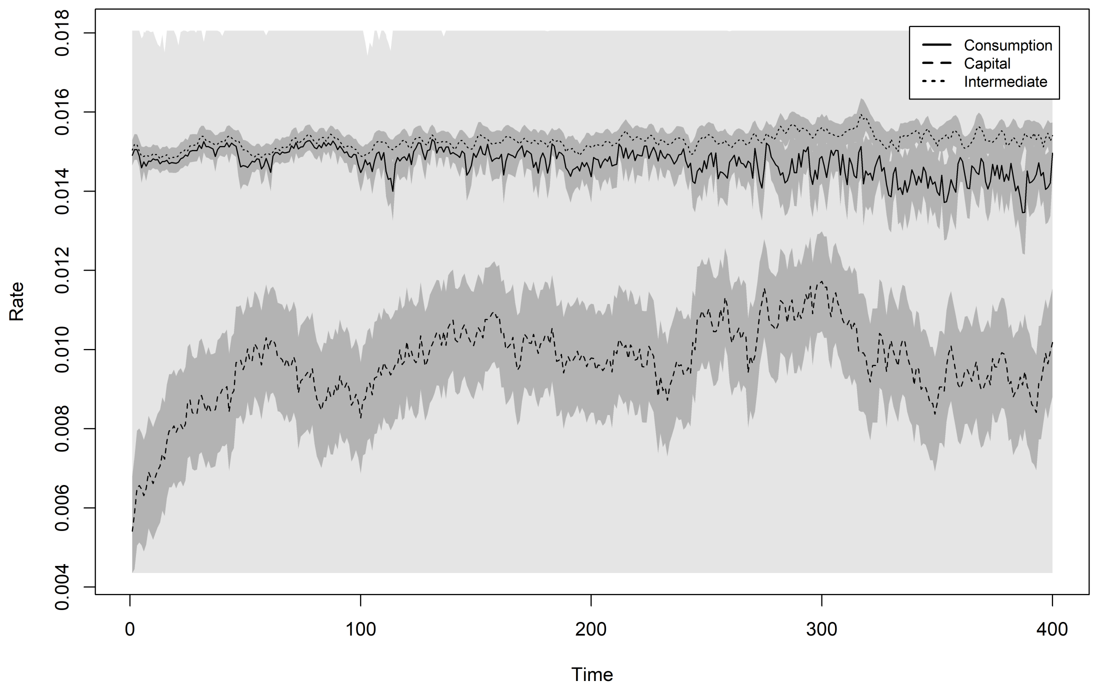
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the normalized inverse Herfindahl-Hirschman Index of the consumption, intermediate and capital sectors. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.35: Baseline Results - Sectoral Average Debt Rate



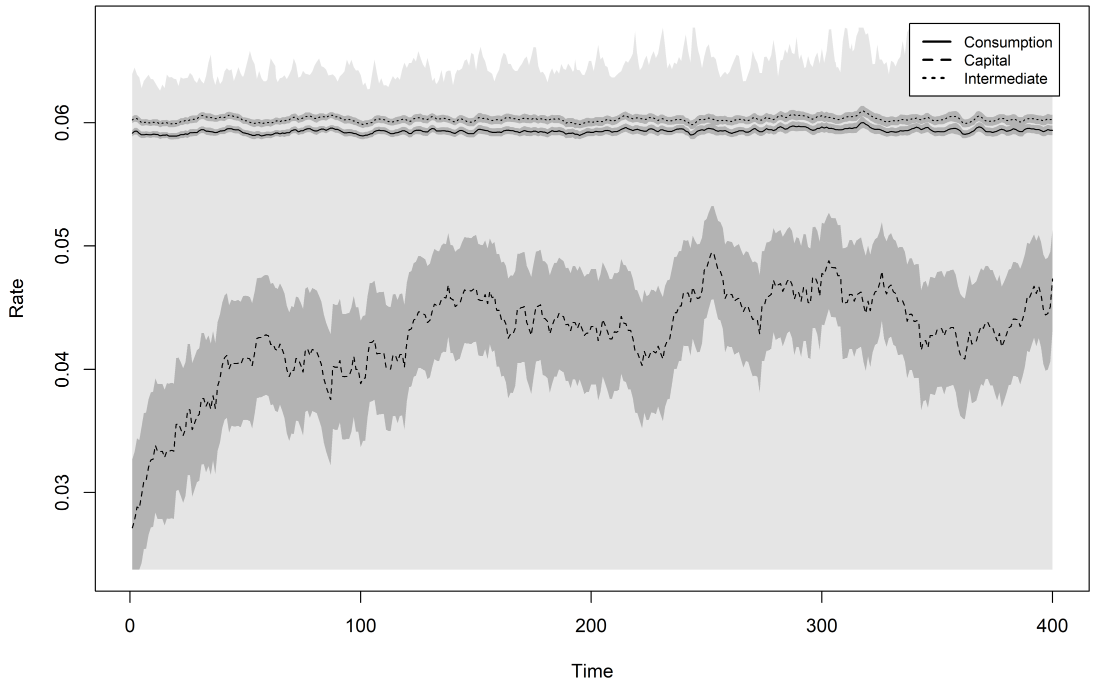
Source: Author's elaboration. MonteCarlo averages from 100 simulations of the average debt rate of the consumption, intermediate and capital sectors. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

Figure C.36: Baseline Results - Sectoral Average Short-term Interest Rate



Source: Author's elaboration. MonteCarlo averages from 100 simulations of the average interest rate on short-term loans of the consumption, intermediate and capital sectors. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

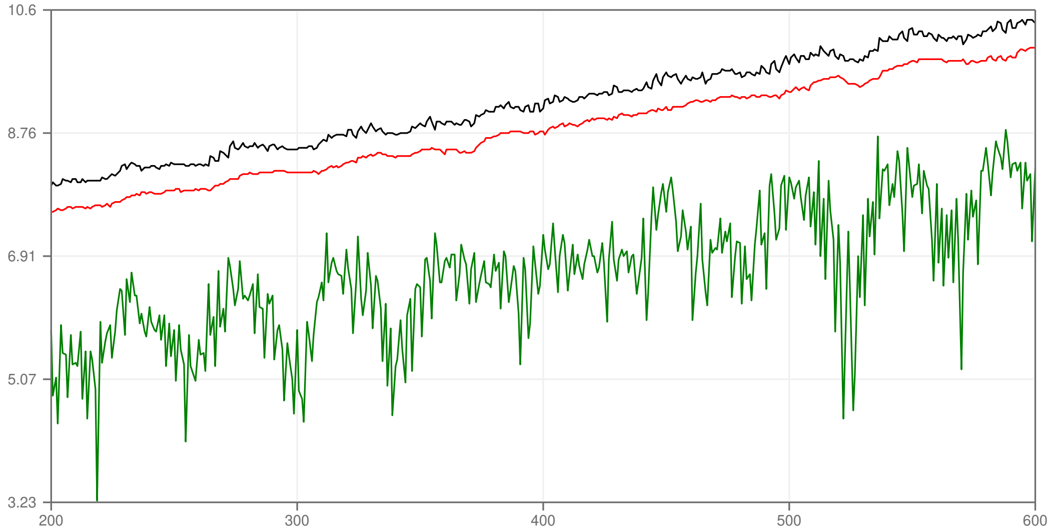
Figure C.37: Baseline Results - Sectoral Average Long-term Interest Rate



Source: Author's elaboration. MonteCarlo averages from 100 simulations of the average interest rate on long-term loans of the consumption, intermediate and capital sectors. Dark grey bands represent the 95% confidence interval. Light grey bands represent the minimum and maximum values of the MonteCarlo replications.

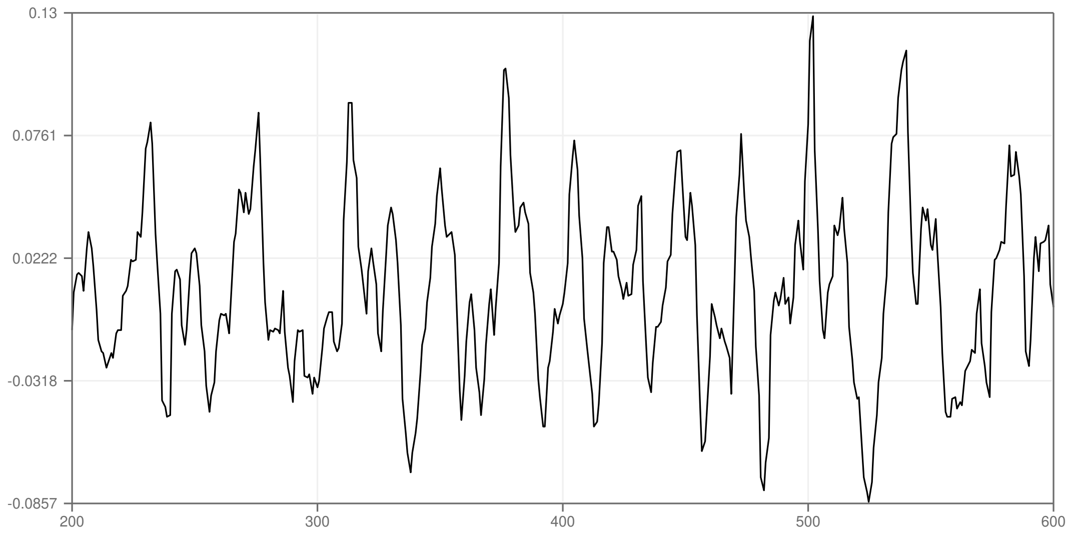
C.6 1 Simulation and Micro Variables

Figure C.38: 1 Baseline Simulation - GDP, Consumption and Investment (Series in Log)



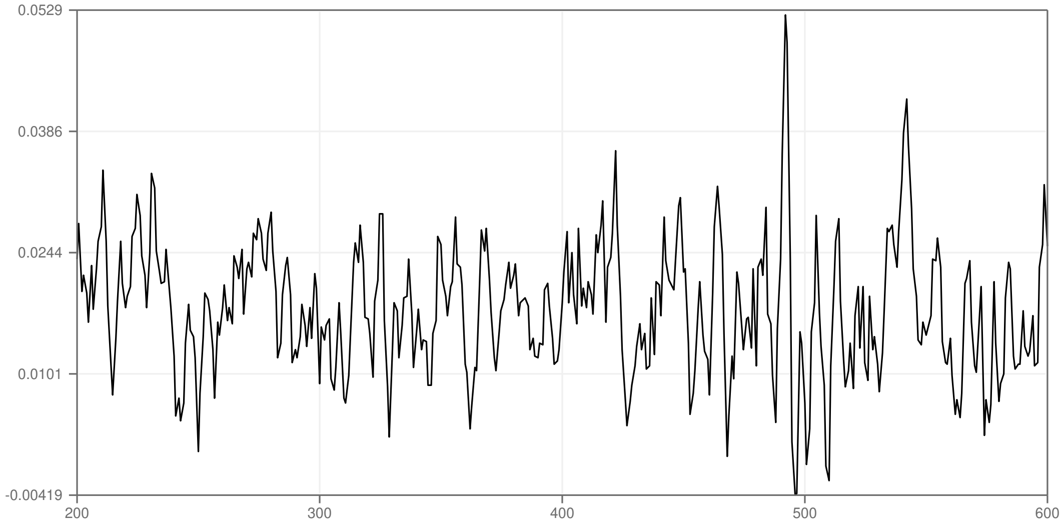
Source: Author's elaboration. 1 simulation result of GDP (black line), consumption (red line) and investment (green line) in logs.

Figure C.39: 1 Baseline Simulation - Real GDP Annual Growth Rate



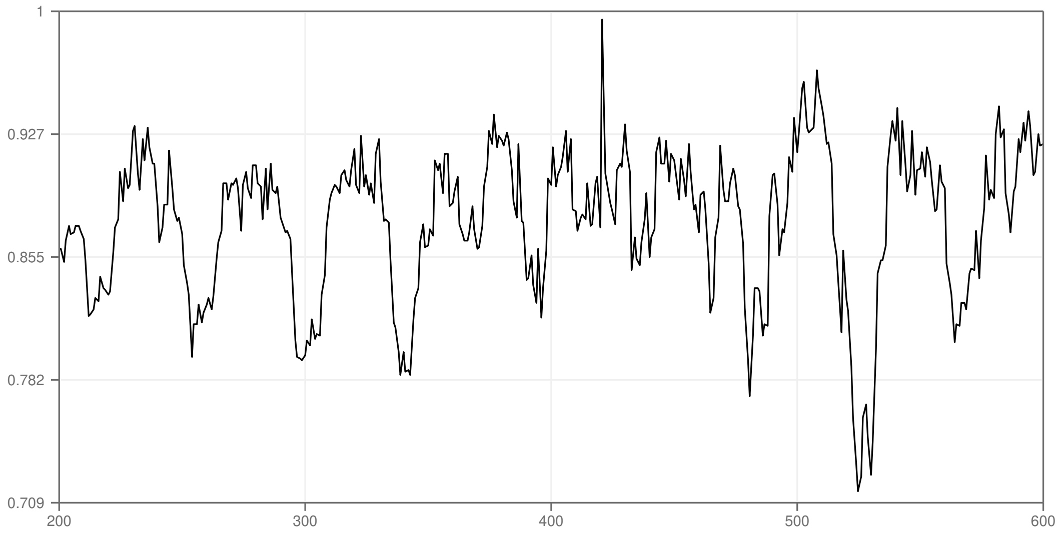
Source: Author's elaboration. 1 simulation result of the real GDP annual growth rate.

Figure C.40: 1 Baseline Simulation - CPI Annual Inflation Rate



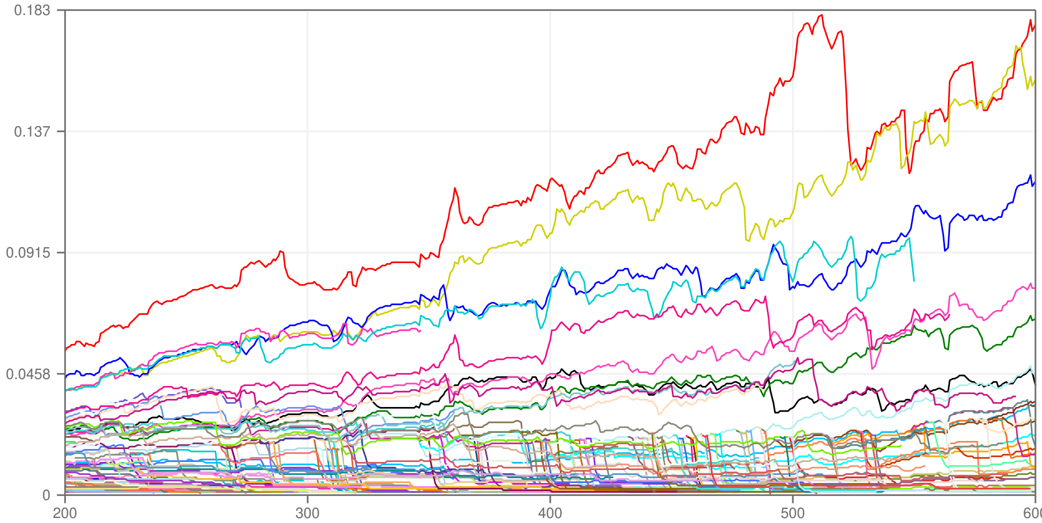
Source: Author's elaboration. 1 simulation result of the CPI annual inflation rate.

Figure C.41: 1 Baseline Simulation - Average Productive Capacity Utilization Rate



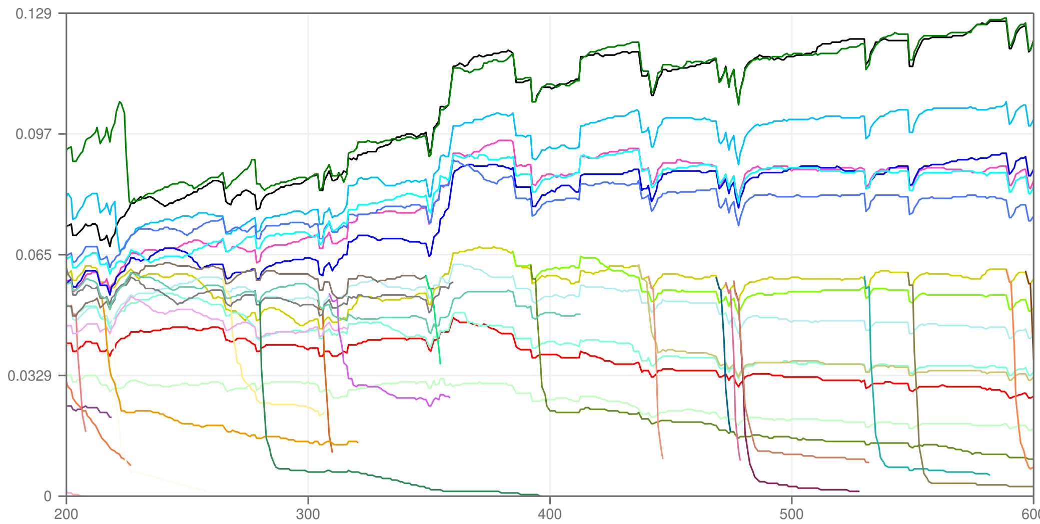
Source: Author's elaboration. 1 simulation result of the average productive capacity utilization rate.

Figure C.42: 1 Baseline Simulation - Consumption Firm's Market Share



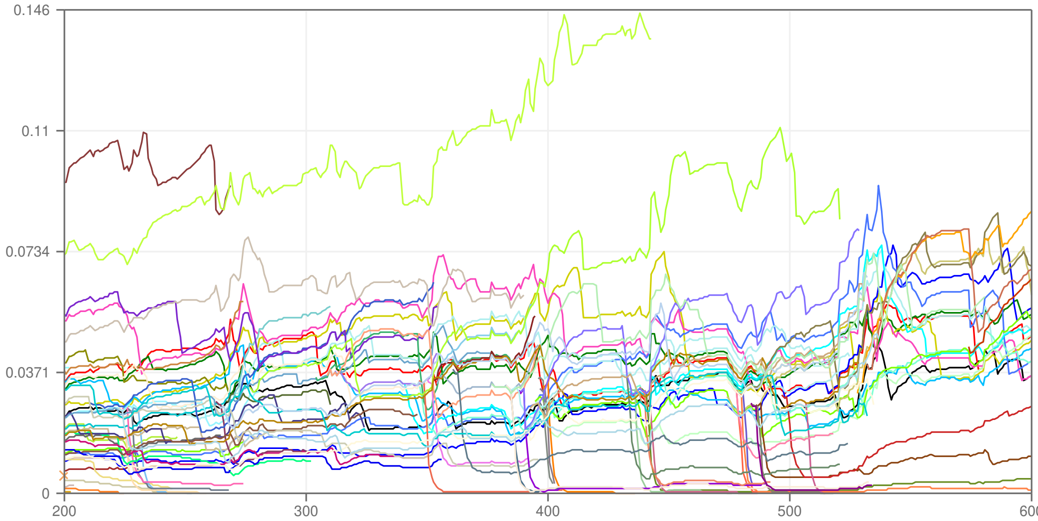
Source: Author's elaboration. 1 simulation result of consumption good firms' market share.

Figure C.43: 1 Baseline Simulation - Capital Firm's Market Share



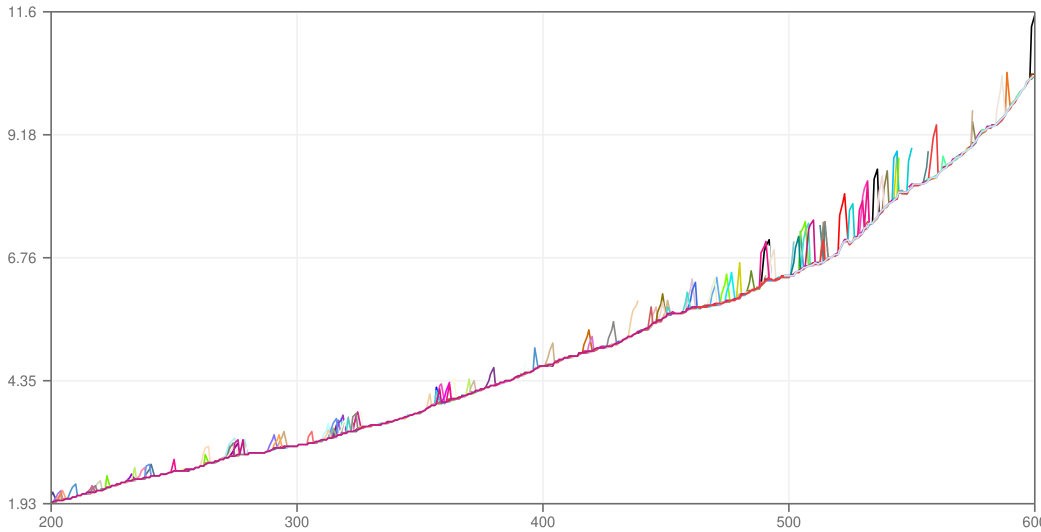
Source: Author's elaboration. 1 simulation result of capital good firms' market share.

Figure C.44: 1 Baseline Simulation - Intermediate Firm's Market Share



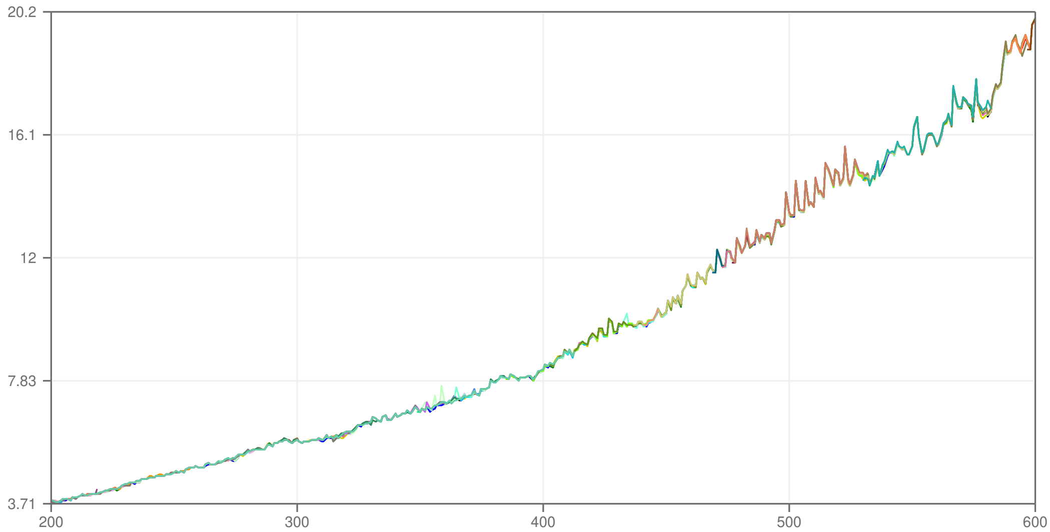
Source: Author's elaboration. 1 simulation result of intermediate good firms' market share.

Figure C.45: 1 Baseline Simulation - Consumption Firm's Price



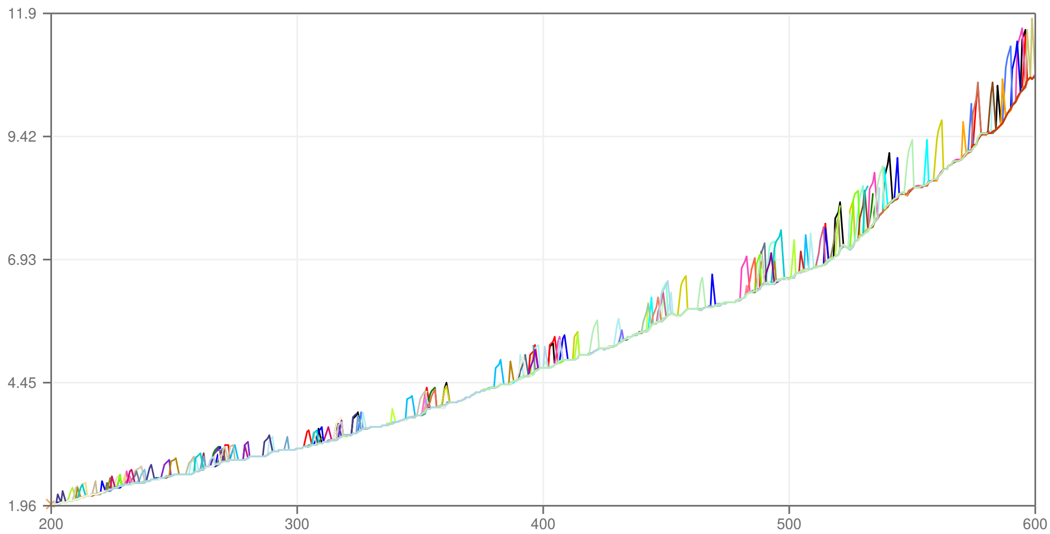
Source: Author's elaboration. 1 simulation result of consumption good firms' price.

Figure C.46: 1 Baseline Simulation - Capital Firm's Price



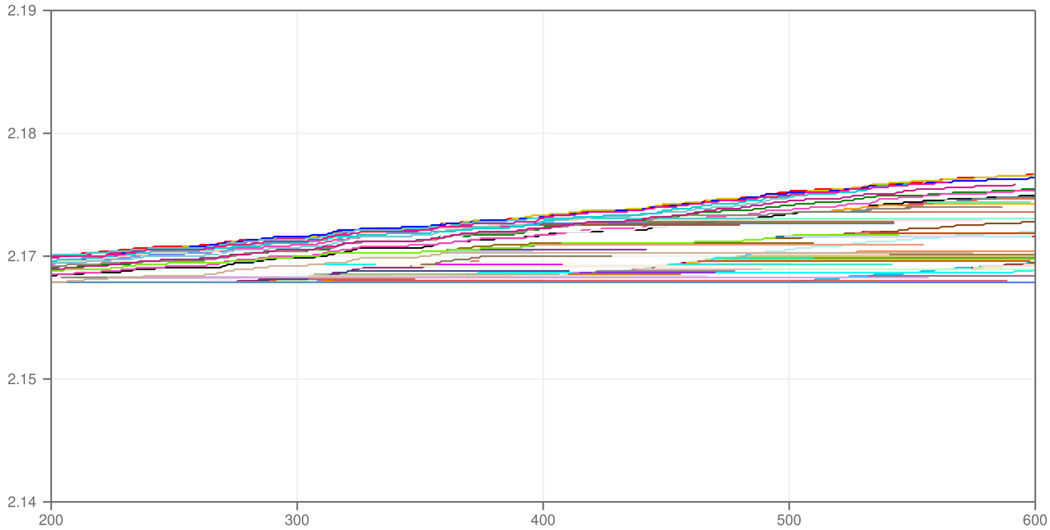
Source: Author's elaboration. 1 simulation result of capital good firms' price.

Figure C.47: 1 Baseline Simulation - Intermediate Firm's Price



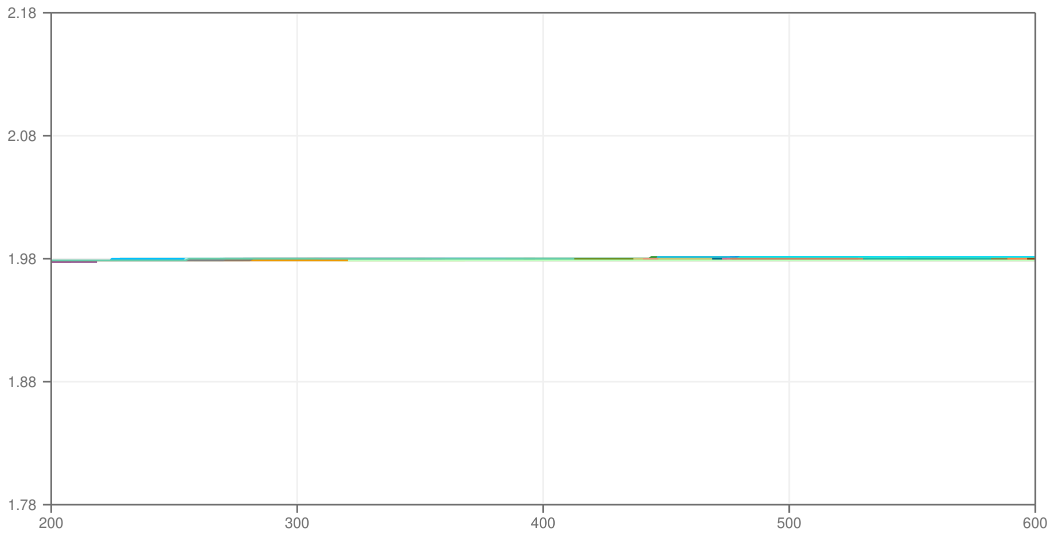
Source: Author's elaboration. 1 simulation result of intermediate good firms' price.

Figure C.48: 1 Baseline Simulation - Consumption Firm's Desired Mark-up



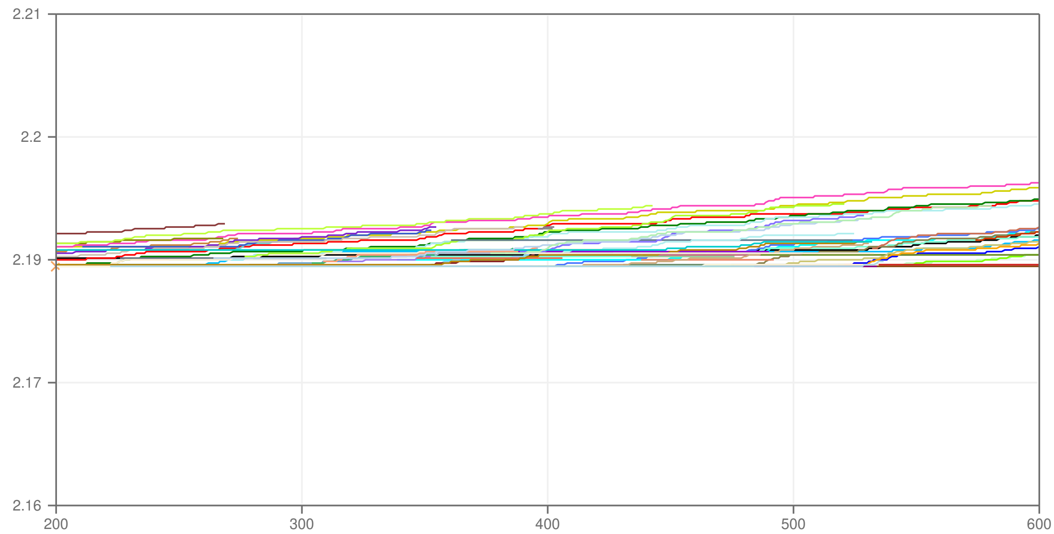
Source: Author's elaboration. 1 simulation result of consumption good firms' desired mark-up.

Figure C.49: 1 Baseline Simulation - Capital Firm's Desired Mark-up



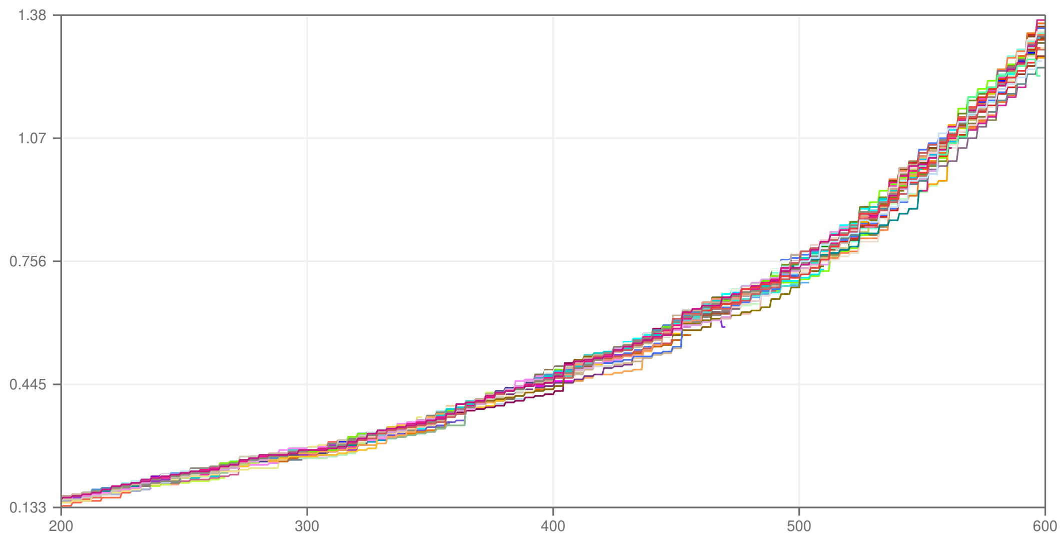
Source: Author's elaboration. 1 simulation result of capital good firms' desired mark-up.

Figure C.50: 1 Baseline Simulation - Intermediate Firm's Desired Mark-up



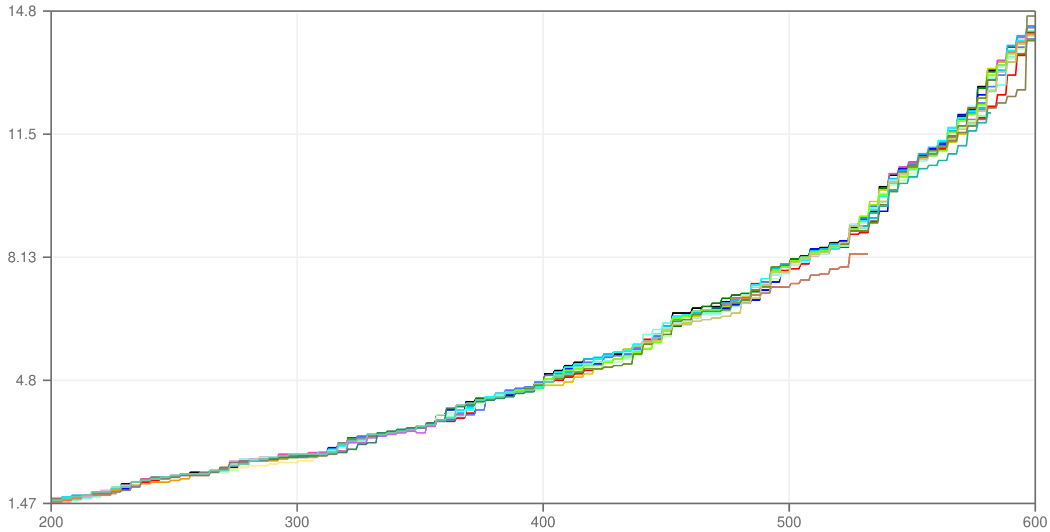
Source: Author's elaboration. 1 simulation result of intermediate good firms' desired mark-up.

Figure C.51: 1 Baseline Simulation - Consumption Firm's Wage Rate



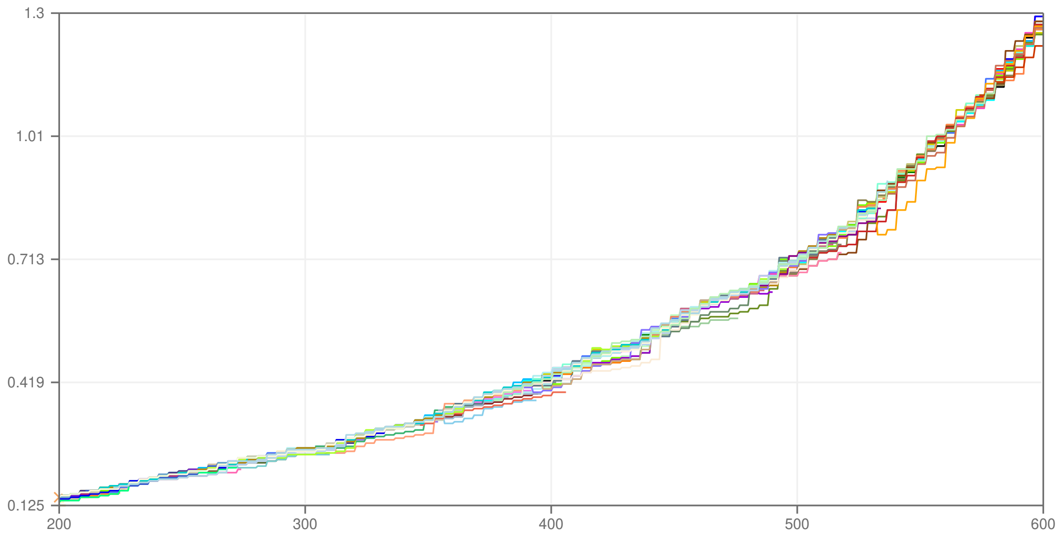
Source: Author's elaboration. 1 simulation result of consumption good firms' nominal wage rate.

Figure C.52: 1 Baseline Simulation - Capital Firm's Wage Rate



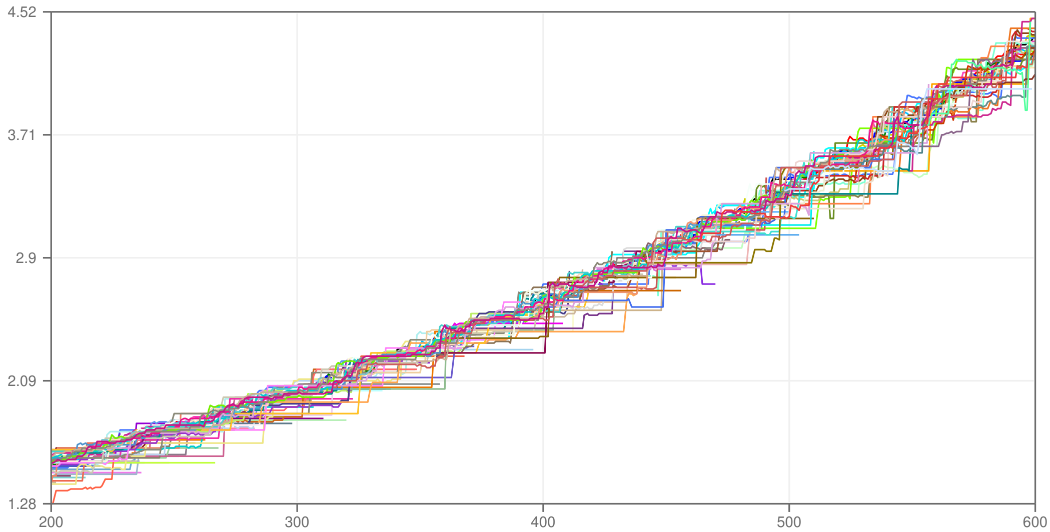
Source: Author's elaboration. 1 simulation result of capital good firms' nominal wage rate.

Figure C.53: 1 Baseline Simulation - Intermediate Firm's Wage Rate



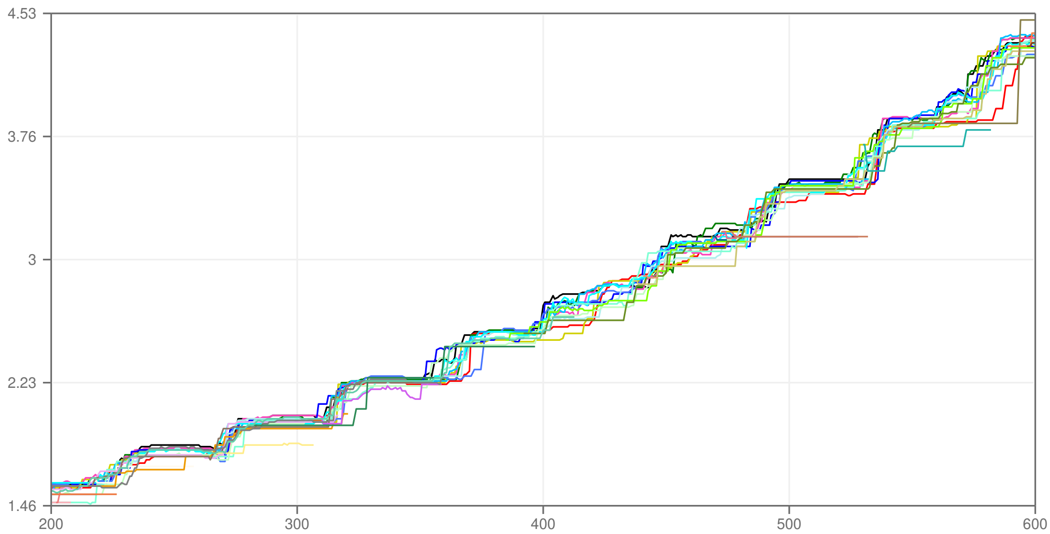
Source: Author's elaboration. 1 simulation result of intermediate good firms' nominal wage rate.

Figure C.54: 1 Baseline Simulation - Consumption Firm's Average Productivity



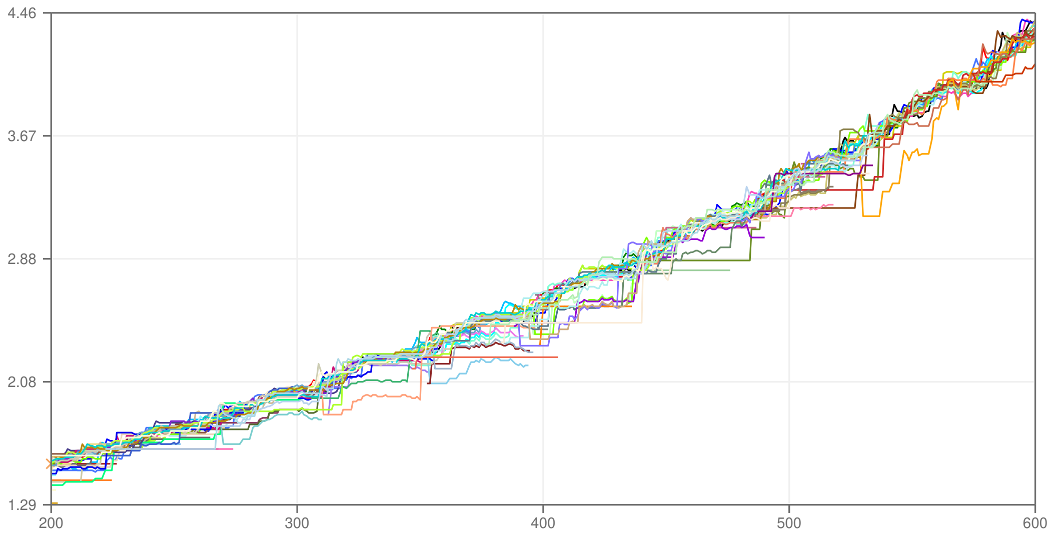
Source: Author's elaboration. 1 simulation result of consumption good firms' productivity.

Figure C.55: 1 Baseline Simulation - Capital Firm's Average Productivity



Source: Author's elaboration. 1 simulation result of capital good firms' productivity.

Figure C.56: 1 Baseline Simulation - Intermediate Firm's Average Productivity



Source: Author's elaboration. 1 simulation result of intermediate good firms' productivity.