Appropriate Macroeconomic Policy for Complex Economies

Giovanni Dosi*[1], Giorgio Fagiolo[1], Mauro Napoletano[1,3], Andrea Roventini[1,2,3] and Tania Treibich[1,4,5]

[1]Sant'Anna School of Advanced Studies, Pisa (Italy)
[2]University of Verona (Italy)
[3]OFCE, Nice (France)
[4]University of Nice-Sophia Antipolis (France)
[5]Maastricht University (Netherlands)

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Abstract

We build an agent-based model that can be employed as a laboratory to explore the effects of macroeconomic policies under different credit dynamics and income distribution scenarios. The model portrays an economy with heterogeneous capital- and consumption-good firms, heterogeneous banks, workers/consumers, a Central Bank and a Government. We carry out several policy exercises. On the fiscal side, our simulation experiments suggest that performing fiscal consolidations during recessions can be very harmful. We find that restricting the Government ability to create deficits does not improve public finances as it depresses aggregate demand thus increasing unemployment, the occurrence of crises and the duration of recessions. When an escape clause is added to the fiscal rule, long term costs are considerably reduced but GDP volatility and unemployment are high. On the monetary side, we study how both financial markets and the Central Bank can affect the real performance of the economy via the spread cost of sovereign bonds. We find that such a channel does not affect the performance of the economy. On the contrary, monetary policy can achieve lower unemployment and lower frequencies of economic crises if the Central Bank focuses also on output stabilization besides inflation. Finally, our conclusions about the effects of different monetary and fiscal policies become sharper as the level of income inequality increases.

Keywords: agent-based model, income distribution, fiscal policy, monetary policy, crises

JEL Classification: E32, E6, G21, O3, O4

*Corresponding author: Institute of Economics LEM, Laboratory of Economics and Management, Sant'Anna School of Advanced Studies; Piazza Martiri della Libertá 33 - I-56127 PISA (Italy); gdosi@sssup.it

1 Introduction

This paper investigates some features of the current global crisis by exploring the transmission mechanisms from finance to real dynamics at the economy-wide level. We employ an evolutionary, agent-based model to explore the effects of a set of different policies that could contribute to put back the economy on a steady growth trajectory. The main contribution of the paper is to expand the K+S model [Dosi et al., 2010, 2013] with an imperfect credit market composed of heterogeneous banks. In this framework, we analyze growth and fluctuations under alternative fiscal and monetary rules, and income distributions.

Our model is a bridge between short-run Keynesian theories of business cycles and long-run Schumpeterian theories of economic growth, with Minskyan financial dynamics. It describes an economy composed of heterogeneous capital and consumption-good firms, a labor force, and banks. Capital-good firms perform R&D and produce heterogeneous machine tools. Consumption-good firms invest in new machines and produce a homogeneous consumption good. The latter type of enterprises finance their production and investments according to a pecking-order rule: if their stock of liquid assets cannot cover the costs, they can ask their bank for credit, which is more expensive than internal funds.

Furthermore, in the model bank failures endogenously emerge from the accumulation of loan losses on banks' balance sheets. Banking crises imply direct bailout costs on the public budget. If bailout costs are the single largest shock on the public sector's balance sheet[1], the indirect costs such as losses in tax revenues or economic contractions due to a credit crunch must also be taken into account when measuring the full cost of such crises. Moreover, it is necessary to take into account the possible complementarities between fiscal and monetary policies in response to banking crises. The issue relates to the multiplicity of objectives a Government wants to jointly achieve: low levels of debt and unemployment, high economic growth and a stable banking sector.

In search for the design of the right policy mix, another issue relates to the fact that rules that are efficient in *normal times* might have reverse effects in times of *financial instability*. Such distinction between normal and bad times is most relevant when considering the financial sector (Wang, 2011). Since the focus is on crises, i.e. when the economy significantly departs from full employment, the model has to be able to diverge *away from equilibrium*. Because DSGE models consider dynamics close to the equilibrium, they are appropriate to study the system in normal times, but find it difficult to explain and reproduce dynamics in times of crisis (Wieland and Wolters, 2011). An evolutionary agent-based model instead is concerned with the emergent properties of a simulated system in which heterogeneous agents' routinized behaviors are aggregated. Following a bottom-up perspective, the outcomes result from the local interactions between a decentralized collection of boundedly rational agents. The evolution of the system is given by these repeated interactions, and gives rise to global regularities which can be statistically studied (Tesfatsion, 2001). Finally, the simulated economic systems can be used as "computational laboratories" where the effects of alternative policy rules on targeted

[1] In their evaluation of the state of public finances after the 2008 crisis, the IMF estimated the upfront Government financing cost to range between zero and 19.8% (Cottarelli, 2009, Table 1). Considering instead 122 banking crises since 1976, Laeven and Valencia [2008] report gross fiscal costs higher than 50% of GDP in two occasions (Argentina, 1980 and Indonesia, 1997).

aggregates can be tested and compared.

Before carrying out policy analysis, we empirically validate the model by showing that, besides the macroeconomic and microeconomic stylized facts reproduced by the K+S model (Dosi et al., 2010; Dosi et al., 2013), the current version with heterogenous banks provides a richer description of the banking sector matching new stylized facts related to credit and banking crises. Examples include the cross-correlations between output and credit variables, or between debt and loan losses, as well as the distributional properties of bank crises duration

Next, we test different experiments on the interaction between fiscal and monetary policies and income distributions. On the fiscal side, we find that that restricting the Government ability to create deficits by way of fiscal rules do not improve public finances as it depresses aggregate demand thus increasing unemployment, the occurrence of crises, the length of recessions, but also the long-run growth performance of the economy. When an escape clause in case of recessions is added to the fiscal rules, the long term costs are considerably reduced but GDP volatility and unemployment remains high. Our results thus suggest that recessions are not the appropriate time for fiscal consolidations which end up being self-defeating.

Our model also allows us to evaluate the influence that financial markets could have on the real performance of the economy via the spread cost of sovereign bonds. In contrast to the findings provided by the supporters of expansionary austerity [e.g Alesina and Ardagna, 2010, 2012], fiscal rules depress the economic activity and worsen the state of public finance even when there is a feedback mechanism between the ratio between public debt and GDP and the interest rates of sovereign bonds.

On the monetary police side, we find that a less conservative Central Bank, which focuses both on output and price stabilization, can achieve lower unemployment and frequency of economic crises without increasing the inflation rate. Moreover, quantitative easing interventions that keep the cost of sovereign bonds low and stable do not affect the real dynamic of the economy, but they reduce the cost of financing of the Government thus reducing the ratio between public debt and outout.

Finally, our conclusions about the effects of different monetary and fiscal policies become sharper as the level of income inequality increases.

The paper is organized as follows. In section 2, we focus on the previous empirical and theoretical works that guide our modeling strategy, presented in section 3. The model is then empirically validated in section 4, which finally allows us to conduct a series of policy experiments in section 5. Section 6 concludes.

2 Literature review

If models of the credit market have first been developed in the banking literature, more recently the relation between the banking and the real sector has been studied in macroeconomics, both embedded in a representative agents framework or not. At the same time an empirical literature about the costs of banking crises has emerged with the creation of international databases. Finally, Eurozone fiscal rules have received an increasing attention in recent years in representative agent models [Buti et al., 2003, Creel, 2003, Creel et al., 2013]. In this section, we review such a literature in order to stress the possible interactions between banking crises and fiscal rules which will be later studied with our evolutionary agent-based model.

2.1 Macroeconomic models with financial frictions

Including financial frictions in a macroeconomic model might be important for policy analysis: Dedola and Lippi [2005] and Aghion et al. [2012] have shown empirically that the effects of monetary policy depend on sectoral characteristics, especially on how much liquidity constrained a sector is. Further, Aghion et al. [2011] have also reported the higher impact of cyclical fiscal policy on industry growth in sectors that are more financially constrained. The availability of credit in the economy might therefore affect the impact of monetary policy.

New Keynesian, DSGE models with financial frictions [see Gertler and Kiyotaki, 2010, for a survey] study market reactions to changes in monetary as well as macro-prudential policy. However, they have several limits which can be only overtaken by switching from a representative agents to an agent based model framework. First and foremost, the symmetric equilibrium condition constrains any analysis to be done close to the steady state level, and prevents those models from realistically explaining what happens in times of crisis[2]. Second, fluctuations, crises and failures in these models are due to exogenous shocks, while in agent based models they can be endogenously generated.

Previous work with agent-based models integrating a banking sector, such as Delli Gatti et al. [2005], Gaffeo et al. [2008], Raberto et al. [2012], have aimed at creating an endogenous dynamic path of macroeconomic variables that is able to replicate the properties of business cycles, assuming imperfect information on the credit market. Other network models such as the one by Krause and Giansante [2012] or Battiston et al. [2012] have provided important insights on the role of the interbank market in the propagation of bank failures in a network. Raberto et al. [2012] use the Eurace agent-based model to study the impact of regulatory policies providing time varying capital requirements for banks on macroeconomic performance. Finally, Ashraf et al. [2011] confirm the importance of studying the differences between "normal times" and "worst case scenarios" when financial instability is endogenously created.

If these models include endogenous banking failures, the authors were more interested in understanding the development of systemic risk and failure contagion in a network. As a consequence, they did not explicitly consider the fiscal costs of bank failures or bank bailout policies.

2.2 Banking crises

The costs of banking crises on the public budget and spending, as well as the real economy have been empirically studied by Honohan and Klingebiel [2000], Hoggarth et al. [2002], and more recently by Laeven and Valencia [2008] and Reinhart and Rogoff [2009].

[2]The ability of DSGE models to forecast correctly in times of crisis has been documented by Wieland and Wolters [2011]. Comparing six different models (three small-scale New Keynesian models, a non-structural Bayesian VAR model and two medium-scale New-Keynesian DSGE models) they show that although their forecasts in times of recovery are close to the observed time series, they did not anticipate the crisis.

Honohan and Klingebiel [2000] have analyzed forty crises around the world[3] and found that crisis management policies such as liquidity support, recapitalizations or bailouts have had a significant impact on fiscal costs. They also show that such interventions did not have any positive effect on economic recovery.

In a similar exercise, Hoggarth et al. [2002] have measured fiscal costs but also output losses due to banking crises. Indeed, besides fiscal costs, banking crises can reduce the supply of credit to firms and households, further reducing production and consumption levels. Using a control group of similar countries that have not experienced a banking crisis, they show that significant differences in output losses can be attributed to banking crises in high income countries.

Laeven and Valencia [2008] have set up another database on 122 systemic banking crises from 37 countries, but their focus is instead on the policy responses and their costs[4]. They consider bailout costs but also the negative effect of reallocating wealth from taxpayers to the financial sector, or the effects on banks' incentives to take even more risks. Their study concludes that policies supporting the banking sector do not help in reducing the recovery period.

Finally, Reinhart and Rogoff [2009] have studied the aftermath of financial crises. They observe a severe effect on the unemployment rate for several years after a crisis, as well as multi-year recessions (up to four years) and higher public debt.

2.3 Fiscal rules

The creation of a monetary union in the European Union has led to the introduction of fiscal rules for its member countries. The first one has been the Stability and Growth Pact (SGP), which has governed the European Union members' fiscal status since 1997. The main fiscal constraint imposed by the SGP is the limit of 3% to the annual budget deficit to GDP ratio. The SGP received many critics, which called for further reforms of the treaty [see e.g. De Grauwe, 2003, Buti et al., 2003, Creel, 2003]. In 2005, under the pressure from several Governments to allow more flexibility to the SGP rules, a reform was passed which allows "exceptional and temporary" excesses of the deficit over the reference value in case of negative output growth(CEU, 2005).

In response to the sovereign debt crisis, several reforms to the SGP have been decided. In particular, the Treaty on Stability, Coordination and Governance (also known as "Fiscal Compact"), a new agreement governing fiscal matters in the European Union has been signed and could enter into force in January 2013, conditional on member states' ratification. The Fiscal Compact departs from the SGP by targeting a minimum "structural deficit" (that is, net of cyclical effects and one-off measures) of $0,5\%$ of GDP instead of the nominal 3% threshold. Moreover, a debt reduction rule is clearly quantified: member states with excessive debt to GDP ratios should reduce them at the average rate of 5% of the distance between the current and reference levels in every year, until the target is met. Again, the same escape clause of the SGP in case of negative output growth applies.

A systematic comparison of the alternative rules has been carried out by Creel [2003], Creel et al. [2013] and Fatas and Mihov [2012]. According to Creel et al. [2013], debt reduction

[3] Their "Banking Crisis Database" has later been extended and published in Honohan and Laeven [2005] and later in Laeven and Valencia [2008].

[4] We will use their data on the fiscal cost of banking crises in order to assess the quality of our results and validate the model (section 4).

policies cause very high volatility, and the three percent limit to deficit to GDP ratio performs best in normal times. However, when the Government is initially endowed with high debt, an "Investment rule" which requires a structural budget balance net of investment is preferred. What they emphasize is therefore that policies effective in *normal times* might not be optimal in times of crisis. This relates to the observation by Perotti [1999] and Auerbach and Gorodnichenko [2012] that fiscal multipliers change according to the state of the economiy [see also Ferraresi et al., 2013]. Indeed, if the unemployment rate is too high, fiscal multipliers can be very large, and fiscal consolidation policies might have self-defeating effects. Too much austerity in times of economic distress can thus imply an increase in public debt due to the deepening of the recession.

3 The Model

The economy is composed of a machine-producing sector made of F_1 firms (denoted by the subscript i), a consumption-good sector made of F_2 firms (denoted by the subscript j), L^S consumers/workers, a banking sector made of B commercial banks (denoted by the subscript k), and a public sector. Capital-good firms invest in R&D and produce heterogeneous machines. Consumption-good firms combine machine tools bought by capital-good firms and labor in order to produce a final product for consumers. The banks provide credit to consumption-good firms using firms' savings. Finally, the public sector levies taxes on firms' and banks' profits and pays unemployment benefits.

3.1 The Timeline of Events

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

1. Policy variables (e.g. capital requirement, tax rate, unemployment benefits, etc.) are fixed.
2. Total credit provided by the banks to each of their clients is determined.
3. Machine-tool firms perform R&D, trying to discover new products and more efficient production techniques and to imitate the technology and the products of their competitors. They then advertise their machines to consumption-good firms.
4. Consumption-good firms decide how much to produce and invest. If internal funds are not enough, firms borrow from their bank. If investment is positive, consumption-good firms choose their supplier and send their orders.
5. In both industries firms hire workers according to their production plans and start producing. They can get external finance from banks to pay for production.
6. Imperfectly competitive consumption-good market opens. The market shares of firms evolve according to their price competitiveness.
7. Firms in both sectors compute their profits. If profits are positive, firms pay back their loans to their bank and deposit their savings.

8. The Government determines the amount of unemployment subsidies to allocate, possibly being limited by the fiscal rule

9. Banks compute their profits and net worth. If the latter is negative they fail and they are saved by the Government.

10. Entry and exit take places. In both sectors firms with near zero market shares and negative net liquid assets are eschewed from the two industries and replaced by new firms.

11. Machines ordered at the beginning of the period are delivered and become part of the capital stock at time $t+1$.

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

3.2 The capital and consumption-good industries

Firms in the capital-good industry produce machine-tools using only labor. They innovate and imitate in order to increase the labor productivity of the machines they sell to the consumption-good firms as well as to reduce their own production costs[5]. They sell their machine-tools at a price which is defined with a fixed mark-up over their unit costs. Innovation and imitation allow to increase the firms' process productivity and product quality, but they are costly. Indeed, firms need to invest a fraction of their past sales into the R&D process. Finally, because capital-good firms produce using the cash advanced by their customers, they do not need external funding from banks.

Consumption-good firms produce a homogeneous good using their stock of machines and labor under constant returns to scale. Firms plan their production according to adaptive demand expectations. They decide on their desired production level based on expected demand, desired inventories and their stock of inventories. If their capital stock is not sufficient to produce the amount desired, they invest in order to expand their production capacity, and may thus acquire machines of a more recent vintage than the one they already have. Their overall labor productivity thus evolves according to the technology embedded in their stock of capital.

Firms can also invest to replace the machines that have become obsolescent. Imperfect information affect the choice of the capital-good supplier: capital-good firms advertise their machines (price and productivity levels) by sending "brochures" to a subset of consumption-good firms, which choose the machines with the lowest price and unit cost of production.

Once the desired levels of investment and production are decided, consumption-good firms have to finance their investments and their production (Q_j), as they advance worker wages and pay the ordered machines. Firms can use internal funds (cash flow) or external funds (loans) to do so. In line with a growing number of theoretical and empirical papers [e.g. Stiglitz and Weiss, 1981, Greenwald and Stiglitz, 1993, Hubbard, 1998] we assume imperfect capital markets. This implies that the financial structure of firms matters (external funds are more expensive than internal ones) and firms may be credit rationed. Indeed, banks are unable to

[5]More details on the innovation and imitation processes can be found in the appendix, as detailed in Dosi et al. [2010] and Dosi et al. [2013]

allocate credit optimally due to imperfect access to information about the creditworthiness of the applicant. According to the “financial pecking-order” theory (Myers, 1984) and the assumption of asymmetric information (Myers and Majluf, 1984), there is an imperfect substitutability of internal and external sources of finance. Therefore, the Modigliani and Miller [1958] theorem does not hold and the firms first use their internal source of funding ($NW_{j,t}$) and if it is not enough they ask the remaining part to their bank. This financing hierarchy defines the demand for credit of each firm, $L^d_{j,t}$. The firm can be credit constrained so that it is not able to reach its desired production and/or investment levels. First, a loan-to-value ratio limits the maximum amount of debt each firm can sustain. Second firms could not get the amount of external funding required to top up thier available internal funds[6]. Credit-constrained firms have to reduce their desired investment and production to the amount that they can finance[7]. Finally, the interest rate paid on the loan $r_{deb,j,t}$ depends on the central bank interest rate r_t and on the firm's credit rating (see equation 6).

Consumption-good firms define their prices (p_j) by applying a variable markup on their unit cost of production (c_j), which depends on the average labor productivity allowed by their machine-tools. As shown in more detail in the appendix (see section A.2), each firm sets a markup which is positively related to its market power, as defined by its market share. Firms' market shares evolve according to a “quasi” replicator dynamics: more competitive firms expand while firms with a relatively lower competitveness level shrink (those dynamics are determined in equations A.2 and 27 in the appendix).

Firm profits are computed as the difference between the firm revenues minus its expenses as follows:

$$\Pi_{j,t} = S_{j,t} + r_D NW_{j,t-1} - c_{j,t}Q_{j,t} - r_{deb,j,t}Deb_{j,t}, \tag{1}$$

where total sales are computed as $S_{j,t} = p_{j,t}D_{j,t}$, production costs are $c_{j,t}Q_{j,t}$, and debt costs are $r_{deb,j,t}Deb_{j,t}$, where Deb denotes the stock of debt. Firms pay taxes on their profits at the tax rate tr. Therefore, the investment choices of each firm and its net profits determine the evolution of its stock of liquid assets ($NW_{j,t}$):

$$NW_{j,t} = NW_{j,t-1} + (1 - tr)\Pi_{j,t} - cI_{j,t},$$

where cI_j is the amount of internal funds employed by firm j to finance investment.

3.3 The Banking sector

As firms in the capital-good sector are paid before starting the production of machines, credit is provided only to consumption-good firms. In the banking sector there are B commercial banks that gather deposits and provide credit to firms. In what follows, we first describe how total credit is determined by each bank, and how credit is allocated to each firm. Next, we move to describe the organization of the credit flowd in the economy and the liquidity account of the banks. Finally, we describe how banking failures are managed in the model.

The number of banks is fixed and depends on the number of firms in the consumption-good

[6] The credit allocation process defining the quantity and price obtained by the firm is detailed in section 3.3.
[7] In this case, firms give priority to production over investmnet.

sector F_2:

$$B = \frac{F_2}{a}$$

where a depends on the level of competition in the banking market. The empirical literature on topologies of credit markets (De Masi and Gallegati, 2007 for Italy, and De Masi et al., 2010 for Japan) defines this ratio as around 1 bank for 15 firms. Bank-firm couples are drawn initially and maintained fixed over time (the relationship holds both for deposits and credit). Banks are heterogeneous in their number of clients which is determined by a random draw NL_k from a Pareto distribution defined by the shape parameter $pareto_a$. Therefore, each bank k has a portfolio of clients Cl_k with clients listed as $cl = 1, ..., Cl_k$.

3.3.1 Supply and allocation of bank credit

Banks are heterogenous in terms of their fundamentals, their supply of credit, and their client portfolio. Banks set their supply of credit as a function of their equity. This is therefore a simplified version of the capital adequacy requirements of the Basel-framework rules [see e.g. Delli Gatti et al., 2005]. Therefore, according to such Basel capital adequacy rule, the maximum amount lent by a bank is:

$$TC_{reg,k,t} = \frac{NW^b_{k,t-1}}{\tau_b}, \quad 0 \leq \tau_b \leq 1 \tag{2}$$

where NW^b is the net worth of bank k, and τ_b is a parameter which measures the ratio between internal funds and total exposure of the bank, and that can be varied by the regulatory authority. Credit supply is thus impacted by changes in the banks' balance sheet, which itself is negatively affected by bank profits and loan losses. This creates a negative feedback loop from loan losses to changes in banks' equity with a reduction in the amount of credit supplied by the lender.

In every period, loan losses (or bad debt, $BadDebt$) represent a negative shock to the banks' balance sheet. As explained by Cavallo and Majnoni [2001], there are two types of buffers for such negative shocks. The first category refers to loan loss provisions, representing an expense in the income statement (Beaver and Engel, 1996, Ahmed et al., 1999) while the second one, regulatory capital, is guided by policy. The former covers expected losses, as anticipated from a statistical analysis of the distribution of loan losses, or, more simply, by past experience. The latter instead aims at preparing the bank for unexpected losses. The amount allocated by the bank for both types of reserves depends on the bank's dynamic strategy and is determined *ex ante*. First, banks can thus decide to smooth their income over the business cycle, and use loan loss provisions strategically (Laeven and Majnoni, 2003, Bikker and Metzemakers, 2005, Bouvatier and Lepetit, 2008, Fonseca and González, 2008, Alali and Jaggi, 2011). Second, it has been shown that banks maintain a buffer over the regulatory level of capital (BIS, 1999), and again the magnitude of such buffer is altered strategically by banks over the business cycle (Lindquist, 2004, Stolz and Wedow, 2005, Bikker and Metzemakers, 2005). Given this empirical evidence, we model a dynamic and heterogeneous loan loss provisioning behavior where banks adjust their capital buffer according to their financial fragility. Following Tasca and Battiston [2011], we proxy banks' fragility by their leverage ($Lev_{k,t}$), defined in our model as the ratio of their accumulated bad debt ($BadDebt_{k,t}$) to their assets, i.e. cash ($BankCash_{k,t}$ plus Government bonds ($Bonds_{k,t}$)[8]. Therefore, the higher a bank's leverage, the lower the total credit it provides to its clients:

$$TC_{k,t} = \frac{NW^b_{k,t-1}}{\tau_b * (1 + \beta * Lev_{k,t-1})} \tag{3}$$

where β is a parameter which measures the banks' intensity of adjustment to its financial fragility.

Each consumption-good firm needing credit applies to its bank for a loan. Banks take their allocation decisions by ranking the applicants in terms of their quality, defined by the ratio between past net worth (NW_j) and past sales (S_j). Banks give credit as long as their supply of credit ($TC_{k,t}$) is not fully distributed. A firm's probability to be given credit depends therefore on its financial status which determines its ranking, but also on its bank's equity base. If total credit available is insufficient to fulfill the demand of all the firms, credit rationing arises. On the other hand, total demand for credit can be lower than total supply of credit. In this case all demands of firms in the pecking order are fulfilled. It follows that in any period the stock of loans of the bank satisfies the following constraint:

$$\sum_{cl=1}^{Cl_k} Deb_{cl,t} = Loan_{k,t} \leqslant TC_{k,t}. \tag{4}$$

3.3.2 Interest rates and bank profits

Banks make profits out of the loans they allocate as well as the Government bonds they own[9]. In our setting, firm-bank links are fixed, thus interest rates on loans are not used by banks to compete between themselves, but rather to mirror the riskiness of their clients. The interest rate on loans r_{deb} is computed with a constant mark-up on the central bank interest rate r_t. The latter changes in every period following a Taylor rule which responds to changes in prices:

$$r_t = r_{target} + \gamma_{dcpi} * (dcpi_t - dcpi_{target}) \tag{5}$$

where $dcpi_t$ is the inflation rate of the period, r_{target} the target interest rate and $dcpi_{target}$ the target inflation rate.

Banks fix the *risk premium* paid by their clients depending on their position in the credit ranking. Four credit classes are created by the banks, corresponding to the quartiles in their ranking of clients[10]. As a general rule, firm j in credit class $q = 1, 2, 3, 4$ pays the following interest rate :

$$r_{deb,j,t} = r_{deb,t} \left(1 + (q - 1) * k_{const}\right) \tag{6}$$

with r_{deb} the base loan rate and k_{const} a scaling parameter.

Firms' deposits are remunerated at the price r_D, banks' reserves at the central bank are remunerated at the reserves rate r_{res}, and government bonds pay an interest rater_{bonds}. The

[8] This variable is bounded between 0 and 1 since a bank fails when its accumulated bad debt exceeds its total assets.

[9] The way Government bonds are issued and bought by banks is described in section 3.5.

[10] The credit rating class to which the firm belongs can change in every period, as the banks' ranking of its clients is updated.

different interest rates are set so that $r_D \leq r_{res} \leq r_{bonds} \leq r \leq r_{deb}$.

Whenever a firm is not able to repay its debt, it defaults and exits the market. It follows than bank profits $\pi^b_{k,t}$ can be computed as:

$$\pi^b_{k,t} = \sum_{cl=1}^{Cl_k} r_{deb,cl,t} * Deb_{cl,t} + r_{res}Cash_{k,t} + r_{bonds,t}Bonds_{k,t} - r_D Dep_{k,t} - BadDebt_{k,t} \tag{7}$$

where $Deb_{cl,t}$ represent the debt of client cl to bank k, $Cash_{k,t}$ are the liquidities of bank k and $Bonds_{k,t}$ are the stock of government bonds held by bank k. Loan losses $BadDebt_{k,t}$ thus represent a negative shock on the bank's profit, which can therefore be negative. Banks' profits are then added to their net worth.

3.3.3 Net worth, bank failure and bailout policies

To complete the description of the banking sector, we need to determine bank's net-worth at the end of the period, $NW^b_{k,t}$. A bank goes bankrupt if its net-worth becomes negative.

The net-worth of the bank is equal to the difference between its assets and its liabilities:

Assets	**Liabilities**
Cash	Deposits
Government Bonds	
Loans to firms	Net Worth

The bank's assets are composed of its stock of liquid assets ($Cash$), its stock of government bonds ($Bonds$) and the stock of loans to its clients ($Loans$). The bank's liabilities are only composed of firms' deposits ($Depo_{k,t}$). Accordingly the expression for the net-worth of the bank reads as:

$$NW^b_{k,t} = Loans_{k,t} + Cash_{k,t} + Bonds_{k,t} - Depo_{k,t} \tag{8}$$

Every time a bank fails ($NW^b_{k,t} < 0$), the Government steps in and bails out the bank providing fresh capital. We assume that the bank's equity after the bailout is a multiple[11] of the smallest incumbent's equity, provided it respects the capital adequacy ratio. The cost of public bail out $Gbailout_{t,k}$ is therefore the difference between the failed bank's equity before and after the public intervention.

3.4 Schumpeterian Exit and Entry Dynamics

At the end of each period a firm exit if it has a (quasi) zero market share or if it goes bankrupt, i.e. the stock of its liquid assets becomes negative[12].

We keep the number of firms fixed, hence any dead firm is replaced by a new one. Furthermore, in line with the empirical literature on firm entry [Caves, 1998, Bartelsman et al., 2005], we

[11] Mirroring the entry rule in the real sector, this value is a random draw from a Uniform distribution with support $[\phi_1, \phi_2], 0 < \phi_1, < \phi_2 \leqslant 1$.

[12] Note that a bad debt may occur even when the firm exits because of competitiveness reasons. In the latter case the bad debt for the bank is equal to $\min\{0, Deb_{j,t} - NW_{j,t}\}$.

assume that entrants are on average smaller than incumbents, with the stock of capital of new consumption-good firms and the stock of liquid assets of entrants in both sectors being a fraction of the average stocks of the incumbents. The stock of capital of a new consumption-good firm is thus obtained multiplying the average stock of capital of the incumbents by a random draw from a Uniform distribution with support$[\phi_1, \phi_2], 0 < \phi_1, < \phi_2 \leqslant 1$. In the same manner, the stock of liquid assets of an entrant is computed multiplying the average stock of liquid assets of the incumbents of the sector by a random variable distributed according to a Uniform with the same support. Concerning the technology of entrants, they randomly copy an incumbent's technology.

3.5 Consumption and the Government sector

Workers fully spend their wages (w_t). The share of unemployed workers in the economy is simply the difference between the fixed labor supply L^S and firms' total labor demand iL^D. Unemployed workers receive a public subsidy (w^u) which is a fraction of the current wage, with $w_t^u = \varphi w_t$, with $\varphi \in [0, 1]$. The total amount of unemployment subsidies to be paid by the Government G is therefore:

$$G_t = w_t^u (L^S - L^{D,t})$$

Aggregate consumption (C) depends on the income of both employed and unemployed workers

$$C_t = c[w_t L^{D,t} + G_t + r_D(1 - c)C_{t-1}]. \tag{9}$$

where $0 < c \leqslant 1$ is the marginal propensity to consume (in the present setup $c = 1$).

An otherwise black boxed public sector levies taxes on firms' and banks' profits and pays to unemployed workers a subsidy, which is a fraction of the current market wage. In fact, taxes and subsidies are the fiscal leverages that contribute to the aggregate demand management regimes.

Taxes paid by firms and banks on their profits are gathered by the Government at the fixed tax rate tr. Public expenditures are composed of the cost of the debt ($Debt_{cost}$), the bank bailout cost ($Gbailout$) and the unemployment subsidies (G). Public deficit is then equal to:

$$Def_t = Debt_{cost,t} + Gbailout_t + G_t - Tax_t. \tag{10}$$

If $Def_t > 0$, the Government has to issues new bonds, which are bought by banks according to their shares (s_k) in the total supply of credit[13]. In each period, the new bonds bought by each bank are added to its stock of bonds, while a share $bonds_{share}$ of the public debt is repaid by the Government. If the demand for bonds from the Government is higher than what banks are able to buy, the central bank buys the remaining debt which is paid at a zero interest rate.[14] The cost of public debt at time t is therefore:

$$Debt_{cost,t} = (r_{bonds,t} + bonds_{share})Bonds_{stock,t-1} \tag{11}$$

[13] Banks buy Government bonds employing only their net profits

[14] The fact that Government bonds held by the central bank incur no cost relates to the fact that the central bank is part of the Government therefore the profits of the central bank are paid back to the Government.

The dynamics generated at the micro-level by decisions of a multiplicity of heterogeneous, adaptive agents and by their interaction mechanisms is the explicit microfoundation of the dynamics for all aggregate variables of interest (e.g. output, investment, employment, etc.). The model naturally satisfies the standard national account identities: the sum of value added of capital- and consumption goods firms (Y) equals their aggregate production since in our simplified economy there are no intermediate goods, and that in turn coincides with the sum of aggregate consumption, investment and change in inventories (ΔN):

$$\sum_{i=1}^{F_1} Q_{i,t} + \sum_{j=1}^{F_2} Q_{j,t} = Y_t \equiv C_t + I_t + \Delta N_t.$$

3.6 Fiscal rules

In the benchmark scenario, the tax and unemployment subsidy rates are kept fixed throughout all the simulations. This implies that they act as automatic stabilizers and that the public deficit is free to fluctuate over time. In the policy experiments below we studied the effect of different fiscal rules, namely the *3% deficit rule* (mirroring the condition in the European Stability and Growth Pact, SGP)) and the *debt-reduction rule* (mirroring the Fiscal compact).

3% deficit rule. Whit a fiscal rule mimicking the SGP, the Government becomes constrained in the size of its public deficit.

$$Def_t \leq def_{rule} * GDP_{t-1} \tag{12}$$

with $def_{rule} = 0.03$ being the maximum value of the deficit to GDP ratio allowed. When the rule is binding, the Government has to reduce the amount of subsidies distributed in the period (G_t).[15] In our experiments, we implement two versions of such rule: the first one corresponds to the original version of the SGP, and the second one includes its 2005 revision allowing for more flexibility in bad times. More precisely, the fiscal rule is not binding if the nominal output growth rate is negative. We will refer to this second case as the SGP supplemented with an "escape clause".

Debt-reduction rule. The second fiscal rule is inspired by the Fiscal compact. In this case we add to the deficit over GDP ratio a debt-reduction rule: if the ratio of public debt on nominal GDP is over the SGP target of 60%, it should be reduced by 1/20th (5%) of the difference between the current and target levels every year.[16] If the debt-reduction rule is binding, the surplus necessary to satisfy it is:

$$Def_t = -0.05 * (\frac{Deb_{t-1}}{GDP_{t-1}} - 0.60) \tag{13}$$

[15] If the deficit rule is binding, the Government sets as priority the bailout of banks before the payment of unemployment subsidies, which have to be reduced to satisfy the 3% deficit condition.

[16] It is not the exact replica of the Fiscal Compact as we do not consider the limit to the structural deficit. Still, we are closer in spirit to the Fiscal compact because we consider jointly the debt reduction and the 3% deficit rules, and we also consider the escape clause in case of recession.

In this case, both the excessive debt (60% of GDP) and excessive deficit (3% of GDP) conditions have to be met, which means that the maximum deficit allowed is the minimum between the one of the 3% rule and the one of the debt reduction rule. Because the debt-reduction rule requires a surplus, it will always prevail. Also in this case, if the rule is binding, the amount of unemployment subsidies is reduced accordingly.

Bonds spread adjustment policy. What is the impact of high public debt levels in the model? Should it feed back into the cost of issuing new debt thus supporting the case for fiscal consolidations? Even if several models assume a positive correlation between public debt to GDP levels and bond yields, the empirical debate on such a link is not resolved (Alper and Forni, 2011). This is why we did not include such a mechanism into the model. However, as a positive correlation is apparent in some extreme cases[17] we perform a simulation exercise where a debt risk premium is added to the interest rate on sovereign bonds. This introduces a negative feedback effect on the sovereign bond interest rate stemming from excessive public debt:

$$r_{bonds,t} = (0.66 * r_t) * (1 + \beta_{bonds} * Debt_{t-1}/GDP_{t-1}) \tag{14}$$

Following empirical evidence [Alper and Forni, 2011], we set the β_{bonds} parameter to 0.04.

4 Empirical Validation

We resort to computer simulations for the analysis of the properties of the model. In what follows, we perform extensive Montecarlo simulations and wash away across-simulation variability. Consequently, all results below refer to across-run averages over several[18] replications and their standard error bands. The benchmark parametrization is presented in Table 2 in the Appendix.

In the presentation of model's results we first start with a "benchmark" setup and we check whether the model is "empirically validated", i.e. is able to reproduce a wide spectrum of macroeconomic and microeconomic stylized facts [see also Dosi et al., 2006, 2008, 2010, 2013].

We start with the macroeconomic stylized facts. We find that the model is able to robustly generate endogenous self-sustained growth patterns characterized by the presence of persistent fluctuations (cf. Figure 1, left). Moreover, bandpass-filtered output, investment and consumption series [Bpf, cf. Baxter and King, 1999] display business cycle dynamics (see Figure 1, right) similar to those observed in real data [e.g. Stock and Watson, 1999, Napoletano et al., 2006]. Considering the comovements between macroeconomic variables at the business cycle frequencies, we find that consumption is procyclical and coincident, net investment, changes in inventories, productivity, nominal wages and inflation are procyclical; unemployment, prices and markups are countercyclical, real wage is acyclical[for the empirics and discussion cf. Stock and Watson, 1999, Rotemberg and Woodford, 1999].

[17] De Grauwe and Ji [2012] test the correlation between spreads and debt-to-GDP ratios in Eurozone countries for the period 2000-2011. A positive link emerges only in the cases of Greece, Ireland and Portugal after 2008.

[18] All results refers to MC=100 Montecarlo iterations of T=600 iterations. Preliminary exercises confirm that, for the majority of statistics under study, Monte-Carlo distributions are sufficiently symmetric and unimodal to justify the use of across-run averages as meaningful synthetic indicators

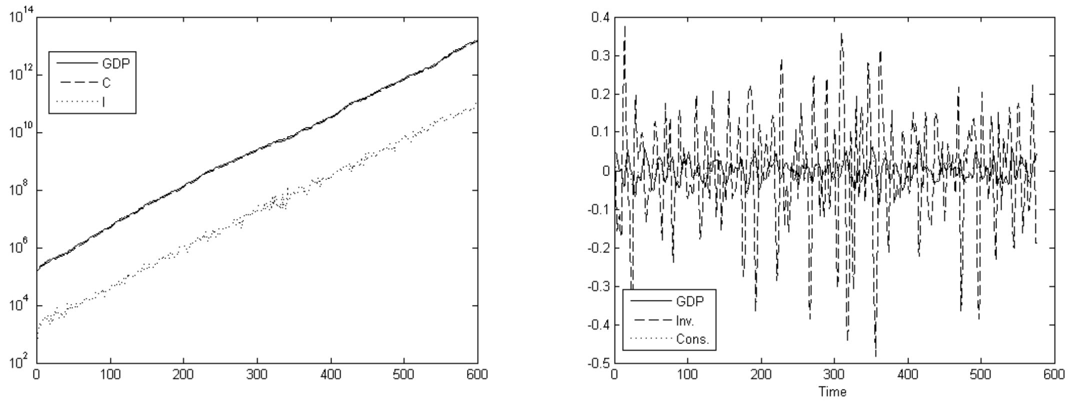


Figure 1: **Left:** Level of Output, Investment, and Consumption (logs); **Right:** Bandpass-Filtered series

The model also matches the major business cycle stylized facts concerning credit (as reported for instance by Bikker and Metzemakers, 2005). Indeed, firms' total debt and bank profits are pro-cyclical. In turn, loan losses (bad debt) are countercyclical[19].

Studies about credit dynamics [e.g. Mendoza and Terrones, 2012] have found that credit booms are often followed by banking or currency crises characterizing a boom-bust cycle. These aggregate dynamics are matched the Minskyan evolution of firms' financial health over the cycle. At the onset of an expansionary phase firms profits and cash flow improve. This pushes higher production and investment expenditures, therefore inducing a rise in firms debt. In turn the rise in debt costs gradually erodes firms' cash flows and savings, therefore leading to higher bankruptcy ratios and setting the premises for the incoming recession phase. In line with such a dynamics we find that higher level of firm debt lead to higher firm default: bad debt is positively correlated with firm debt, with a lag (cf. Figure 2). Loan growth thus entails higher default rates, further weakening banks' balance sheet, as reported by Foos et al. [2010].

The model is also able to generate economic and banking crises, matching empirical distributional properties of recessions and fiscal costs of banking failures. We observe that in the model, the large majority of crises are short-lived, lasting only one year, as reported by Ausloos et al. [2004]. Moreover, in line with the empirical literature the distribution of recession durations is exponential [Wright, 2005]. Finally, in the benchmark model, recessions can last up to 8 years, close to the maximum of 7 years observed empirically. Moving to stylized facts about banking crises [Laeven and Valencia, 2008, Reinhart and Rogoff, 2009], we find, again in line with the empirical literature, that the distributions of the ratio between the fiscal cost of banking crises and GDP is characterized by excess kurtosis, with tails heavier than the normal distribution

Finally, the model is also able to replicate a large array of microeconomic empirical regularities concerning firm-size and growth-rate distributions, firm-productivity dynamics, and firm-investment patterns

[19] The relation between default rates and the business cycle has sometimes been found to be ambiguous. Some authors report a negative link between default rates and GDP (Bikker and Metzemakers, 2005), but Koopman and Lucas [2005] show that the correlation is due to a common shock rather than a causal link. In their study of the determinants of default intensities, Das et al. [2007] report that they are negatively impacted by the production level but GDP growth rates have no explanatory power in their model.

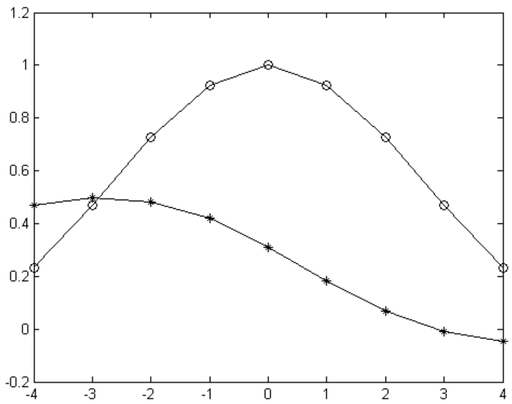


Figure 2: Average cross-correlations of Bad debt with Private debt at different leads and lags (circles) together with average Debt autocorrelation (diamonds).

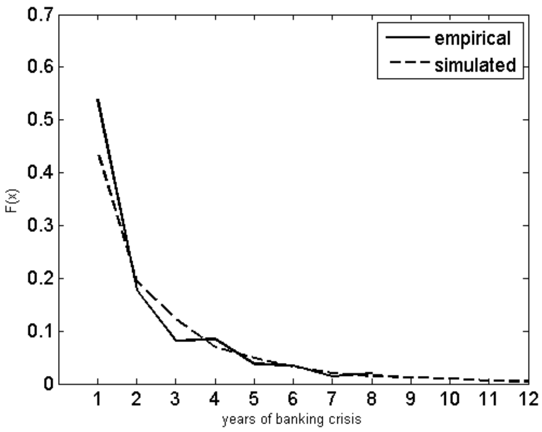


Figure 3: Distribution of banking crises duration. Empirical data:Reinhart and Rogoff, 2009

5 Policy Experiments

The results described in the previous section indicate that the model is able to robustly account for a wide set of empirical stylized facts. Encouraged by that empirical performance of the model, we now turn to policy experiments. All along this section we study the impact of changes in either parameter values or policy scenarios on a set of target variables. These include the GDP growth rate, which indicates whether such changes have a long term structural impact, and the public debt to GDP ratio, as a measure of fiscal sustainability. Others, such as GDP volatility, the unemployment rate and the occurrence of economic crises allow to evaluate the effect of policies at the business cycle frequencies. Finally, we include indicators related to the stability of the banking sector (the bank failure rate) as well as its impact on the real sector (financial constraints to firms).

The analysis proceeds in two steps. *First,* we investigate the role of fiscal policy and austerity rules under different income distribution levels, by tuning the base mark-up rate of consumption-good firms. Although the impact of income inequality on the general economy is studied in detail in Dosi et al. [2013], our setting with multiple banks now allows us to study the impact of banking crises on firms and public finances. Indeed, a lower mark-up reduces prices and benefits consumers at the expense of firms, whose profit rate shrinks, and limits their availability of internal finance. As a consequence, also the weight and the strength of the banking sector should evolve across different mark-up values. On the other side, following Dosi et al. [2013] we expect the effect of fiscal policy to be altered by the level of income inequality between firms and workers. *Second,* we are interested in the interaction between fiscal and monetary policies. We consider five fiscal models against four monetary ones. For clarity of presentation, all the experiments are displayed in Table 1, where the couple $[fisc0, mon0]$ corresponds to our benchmark parametrization.

	Fiscal models
$fisc0$	Baseline : no limit to public deficit
$fisc1$	SGP : 3% deficit rule
$fisc2$	SGP + recessions escape clause
$fisc3$	Fiscal compact (debt reduction rule)
$fisc4$	Fiscal compact + recessions escape clause
	Monetary models
$mon0$	Baseline : Taylor rule on inflation gap
$mon1$	Taylor rule on inflation + unemployment gap*
$mon2$	Quantitative easing: interest rate on bonds is fixed to 1%
$mon3$	Bonds spread adjustment to the public debt to GDP ratio**
$mon4$	QE and Taylor rule on inflation + unemployment gap

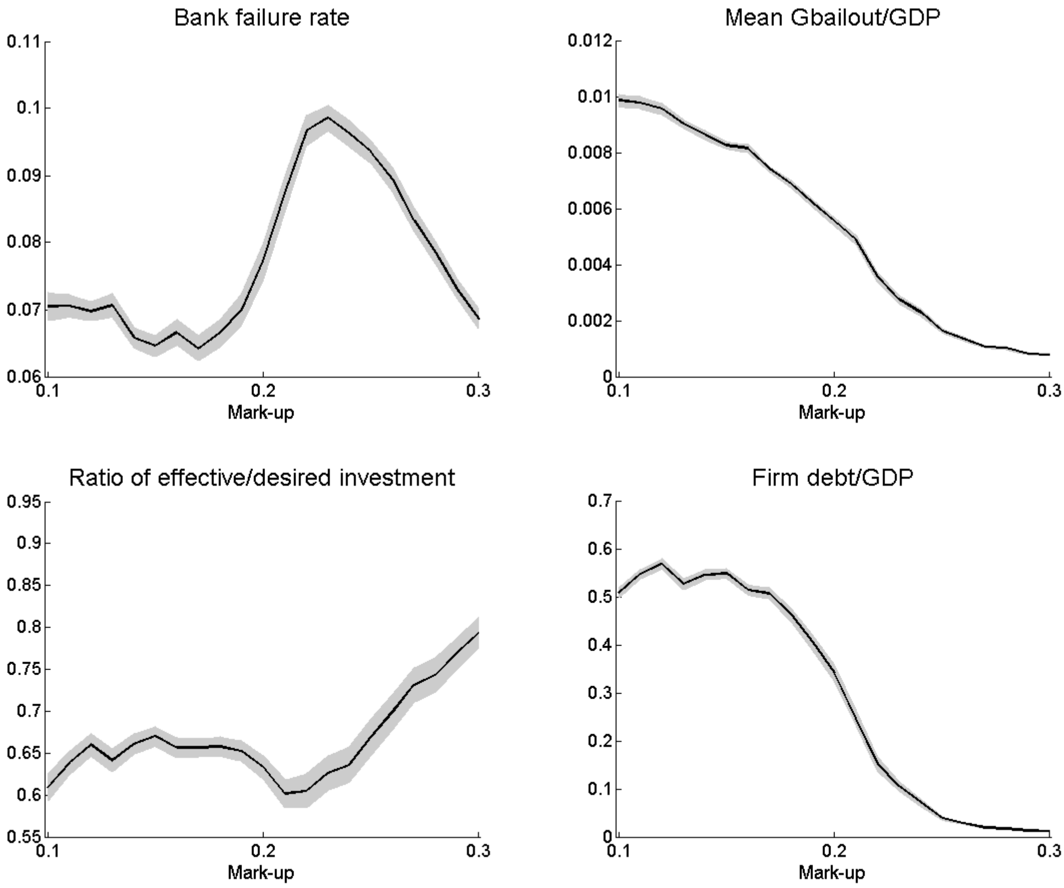
Table 1: Experiments description

Notes: * unemployment adjustment parameter=1.1; ** beta_bonds=0.04.

5.1 Impact of the mark-up rate

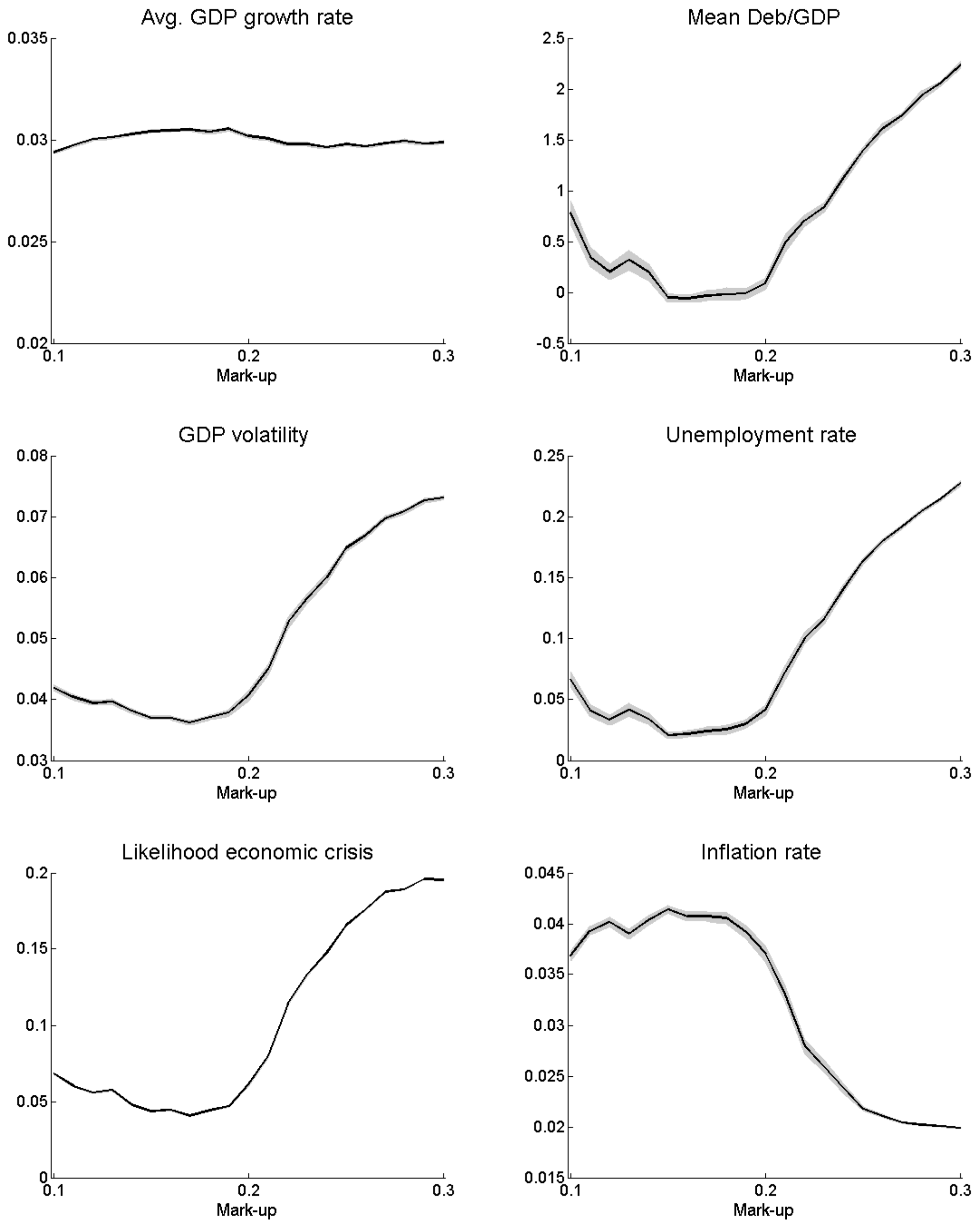
In order to understand the workings of the model, before carrying out policy experiments we show in Figures 4 and 5 how our target variables evolve when we modify the income distribution under the benchmark scenario ($[fisc0, mon0]$). First, the size of the banking sector is negatively associated with the mark-up rate. This implies that the cost of banking crises over GDP (Fig. 4 top right) increases as the mark-up shrink notwithstanding the dynamics of the bank failure rate. Failed banks are indeed on average larger when the mark-up is low as they provide more credit to the firms which have a reduced ability to finance their investment with their own accumulated profits (Fig. 4 bottom left and right).

Firm margins, by impacting on income inequality and then on aggregate demand, affect also the macroeconomic dynamics (cf. Fig. 5). If, on the one hand, the average GDP growth rate is stable for different levels of mark-up, on the other hand, the U-shape pattern displayed by GDP volatility, the unemployment rate and by the likelihood of economic crisis reveal the existence of two "regimes". In the "financial constraints regime" (low mark-up), firms have a higher failure rate which increases bad debt and the failure rate in the banking sector. As a consequence, firms can be financially constrained, which reduces their investment and increases unemployment rates. In the "demand constraints regime", consumption-good firms set higher mark-ups and prices, which reduces aggregate consumption. Although they have a high profit rate, firms do not invest because expected demand is too low. Such demand constraints have a negative impact on GDP volatility, unemployment and on investment which is depressed by low demand expectations. This is in line with the findings in Dosi et al. [2013].



Note: Confidence interval bands are shown in a lighter color, they are computed as plus or minus twice the standard error. Average value over 100 Montecarlo iterations.

Figure 4: **Income distribution experiment - Credit variables**



Note: Confidence interval bands are shown in a lighter color,they are computed as plus or minus twice the standard error. Average value over 100 Montecarlo iterations.

Figure 5: **Income distribution experiment - Macroeconomic target variables**

5.2 Impact of fiscal rules

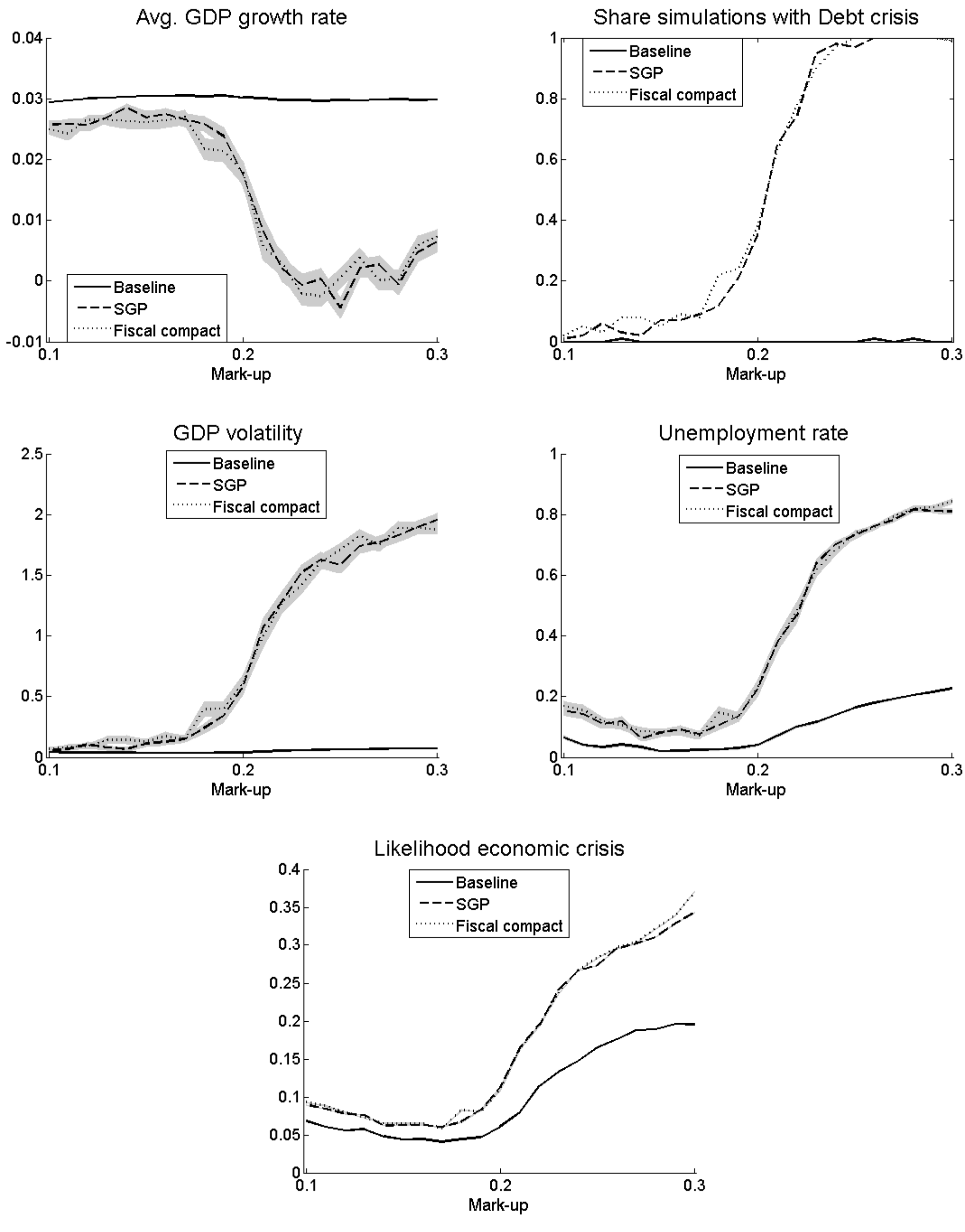
Why should the impact of fiscal rules change along with the income distribution? In the "Financial constraints regime", the bailout costs are high (see Figure 4). This in turn could worse the public budget and as public expenses are limited, both demand and financial constraints would be binding. On the other side, Dosi et al. [2013] have shown that when income inequality favors firms (higher margins), fiscal policy is more effective and needed. We test here the corollary, which is that fiscal discipline is *more harmful* when the income distribution is biased towards firms' profit.

In Figure 6, the benchmark parametrization is compared to both the 3% deficit rule (mimicking the Stability and Growth pact - SGP) and the debt reduction rule (mimicking the Fiscal compact), corresponding to experiments $fisc1$ and $fisc3$ respectively. The fiscal rules appear to have a strong and negative impact on the performance of the economy: they reduce GDP growth and increase unemployment and output volatility. The deterioration of the macroeconomic conditions lead to an explosion of the ratio between public debt and GDP (not shown). Hence austerity policies appear to be self-defeating. Even if these results hold for every level of income inequality, the negative impact of fiscal rules is even more pronounced in the "Demand constraints regime" where consumption is more limited due to firms' higher margins. This confirms that fiscal discipline is *more harmful* as the income distribution becomes more biased towards firms' profits. Indeed, although in this regime firms have access to both internal and external financial resources, they do not invest for a lack of aggregate demand. This reduces the average GDP growth rate and, together with the increases of public expenditures to pay for unemployment subsidies, it leads to the explosion of the public debt to GDP ratio. What is more, there is a net increase in the occurrence of deep recessions (GDP growth rates below -0.03), confirmed also by the high volatility of GDP.

5.3 Fiscal rules and escape clause in case of recession

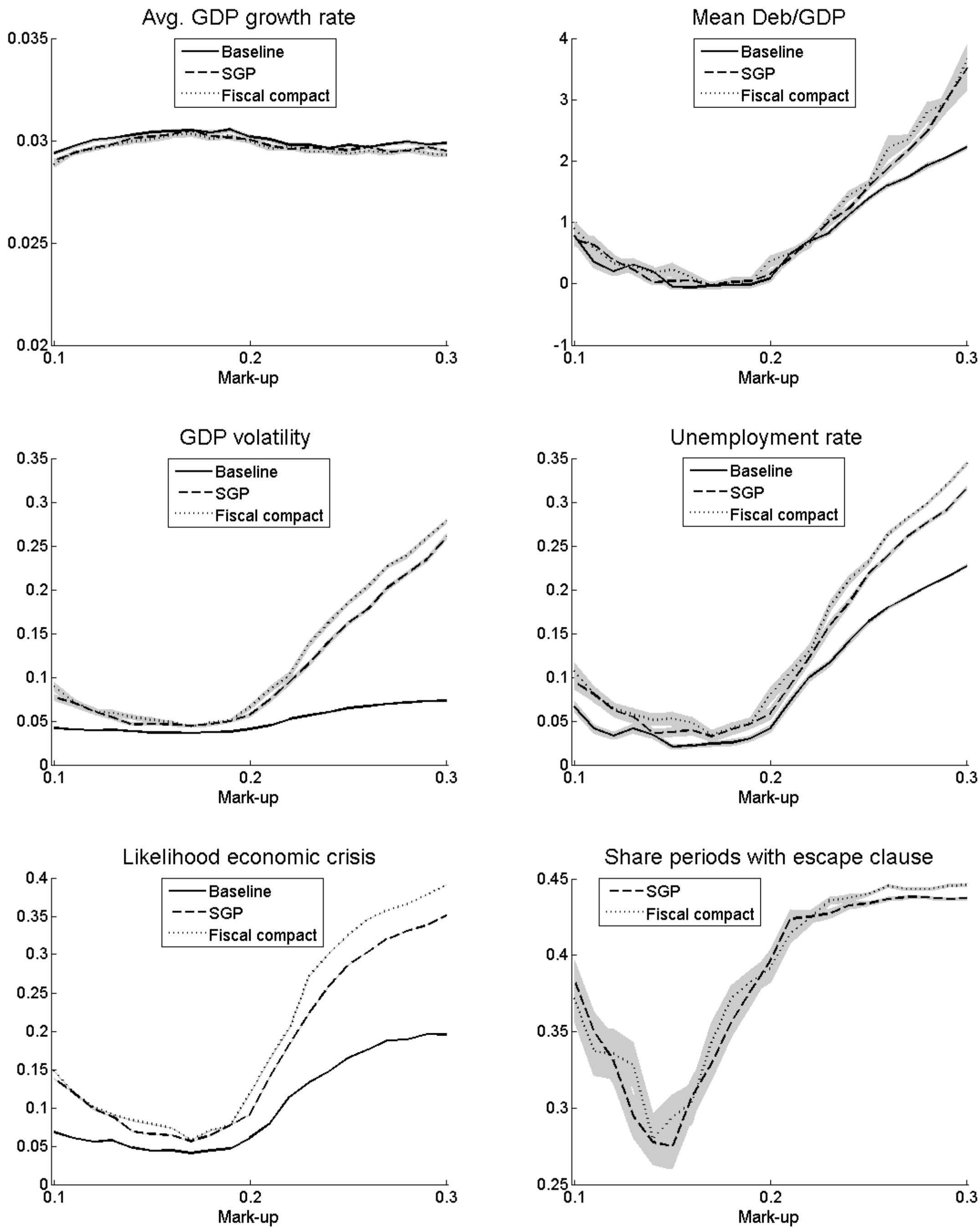
The two fiscal rules implemented so far however do not fully follow the European SGP and Fiscal compact. As noted by Schaechter et al. [2012], many escape clauses which suspend the implementation of fiscal rules in case of "exceptional circumstances", have been added. The importance of taking into account such extraordinary events, in particular recessions, is not yet clear. Whether or not fiscal discipline should be observed in periods of economic crisis has indeed been under debate in recent years. Advocates of fiscal discipline fear the explosion of public debt if fiscal policy is unchained, while their opponents put forward the risks associated with putting further restrictions on demand when it is already weak. Our experiments thus intend to compare the impact of the fiscal rules with and without such clauses.

Figure 7 presents the comparison of the benchmark parametrization ($fisc0$) with the fiscal rules with escape clause in case of recession, $fisc2$ for the SGP and $fisc4$ for the Fiscal Compact. In this case, we find that the harm of fiscal rules to the performance of the economy is considerably reduced. For instance, average GDP growth is close to the one observed with the benchmark fiscal policy. This result stems from the fact that the escape clauses prevent the activation of fiscal rules up to 40% of the periods (Fig. 7, bottom right). However, even in presence of escape clauses, the fiscal rules are still responsible for a higher GDP volatility,



Note: Confidence interval bands are shown in a lighter color, they are computed as plus or minus twice the standard error. Average value over 20 Montecarlo iterations.

Figure 6: **Fiscal rule experiment - No escape clause**



Note: Confidence interval bands are shown in a lighter color, they are computed as plus or minus twice the standard error. Average value over 20 Montecarlo iterations.

Figure 7: **Fiscal rule experiment - Recessions escape clause**

unemployment and occurrence of economic crises vis-à-vis the benchmark scenario. Moreover, when income inequality is high, we keep on observing a self-defeating effect of fiscal rules on public debt. These results confirm that countercyclical fiscal policies have a relevant role in supporting demand during recessions thus improving the performance of the economy. For instance, average GDP growth is close to the one observed with the benchmark fiscal policy. This result stems from the fact that the escape clauses prevent the activation of fiscal rules up to 40% of the periods (Fig. 7, bottom right). However, even in presence of escape clauses, the fiscal rules are still responsible for a high GDP volatility and a higher occurrence of economic crises. Moreover, when income inequality is high, the unemployment rate is also higher and we even observe a self-defeating effect of fiscal rules on public debt. These results confirm that countercyclical fiscal policies have a relevant role in supporting demand during recessions thus improving the performance of the economy.

Finally, we identify significant differences between the influence of the Fiscal Compact and the SGP rules. Indeed, as the debt reduction rule is more demanding in terms of budget cuts than the 3% deficit one, it creates a higher volatility of GDP, a higher unemployment rate as well as a higher occurrence of economic crises. Such differences were not apparent in the case without escape clauses because the production sector was too much harmed by both rules.

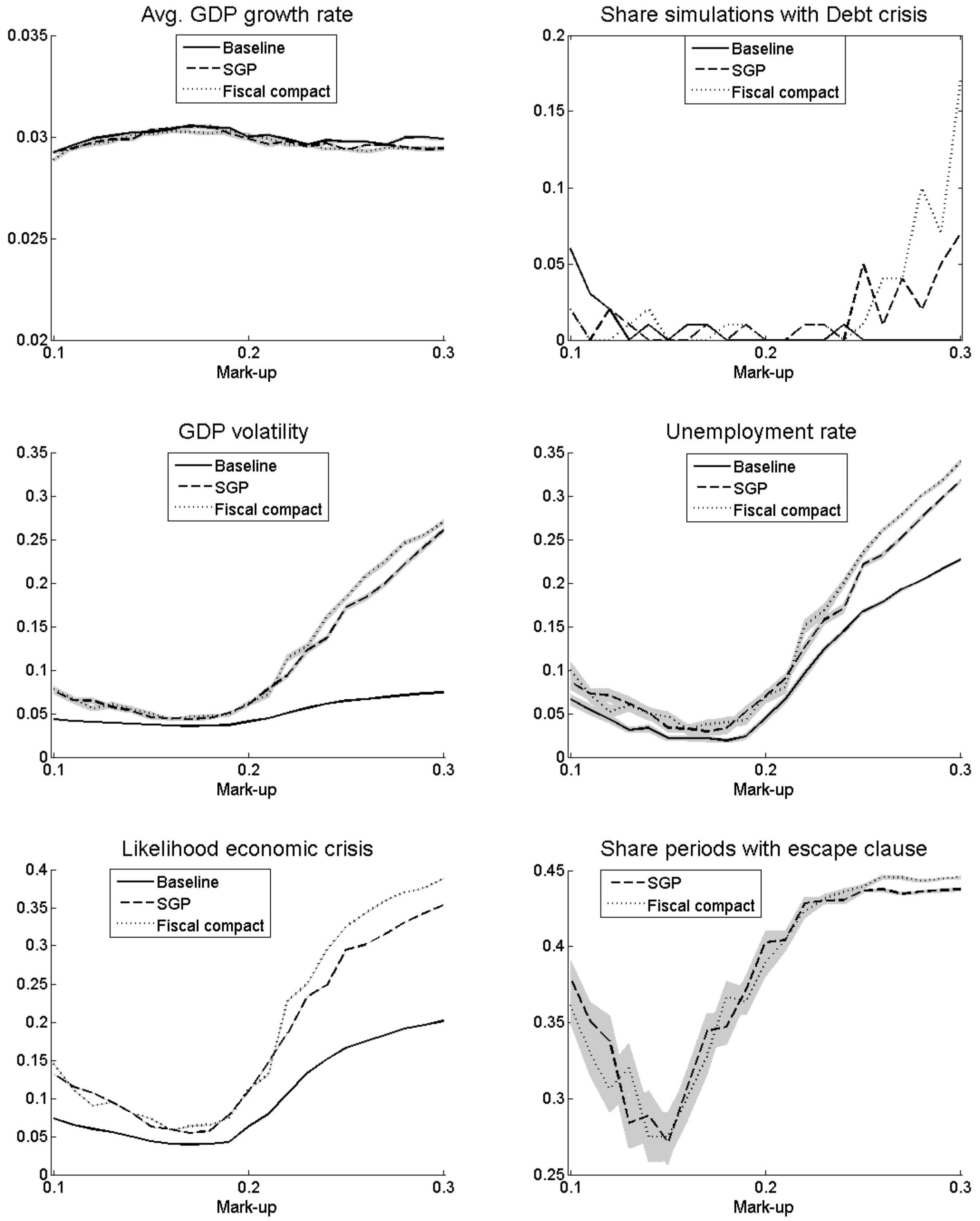
5.4 Fiscal rules and bonds spread adjustment scenario

The evidence on the link between sovereign bonds rates and debt to GDP levels is inconclusive [De Grauwe and Ji, 2012]. However, in some extreme cases such as Greece, Portugal and Ireland during the current crisis, a reduction in public debt levels was considered a necessary condition for limiting sovereign risk premia thus allowing the economy to start growing again. Would our results of the effects of fiscal rules differ if we took into consideration the positive effect of public debt on the spread cost of Government bonds?

We implement this scenario ($mon2$) for our different fiscal policies and compare them in Figure 8. We find that the results of our previous experiment (Fig 7) are robust to the inclusion of a debt premium. Indeed, when the spread increases according to the level of public debt, the benchmark fiscal model ($fisc0$) performs better than the austerity rules. The scenario which puts the highest constraint on public debt, i.e. the fiscal Compact ($fisc3$), has the worst impact on the public budget (Figure 8 top, right). The results are robust even when escape clauses are taken into account.

5.5 Impact of monetary policy and quantitative easing

The final experiments study the role monetary policy as stabilization tools. In the baseline model, we assume that the Central Bank is conservative by employing a simple Taylor rule which adjusts the central bank interest rate only to the inflation gap ($mon0$). In the experiment $mon1$, we let the Central Bank caring also about the state of the economy by including an adjustment to the unemployment gap in the Taylor rule (with a 5% unemployment rate target). Moreover, in the $mon3$ experiment we implement a quantitative easing policy: the Central Bank commits to buy an unlimited quantity of Government bonds in order to keep the interest rate on sovereign bonds to 1%. This policy is supposed to reduce the financing costs of public debt.



Note: The bonds spread rule is used with a 4% adjustment to the Debt/GDP ratio.
Confidence interval bands are shown in a lighter color, they are computed as plus or minus twice the standard error.
Average value over 20 Montecarlo iterations.

Figure 8: **Fiscal rule experiment - escape clause and bonds spread adjustment.**

Figure 9 shows that the performance of the economy improves when the Central Bank pursues both price and output stabilization. Indeed, for any level of inequality, GDP volatility, unemployment, and likelihood of crises are lower in $mon1$ vis-à-vis $mon0$. Note also that the average inflation rate is just slightly higher as to the case when the Central Bank is more conservative. Hence, when the monetary policy is driven by a Taylor rule considering both price and unemployment stabilization, the macroeconomic performance of the economy considerably improves without experiencing increasing inflationary pressures. How this is possible? Figure 10 helps to understand the mechanisms at play: with a dual-mandate Taylor rule, the banking sector performs better, as shown by a higher share of investment projects that can be financed and thus implemented (Fig 10, top left), as well as a lower rate of banking failures. Both results relate to banks' better ability to accumulate profits due to higher interest rates. A negative feedback loop is indeed at play: lower unemployment pushes interest rates up, which reduces firms' incentives to invest, but strengthens bank's profitability. The increase of the interest rate cool down aggregate demand, while improving the net worth of the banks leading to higher supply of credit when the economy will experience a downturn.

Moving to the quantitative easing policy, we find no significant differences with the baseline experiment, except for a lower public debt burden when the economy is most under tension (and markups are high). These results suggest that quantitative easing policies alone do not help the economy to recover during recessions.

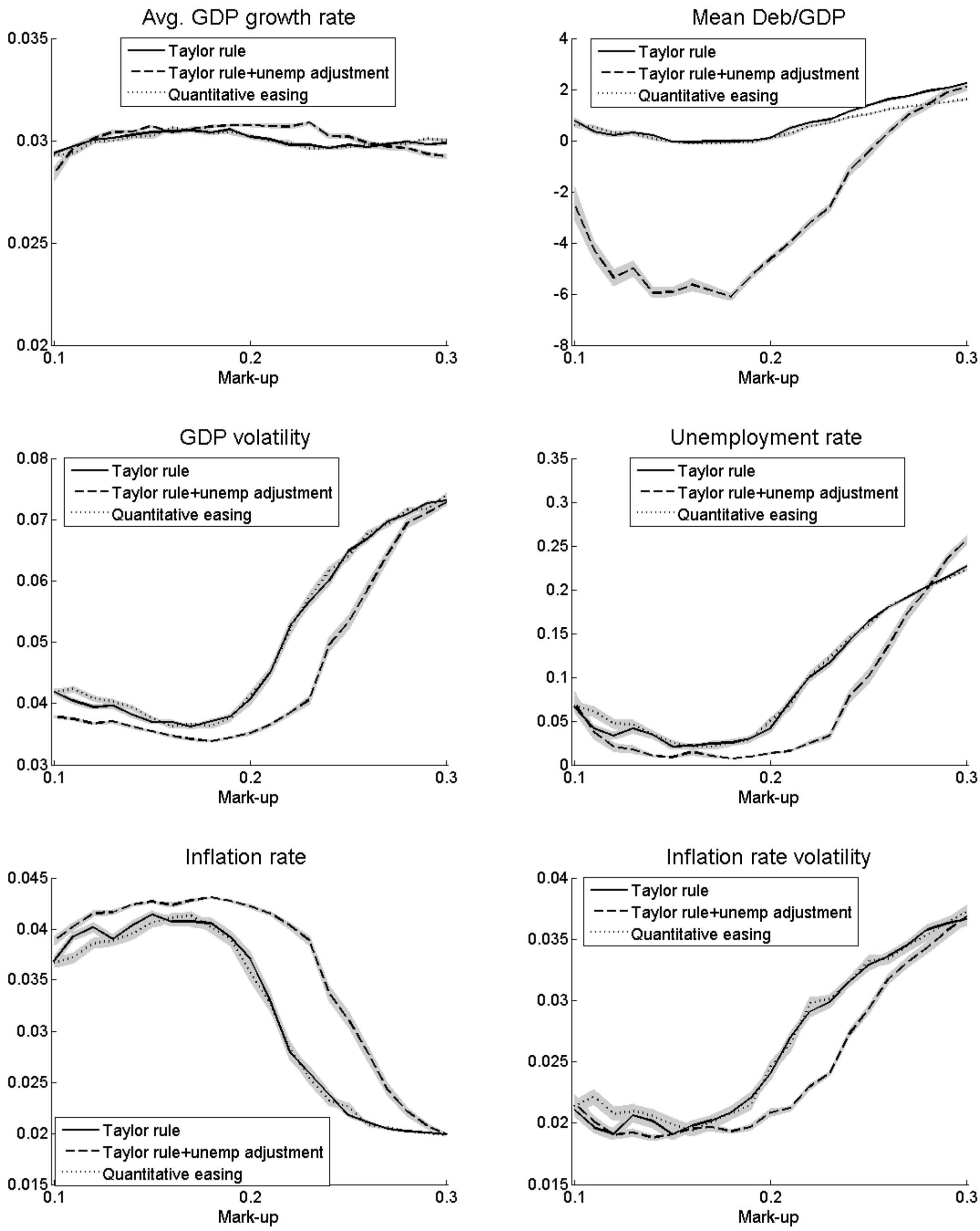
6 Concluding Remarks

Building on previous works (Dosi et al., 2010, Dosi et al., 2013) we have studied the properties of an agent-based model with both a real and banking sector. The model robustly reproduces a wide ensemble of macro stylized facts and distributions of micro characteristics, but also banking crises, endogenously emerging from micro technological and demand shocks which propagate through the economy.

When studying the evolution of the main macroeconomic aggregates for different levels of income distributions, we reveal two different "regimes". The "financial constraints regime" corresponds to low levels of the mark-up rate, where firms are more dependent on external finance and the banking sector is therefore larger. Instead, for higher mark-up rates, the "demand constraints regime" identifies a situation where firms can finance investments with accumulated profits but are constrained in their opportunities due to lower demand.

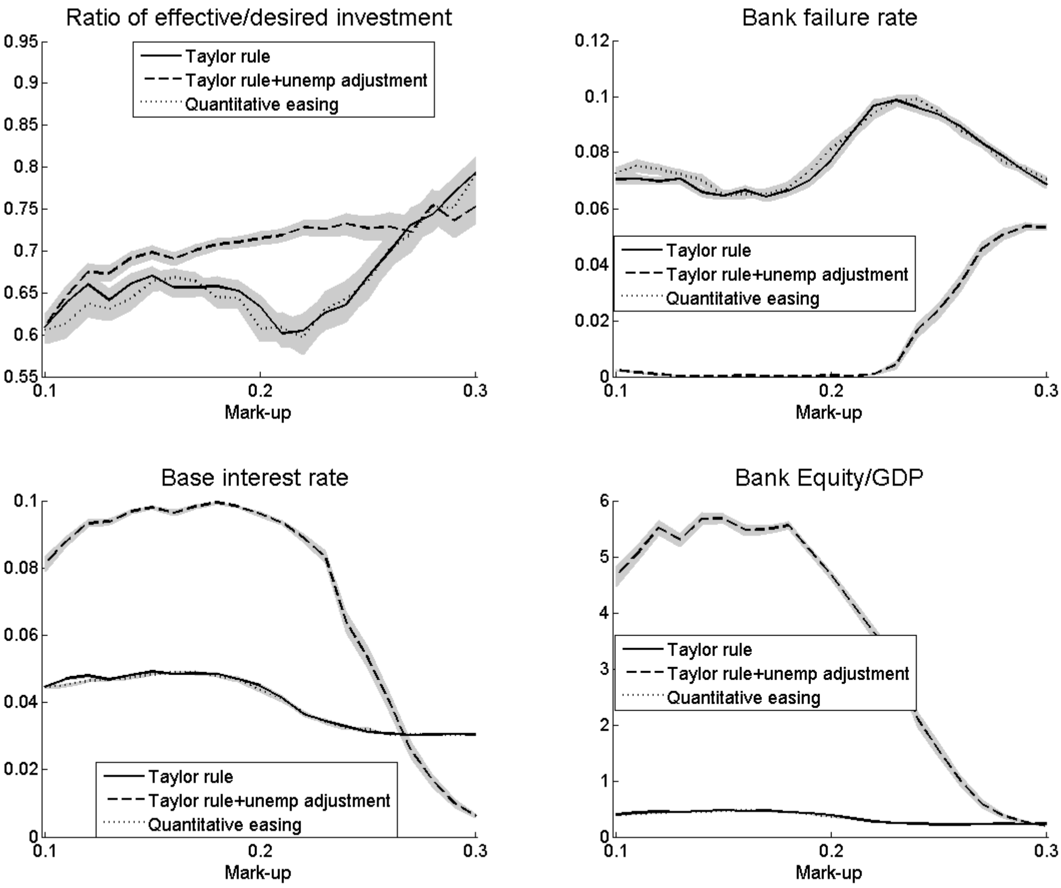
Simulation results show that austerity policies are self-defeating: they worsen the performance of the economy and lead to an increase of the ratio between public debt and GDP. Moreover, austerity policies are even more harmful under the "demand constraints regime". The introduction of escape clauses to fiscal rules limits the damages of austerity policies. Nonetheless, even in this case the GDP volatility, unemployment and probability of economic crises are higher than those observed when fiscal rules are not implemented. Those results are robust to the inclusion of a debt premium on the sovereign bonds interest rate.

On the monetary side, we find that monetary policy can achieve lower unemployment and lower frequency of economic crises if the Central Bank focuses on output stabilization besides inflation.



Note: Confidence interval bands are shown in a lighter color, they are computed as plus or minus twice the standard error. Average value over 100 Montecarlo iterations.

Figure 9: **Monetary policy experiment**



Note: Confidence interval bands are shown in a lighter color, they are computed as plus or minus twice the standard error. Average value over 100 Montecarlo iterations.

Figure 10: **Monetary policy experiment - banking sector variables**

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A Analytical Description of the Model

In this appendix we present the full formal structure of the real side of the model discussed in Section 3. We start with the equations characterizing search processes and the determination of production and prices in the capital-good sector. Next we turn to present the equations related to the determination of production, investment, prices and profits in the consumption-good sector. Finally we consider the labor market.

A.1 The Capital-Good Industry, complements

The technology of a capital-good firms is (A_i^τ, B_i^τ), where the former coefficient stands for the labor productivity of the machine-tool manufactured by i for the consumption-good industry (a rough measure of producer quality), while the latter coefficient is the labor productivity of the production technique employed by firm i itself. The positive integer τ denotes the current technology vintage. Given the monetary wage w, the unit cost of production of capital-good firms is:

$$c_{i,t} = \frac{w_t}{B_i^\tau}. \tag{15}$$

With a fixed mark-up ($\mu_1 > 0$) pricing rule[20], prices (p_i) are defined as:

$$p_{i,t}) = (1 + \mu_1)c_{i,t}. \tag{16}$$

The unit labor cost of production in the machine-tool sector associated with each machine of vintage τ, produced by firm i is:

$$c_{i,t} = \frac{w(t)}{A_i^\tau}.$$

Firms in the capital-good industry "adaptively" strive to increase their market shares and their profits trying to improve their technology both via innovation and imitation. Both are costly processes: firms invest in R&D a fraction of their past sales (S_i):

$$RD_{i,t} = \nu S_{i,t-1}, \tag{17}$$

with $0 < \nu < 1$. R&D expenditures are employed to hire researchers paying the market wage w_t[21]. Firms split their R&D efforts between innovation (IN) and imitation (IM) according to the parameter $\xi \in [0, 1]$[22]:

$$IN_{i,t} = \xi RD_{i,t}$$
$$IM_{i,t} = (1 - \xi)RD_{i,t}$$

We model innovation as a two steps process. The first one determines whether a firm obtains or not an access to innovation — irrespectively of whether it is ultimately a success or a failure — through a draw from a Bernoulli distribution, whose parameter $\theta_{i,t}^{in}$ is given by:

$$\theta_{i,t}^{in} = 1 - e^{-\zeta_1 IN_{i,t}}, \tag{18}$$

with $0 < \zeta_1 \leqslant 1$. Note that according to 18, there are some scale-related returns to R&D investment: access to innovative discoveries is more likely if a firm puts more resources into R&D.

[20]Survey data evidence summarized in Fabiani et al. [2006] show that European firms mostly set prices according to mark-up rules .

[21]In the following, we assume all capital-producing firms to be identical in their R&D propensity. This is not too far from reality: R&D intensities are largely sector specific and associated with the *sector-wide* nature of innovative opportunities and modes of innovative search [more in Pavitt, 1984, Dosi, 1988, Klevorick et al., 1995].

[22]Firms on the technological frontier, lacking anyone to imitate, obviously invest all their R&D budget in the search for innovations.

If a firm innovates, it may draw a new machine embodying technology (A_i^{in}, B_i^{in}) according to:

$$A_{i,t}^{in} = A_{i,t}(1 + x_{i,t}^A)$$

$$B_{i,t}^{in} = B_{i,t}(1 + x_{i,t}^B)),$$

where x_i^A and x_i^B are two independent draws from a Beta(α_1, β_1) distribution over the support $[\underline{x}_1, \overline{x}_1]$ with $\underline{x}_1$ belonging to the interval $[-1, 0]$ and $\overline{x}_1$ to $[0, 1]$. Note that the notional possibilities of technological advance — i.e. *technological opportunities* — are captured by the support of the Beta distribution and by its shape. So, for example, with low opportunities the largest probability density falls over "failed" innovations — that is potential capital goods which are "worse" in terms of costs and performances than those already produced by the searching firm. Conversely, under a condition of rich opportunities, innovations which dominate incumbent technologies will be drawn with high probability.

Alike innovation search, imitation follows a two steps procedure. The possibilities of accessing imitation come from sampling a Bernoulli$(\theta_{i,t}^{im})$:

$$\theta_{i,t}^{im} = 1 - e^{-\zeta_2 IM_{i,t}}, \tag{19}$$

with $0 < \zeta_2 \leqslant 1$. Firms accessing the second stage are able to copy the technology of one of the competitors (A_i^{im}, B_i^{im}). We assume that firms are more likely to imitate competitors with similar technologies and we use a Euclidean metrics to compute the technological distance between every pair of firms to weight imitation probabilities.

All firms which draw a potential innovation or imitation have to put it on production or keep producing the incumbent generation of machines. Comparing the technology competing for adoption, firms choose to manufacture the machine characterized by the best tradeoff between price and efficiency. More specifically, knowing that consumption-good firms invest following a payback period routine (see Section A.2), capital-good firms select the machine to produce according to the following rule:

$$\min \left[p_i^{h,t} + bc^h(A_i^{h,t}) \right], \qquad h = \tau, in, im, \tag{20}$$

where b is a positive payback period parameter (see Eq. 24 below) . Once the type of machine is chosen, we capture the imperfect information pervading the market assuming that each firm sends a "brochure" with the price and the productivity of its offered machines to both its historical (HC_i) clients and to a random sample of potential new customers (NC_i), whose size is proportional to HC_i (i.e., $NC_{i,t} = \gamma HC_{i,t}$, with $0 < \gamma < 1$).

A.2 The Consumption-good industry, complements

Consumption-good firms produce a homogeneous goods using capital (i.e. their stock of machines) and labor under constant returns to scale. Firms plan their production (Q_j) according to adaptive demand expectations (D_j^e):

$$D_{j,t}^e = f(D_{j,t-1}, D_{,t-2}, \ldots, D_{j,t-h}), \tag{21}$$

where $D_j(t-1)$ is the demand actually faced by firm j at time $t-1$ (h positive integer)[23]. The desired level of production (Q_j^d) depends on the expected demand as well as on the desired

[23]For maximum simplicity, here we use the rule $D_{j,t}^e = D_{j,t-1}$. In Dosi et al. [2006] we check the robustness of the simulation results employing more sophisticated expectation-formation rules. We found that increasing the computational capabilities of firms does not significantly change either the average growth rates or the stability of the economy. These properties still hold in the model presented here.

inventories (N_j^d) and the actual stock of inventories (N_j):

$$Q_{j,t}^d = D_{j,t}^e + N_{j,t}^d - N_{j,t-1}, \tag{22}$$

with $N_{j,t}^d = \iota D_{j,t}^e), \iota \in [0,1]$. The output of consumption-good firms is constrained by their capital stock (K_j). If the desired capital stock (K_j^d) — computed as a function of the desired level of production — is higher than the current capital stock, firms invest in order to expand their production capacity :

$$EI_{j,t}^d = K_{j,t}^d - K_{j,t}. \tag{23}$$

The capital stock of each firm is obviously composed of heterogeneous vintages of machines with different productivity. We define $\Xi_{j,t}$ as the set of all vintages of machine-tools belonging to firm j at time t. Firms scrap machines following a payback period routine. Through that, technical change and equipment prices influence the replacement decisions of consumption-good firms[24]. More specifically, firm j replaces machine $A_i^\tau \in \Xi_{j,t})$ according to its technology obsolescence as well as the price of new machines:

$$RS_{j,t} = \left\{ A_i^\tau \in \Xi_{j,t} : \frac{p_t^*}{c(A_{i,\tau}, t) - c_t^*} \leq b \right\}, \tag{24}$$

where p^* and c^* are the price of and unit cost of production upon the new machines. Firms compute their replacement investment summing up the number of old machine-tools satisfying Equation 24[25].

Given their current stock of machines, consumption-good firms compute average productivity (π_j) and unit cost of production (c_j). Prices are set applying a variable markup (μ_j) on unit costs of production:

$$p_{j,t} = (1 + \mu_{j,t})c_{j,t}. \tag{25}$$

Markup variations are regulated by the evolution of firm market shares (f_j)[26]:

$$\mu_{j,t} = \mu_j(t-1)\left(1 + \upsilon \frac{f_{j,t-1} - f_{j,t-2}}{f_{j,t-2}}\right),$$

with $0 \leqslant \upsilon \leqslant 1$.

The consumption-good market too is characterized by imperfect information (antecedents in the same spirits are Phelps and Winter, 1970, Klemperer, 1987, Farrel and Shapiro, 1988; see also the empirical literature on consumers' imperfect price knowledge surveyed in Rotemberg, 2008). This implies that consumers do not instantaneously switch to products made by more competitive firms. However, prices are clearly one of the key determinants of firms' *competitiveness* (E_j). The other component is the level of unfilled demand (l_j) inherited from the previous period:

$$E_{j,t} = -\omega_1 p_{j,t} - \omega_2 l_{j,t}, \tag{26}$$

where $\omega_{1,2}$ are positive parameter [27]. Weighting the competitiveness of each consumption-good firms by its past market share (f_j), one can compute the *average competitiveness* of the consumption-good sector:

[24]This in line with a large body of empirical analyses [e.g., Feldstein and Foot, 1971, Eisner, 1972, Goolsbee, 1998] showing that replacement investment is typically not proportional to the capital stock.

[25]Moreover, they also scrap the machines older than η periods (with η being a positive integer).

[26]This is close to the spirit of "customer market" models originated by the seminal work of Phelps and Winter [1970]. See also Klemperer [1995] for a survey and the exploration of some important macro implications by Greenwald and Stiglitz [2003].

[27]Recall that consumption-good firms fix production according to their demand expectations, which may differ from actual demand. If the firm produced too much, the inventories pile up, whereas if its production is lower than demand plus inventories, its competitiveness is accordingly reduced.

$$\overline{E,t} = \sum_{j=1}^{F_2} E_{j,t} f_{j,t-1}.$$

Such variable represents also a moving *selection criterion* driving, other things being equal, expansion, contraction and extinction within the population of firms. We parsimoniously model this market setup letting firm market shares evolve according to a "quasi" replicator dynamics [for antecedents in the evolutionary camp cf. Silverberg et al., 1988, Metcalfe, 1994]:

$$f_{j,t} f_{j,t-1} \left(1 + \chi \frac{E_{j,t} - \overline{E,t}}{\overline{E,t}}\right), \tag{27}$$

with $\chi > 0$[28].

A.3 The Labor Market

The labor market is certainly not Walrasian: real-wage does not clear the market and involuntary unemployment as well as labor rationing are the rules rather than the exceptions. The aggregate labor demand (L^D) is computed summing up the labor demand of capital- and consumption-good firms. The aggregate supply (L^S) is exogenous and inelastic. Hence aggregate employment (L) is the minimum between L^D and L^S.

The wage rate is determined by institutional and market factors, with both indexation mechanisms upon the inflation gap and average productivity, on the one hand, and, adjustments to unemployment rates, on the others:

$$\frac{\Delta w(t)}{w(t-1)} = dcpi_{target} + \psi_1 * (d_{cpi} - dcpi_{target}) + \psi_2 * \frac{\Delta \overline{AB}_t}{\overline{AB}_{t-1}} - \psi_3 * \frac{\Delta U_t}{U_{t-1}} \tag{28}$$

where d_{cpi} is the inflation rate, $dcpi_{target}$ is the target inflation rate, $\overline{AB}$ is the average labor productivity, and U is the unemployment rate.

[28] Strictly speaking, a canonic replicator dynamics evolves on the unit simplex with all entities having positive shares. Equation 27 allows shares to become virtually negative. In that case, the firm is declared dead and market shares are accordingly re-calculated. This is what we mean by a "quasi-replicator" dynamics. Note that an advantage of such formulation is that it determines at the same time changes in market shares and extinction events.

Description	Symbol	Value
Number of firms in capital-good industry	F_1	50
Number of firms in consumption-good industry	F_2	200
Number of commercial banks	B	10
Consumption-good firm mark-up rule	μ_2	0.20
Uniform distribution supports	$[\phi_1, \phi_2]$	[0.10,0.90]
Wage setting $\Delta\overline{AB}$ weight	ψ_1	1
Wage setting Δcpi weight	ψ_2	0.05
Wage setting ΔU weight	ψ_3	0.05
Tax rate	tr	0.10
Unemployment subsidy rate	φ	0.40
Target interest rate	r_{target}	0.03
Target inflation rate	$dcpi_{target}$	0.02
Banks deposits interest rate	r_{depo}	0
Banks reserve interest rate	r_{res}	$= (1 - 0.33) * r_t$
Public bonds interest rate	r_{bonds}	$= (1 - 0.33) * r_t$
Banks loan rate (class 1)	r_{deb}	$= (1 + 0.3) * r_t$
Bank capital adequacy rate	τ_b	0.08
Share of bonds repaid each period	$bonds_{share}$	0.025
Shape parameter for the distribution of banks' clients	$pareto_a$	0.08
Scaling parameter for interest rate cost	k_{const}	0.1
Capital buffer adjustment parameter	$beta$	1
Fiscal rule max deficit to GDP	def_{rule}	0.03

Table 2: Benchmark parameters

	mon0	mon1	mon2	mon3	mon4
fisc0	1,000	1,019***	1,001**	0,994***	1,016***
		(37,326)	(2,028)	(10,169)	(32,689)
fisc1	0,527***	1,014***	0,716***	0,794***	0,970***
	(68,935)	(11,487)	(51,914)	(39,823)	(11,002)
fisc2	0,995***	1,013***	0,996***	0,991***	1,017***
	(5,509)	(25,733)	(6,918)	(16,653)	(33,244)
fisc3	0,572***	0,958***	0,676***	0,765***	0,954***
	(64,993)	(12,958)	(53,769)	(48,628)	(14,183)
fisc4	0,992***	1,021***	0,995***	0,997***	1,017***
	(13,881)	(41,713)	(7,763)	(5,242)	(34,634)

Table 3: Normalized values of average GDP growth rates across experiments. Notes. t statistic of the difference between baseline and experiment values in parenthesis; *** 1% level significance, **5% level significance, *10% level significance

	mon0	mon1	mon2	mon3	mon4
fisc0	1,000	0,865***	1,015***	1,011***	0,874***
		(60,202)	(5,428)	(3,842)	(57,889)
fisc1	14,645***	2,760***	11,365***	12,873***	2,950***
	(74,659)	(24,015)	(66,776)	(81,029)	(43,700)
fisc2	1,408***	1,027***	1,341***	1,487***	0,999
	(58,560)	(4,501)	(52,802)	(80,512)	(0,292)
fisc3	16,204***	3,172***	12,085***	14,009***	3,201***
	(78,478)	(41,733)	(64,514)	(90,877)	(47,155)
fisc4	1,624***	0,980***	1,543***	1,530***	0,997
	(71,660)	(6,338)	(64,215)	(69,624)	(0,655)

Table 4: Normalized values of average GDP volatility across experiments. Notes. t statistic of the difference between baseline and experiment values in parenthesis; *** 1% level significance, **5% level significance, *10% level significance

	mon0	mon1	mon2	mon3	mon4
fisc0	1,000	0,322***	1,217***	1,068***	0,290***
		(59,033)	(13,879)	(4,681)	(64,093)
fisc1	5,692***	0,909***	4,844***	4,201***	1,312***
	(80,950)	(5,549)	(75,711)	(68,422)	(10,270)
fisc2	1,419***	0,343***	1,563***	1,680***	0,334***
	(20,881)	(55,275)	(25,356)	(34,949)	(57,573)
fisc3	5,706***	1,383***	4,430***	4,963***	1,395***
	(75,846)	(13,505)	(63,259)	(74,429)	(12,561)
fisc4	1,948***	0,317***	1,746***	1,679***	0,331***
	(39,284)	(58,856)	(32,536)	(31,392)	(57,257)

Table 5: Normalized values of average unemployment rate across experiments. Notes. t statistic of the difference between baseline and experiment values in parenthesis; *** 1% level significance, **5% level significance, *10% level significance

	mon0	mon1	mon2	mon3	mon4
fisc0	1,000	0,587***	1,032***	1,031***	0,613***
		(225,287)	(14,873)	(14,603)	(218,896)
fisc1	1,983***	0,813***	1,803***	1,647***	0,882***
	(417,028)	(102,498)	(355,643)	(408,125)	(57,326)
fisc2	1,505***	0,672***	1,472***	1,777***	0,699***
	(225,563)	(179,190)	(222,064)	(356,379)	(162,997)
fisc3	1,880***	0,934***	1,623***	1,798***	0,931***
	(361,540)	(32,051)	(277,603)	(504,052)	(32,499)
fisc4	1,953***	0,675***	1,683***	1,836***	0,691***
	(452,426)	(179,393)	(319,376)	(373,843)	(168,617)

Table 6: Normalized values of average likelihood of economic crisis across experiments. Notes. t statistic of the difference between baseline and experiment values in parenthesis; *** 1% level significance, **5% level significance, *10% level significance

	mon0	mon1	mon2	mon3	mon4
fisc0	1,000	-50,648***	1,294***	1,361***	-53,064***
		(303,770)	(3,627)	(4,265)	(320,025)
fisc1	62897,724***	-45,545***	328,741***	INF	389,939***
	(14,897)	(90,107)	(24,271)		(9,116)
fisc2	1,763***	-53,955***	1,500***	2,958***	-51,714***
	(7,744)	(289,835)	(5,184)	(19,334)	(288,370)
fisc3	41312,952***	-30,529***	254,324***	INF	31,939***
	(16,506)	(32,790)	(24,922)		(6,419)
fisc4	4,078***	-51,369***	2,205***	2,590***	-52,081***
	(24,715)	(318,570)	(11,405)	(14,832)	(299,681)

Table 7: Normalized values of average Debt/GDP across experiments. Notes. t statistic of the difference between baseline and experiment values in parenthesis; *** 1% level significance, **5% level significance, *10% level significance

Notes. t statistic of the difference between baseline and experiment values in parenthesis;
*** 1% level significance, **5% level significance, *10% level significance