Fiscal and Monetary Policies in Complex Evolving Economies

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Abstract

We build an agent-based model that can be employed as a laboratory to explore the effects of alternative combinations of fiscal and monetary policies under different income distribution regimes. In particular, this setting allows us to evaluate fiscal rules in a dynamic environment subject to banking crises and deep recessions. Portraying an economy with heterogeneous capital- and consumption-good firms, heterogeneous banks, workers/consumers, a central bank and a Government, the model is able to reproduce a wide array of macro, micro empirical regularities, as well stylized facts concerning financial dynamics and banking crises. Simulation results show the strength of the interactions between different types of fiscal and monetary policies. The appropriate policy mix to stabilize the economy requires unconstrained anti-cyclical fiscal policies, where automatic stabilizers are free to dampen business cycles fluctuations, and a monetary policy targeting also employment. Instead, "discipline-guided" fiscal rules alike the Stability and Growth Pact or the Fiscal Compact in the eurozone always depress the economy without improving public finances, even when escape clauses in case of recessions are considered. In that, austerity policies appear to be in general self-defeating. Furthermore, the negative effects of austere fiscal rules are magnified by conservative monetary policies focused on inflation stabilization only. Finally, our conclusions about the effects of different monetary and fiscal policies become even sharper as the levels of income inequality increase.

Keywords: agent-based model, fiscal policy, monetary policy, banking crises, income inequality, austerity policies, disequilibrium dynamics

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1 Introduction

This work investigates alternative combinations of fiscal and monetary policies in an agent-based model which naturally yields the possibility of persistent fluctuations, deep recessions and also banking crises.

Endogenous economic crises in general and several originated by systemic failures in the banking sector are recurrent in capitalistic economies (a point already emphasized by Keynes, 1936; Kindleberger, 1986 and more specifically on financial crises by Reinhart and Rogoff, 2008; Laeven and Valencia, 2008). These crises usually impose huge bailout costs on the public sector's balance sheet.[1] Moreover, they also involve indirect costs, such as credit-crunch induced recessions, losses in tax revenues and high government spending. A natural question is what type of fiscal and monetary policy mix to employ to respond to such crises and relatedly the impact of fiscal rules on real economic activity and on government debt. At one extreme, supporters of "expansionary austerity" (e.g Alesina and Ardagna, 2010) claim that tighter constraints on public expenditure are effective in bringing public finances under control, and may even stimulate economic activity. At the other extreme, arguments rooted in the Keynesian tradition (see e.g. Krugman, 2013) and recent empirical evidence (cf. e.g. Guajardo et al., 2011; Blanchard and Leigh, 2013) stress the self-defeating character of austerity. Tighter constraints on public finances may further depress the economy as well as increase government debt, especially when the size of fiscal multipliers is high (i.e. during a recession, see Auerbach and Gorodnichenko, 2012, or when credit markets are under stress, cf. Ferraresi et al., 2013) .

More specifically, dysfunctions in financial markets originated by banking crises and the emergence of the zero-bound may limit the ability to conduct standard monetary policy, thus increasing the importance of fiscal policy as an effective tool to restore aggregate demand and fight unemployment (Woodford, 2011; Christiano et al., 2011; Eggertsson and Krugman, 2012). At the same time, high public deficits imposed by bank bailouts and by the costs of automatics stabilizers may lead to sovereign debt crises (Reinhart and Rogoff, 2009), thus partially or completely hampering the possibility of using the fiscal levers to stimulate the economy.

Indeed, one of the greatest shocks associated with the Great Recession has been upon the economic discipline as such, both in its prevalent macro theory and its conventional policy, big enough to unveil for part of the profession a "brave new world" (Blanchard et al., 2013) or more radically to some others a striking proof that "the economic crisis is the crisis of economic theory" (Kirman, 2010b). Certainly, a powerful lesson seems to be the tall requirement that the possible effects of different ensembles of macroeconomic policies should be studied in models that are able to address far-from-equilibrium dynamics and deep crises generated by the possible endogenous generation and non-linear transmission of non-Gaussian shocks, seemingly at the root of the recent Great Recession (Ng and Wright, 2013). In that the economy should be considered as a complex evolving system, where aggregate outcomes cannot be derived from the properties of individuals' behaviors (Kirman, 1992; Colander et al., 2008). Instead, macroeconomic phenomena such as banking crises, bankruptcy cascades, domino effects, systemic risk and credit

[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).

crunches endogenously emerge out of the interactions occurring between heterogeneous agents (Farmer and Foley, 2009; Kirman, 2010a; Dosi, 2011; Rosser, 2011).

To explore the above issues we expand the Keynes+Schumpeter (K+S) model (Dosi et al., 2010, 2013) to include heterogeneous banks. 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 labour force, banks, a Government, and a central bank. 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 their financing needs, they can ask their bank for credit, which is more expensive than internal funds. Furthermore, bank failures endogenously emerge in the model from the accumulation of loan losses on banks' balance sheets. Banking crises imply direct bailout costs on the public budget and may therefore affect the dynamics of government deficit and debt. The latter can also vary as a consequence of the change in tax revenues and unemployment subsidies over the business cycle.

Our model, rooted in the evolutionary tradition (Nelson and Winter, 1982), belongs to the growing body of literature on macroeconomic agent-based models (Tesfatsion and Judd, 2006; LeBaron and Tesfatsion, 2008).[2] The microeconomic foundations of the model are "behavioural" (Akerlof, 2002): heterogeneous agents (firms, banks, etc.) behave in a "realistic" way — i.e. according to the micro empirical evidence — and they interact without resorting to any ex ante commitment to the reciprocal consistency of their actions, thus implicitly addressing the Solow (2008) call for genuine micro-heterogeneity.

Before studying how different macroeconomic policy mixes affect the dynamics of the economy, we empirically validate the model by showing that the statistical properties of simulated microeconomic and macroeconomic data are in line with the empirically observed ones. As its antecedents (Dosi et al., 2010, 2013), we find that the extended K+S model replicates a rather long list of macro and micro stylized facts. In particular, the current version with heterogeneous 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 crisis duration.

Next, we use the model to perform a battery of experiments on the interaction between fiscal and monetary policies taking into account that rules that are efficient in *normal times* might have reverse effects in times of *financial instability*. Given the long record of financial crises and the recent Great Recession, macroeconomic policy mixes ought to be studied in models that are able to repeatedly diverge away from equilibrium as empirical economies do. Evolutionary, agent-based models like ours are concerned with the emergent properties of a simulated system in which heterogeneous agents' routinised behaviours are aggregated. The evolution of the

[2] For germane ABMs, see Verspagen (2002); Delli Gatti et al. (2005a, 2010, 2011); Saviotti and Pyka (2008); Dawid et al. (2008); Ciarli et al. (2010); Raberto et al. (forthcoming); Mandel et al. (2010); Ashraf et al. (2011); Raberto et al. (2012); Gai et al. (2011); Battiston et al. (2012); Geanakoplos et al. (2012); Seppecher (2012); Salle et al. (2013); Lengnick (2013); Riccetti et al. (2013) and the papers in Gaffard and Napoletano (2012). See also Fagiolo and Roventini (2012) for a critical comparison of policy analysis in DSGE and agent-based models.

system is given by these repeated interactions, which may occur close or very far from full-employment equilibria. Our model is therefore able to account for large, non-Gaussian shocks as well as small ones that push the economy into deep recessions and crises via non-linear transmission mechanisms. In turn, such evolution 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 aggregates can be tested and compared.

Simulation results show that the most appropriate macroeconomic policy mix to achieve steady long-run economic growth together with short-run stability of the economy and of the public budget requires a combination of unconstrained fiscal policy, where automatic stabilizers can fully tackle business cycle fluctuations, together with a dual-mandate monetary policy focused on both inflation and output stabilization. The introduction of fiscal rules *à la* Stability and Growth Pact or Fiscal Compact considerably harms the performance of the economy, while leading to persistent public deficits. This holds also when fiscal rules are supplemented by an escape clause which suspends them in case of recession. In particular, our results thus suggest that recessions are not the appropriate time for fiscal consolidations which end up being *self-defeating*. Furthermore, we 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 claims provided by the supporters of expansionary austerity, fiscal rules depress the economic activity and worsen the state of public finance even when there is a feedback mechanism between the public debt to GDP ratio and the spread paid by the Government on its bonds.

On the monetary side, the switch to a "conservative" Taylor rule, which targets price stabilization only, worsens the performance of the economy especially when fiscal rules are in place. Such costs are not compensated by significant benefits coming from inflation reduction, as the inflation rate is stable and low also when the central bank follows a dual-mandate monetary policy. The existence of bank-based and balance-sheet transmission channels of monetary policy seem to be responsible for the better performance of the dual-mandate Taylor rule (Bernanke et al., 1999; Boivin et al., 2010; Borio and Zhu, 2012).

Finally, the effects of monetary and fiscal policies become sharper as the level of income inequality increases. As a consequence, fiscal-consolidation policies appear to be more painful when the income distribution is more skewed toward profits for they contribute to further reducing the aggregate demand.

The rest of the paper is organized as follows. In Section 2 we present the model, which is empirically validated in Section 3. The results of the policy experiments are reported in Section 4. Finally, Section 5 concludes.

2 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), a central bank and a public sector. Capital-good firms invest in R&D and produce heterogeneous machines. Consumption-good firms combine machine tools bought from capital-good firms and labour in order to produce a final product for consumers. The banks provide credit to consumption-good firms using firms' savings. The central bank fixes the baseline interest rate in the economy and the macro prudential regulatory framework. Finally, the public sector levies taxes on firms' and banks' profits and pays unemployment benefits.

2.1 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, baseline interest rate, 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 bailed out 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.

2.2 The capital- and consumption-good industries

Firms in the capital-good industry produce machine-tools using only labour. They innovate and imitate in order to increase the labour productivity of the machines they sell to the consumption-good firms as well as to reduce their own production costs.[3] Innovation and imitation are costly: firms need to invest a fraction of their past sales into the R&D process. They sell their machine-tools at a price which is defined with a fixed mark-up over their unit cost. Finally, as 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 labour 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 desired amount, 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 labour 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 affects the choice of the capital-good supplier: machine-tool firms advertise their machines' price and productivity levels by sending "brochures" to a subset of consumption-good firms, who in turn 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 production (Q_j), as they advance worker wages and pay the ordered machines. Firms can use internal funds (cash flow) or external ones (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 allocate credit optimally due to imperfect access to information about the creditworthiness of the applicants. 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 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. A 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 their available internal funds.[4] Credit-constrained firms have to reduce their desired investment and production to the amount that they can finance.[5] 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 5).

Consumption-good firms define their prices (p_j) by applying a variable mark-up on their

[3] More details on the innovation and imitation processes can be found in the appendix, section A.1, as detailed in Dosi et al. (2010) and Dosi et al. (2013).

[4] The credit allocation process defining the quantity and price obtained by the firm is detailed in section 2.3.

[5] In this case, firms give priority to production over investment.

unit cost of production (c_j), which depends on the average labour productivity allowed by their machine-tools. As shown in more detail in the appendix (see Section A.2), each firm sets a mark-up 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 competitiveness level shrink (those dynamics are determined in equations 22 and 23 in the appendix).

Consumption-good firm profits are computed as the difference between 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.

At the end of each period a firm exits if it has a (quasi) zero market share or if it goes bankrupt, i.e. the stock of its liquid assets becomes negative. 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 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.[6] Finally, entrants randomly copy the technology of incumbents.

2.3 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. The number of banks is fixed and is related to the number of firms in the consumption-good sector F_2:

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

where a can be taken as a proxy for the level of competition in the banking market.[7] 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. Following empirical evidence on the skewness of the bank size distribution (Berger et al., 1995; Ennis, 2001), banks'

[6]The stock of capital of a new consumption-good firm is 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.

[7]The empirical literature on topologies of credit markets (e.g. 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.

number of clients 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 $cl = 1, ..., Cl_k$.

In what follows, we first present 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 flow in the economy and the liquidity account of the banks. Finally, we report how banking failures are managed in the model.

2.3.1 Supply and allocation of bank credit

Banks are heterogeneous in terms of their fundamentals, their client portfolio, as well as their supply of credit, which is a function of their equity (NW^b). On the one hand, capital adequacy requirements inspired by Basel-framework rules (see e.g. Delli Gatti et al., 2005a; Ashraf et al., 2011; Raberto et al., 2012) constrain banks' credit supply. On the other hand, in line with the empirical evidence (BIS, 1999), banks maintain a buffer over the regulatory level of capital, whose magnitude is strategically altered over the business cycle according to their financial fragility (Bikker and Metzemakers, 2005; Becker and Ivashina, 2011).More precisely, following Adrian and Shin (2010) and Tasca and Battiston (2011), we proxy banks' fragility by the variable $Lev_{k,t}$, defined in our model as the accumulated bad debt ($BadDebt_{k,t}$) to net worth ratio.[8] Therefore, given the parameter $\tau^b \in [0, 1]$ fixed by the regulatory authority, the higher the bad-debt-to-asset ratio, the lower the credit the bank provides to its clients:

$$TC_{k,t} = \frac{NW^b_{k,t-1}}{\tau^b * (1 + \beta * Lev_{k,t-1})}, \tag{2}$$

where $\beta > 0$ is a parameter which measures the banks' intensity of adjustment to its financial fragility. Credit supply is thus impacted by changes in the banks' balance sheet, which itself is 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 the next period.

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 credit worthiness, defined by the ratio between past net worth ($NW_{j,t-1}$) and past sales ($S_{j,t-1}$). Banks provide 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 the financial fragility of its bank. It follows that in any period the stock of loans of the bank satisfies the following constraint:

$$\sum_{cl=1}^{Cl_k} Deb_{cl,k,t} = Loan_{k,t} \leqslant TC_{k,t}. \tag{3}$$

[8] The variable $Lev_{k,t}$ is bounded between 0 and 1.

2.3.2 Interest rate structure

Banks earn 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 mark-up on the central bank interest rate r_t. The latter is fixed by the central bank according to a Taylor rule (the seminal papers here are Howitt, 1992 and Taylor, 1993; see also Bernanke and Mishkin, 1997 for a review of current "inflation targeting" practices of central banks):[10]

$$r_t = r^T + \gamma_\pi(\pi_t - \pi^T) + \gamma_U(U^T - U_t), \qquad \gamma_{pi} > 1,\ \gamma_U \geq 0 \tag{4}$$

where π_t is the inflation rate of the period, U_t the unemployment rate,[11] r^T, π^T, U^T are the target interest, inflation and unemployment rates respectively. In the benchmark parametrisation, the central bank pursues inflation stabilization only ($\gamma_U = 0$). In the policy experiments (see Section 4 below), we will compare such a monetary policy rule with the one where the central bank follows a dual mandate ($\gamma_U > 0$).[12]

Banks fix the *risk premium* paid by their clients depending on their position in the credit ranking. In every period, four credit classes are created by the banks, corresponding to the quartiles in their ranking of clients. Given the base loan rate $r_t^{deb} = (1 + \mu^{deb})r_t$, firm j in credit class $q = 1, 2, 3, 4$ pays the following interest rate :

$$r_{j,t}^{deb} = r_t^{deb}\,(1 + (q-1) * k_{const}) \tag{5}$$

with $\mu^{deb} > 0$ and k_{const} a scaling parameter.[13]

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 rate $r_t^{bonds} = (1 + \mu^{bonds})r_t$, with $-1 < \mu^{bonds} < 0$. The different interest rates are set so that $r^D \leq r^{res} \leq r^{bonds} \leq r \leq r^{deb}$.

[9] The way Government bonds are issued and bought by banks is described in section 2.4.

[10] In the agent-based camp, see Delli Gatti et al. (2005b), Arifovic et al. (2010) and Salle et al. (2013) for careful studies on the central bank's conduct of monetary policy.

[11] The choice of unemployment as a proxy of economic activity is common in macroeconomics and it is supported by the Okun (1970) law. We choose to employ the unemployment gap instead of the output gap because the estimation of the potential output is not straightforward in a model characterized by endogenous technical change.

[12] The Taylor rule parameters have been estimated using a variety of samples and methods (Clarida et al., 2000; Smith and Taylor, 2009; Benati and Goodhart, 2010), and suggest a wide range of values across countries and periods. After the 2008 crisis, the validity of inflation targeting as a stabilizing tool has been put into question, and alternative targets have been suggested (see e.g. Reichlin and Baldwin, 2013). In particular, the weak correlation between inflation and output may imply that inflation targeting is not enough to stabilize economic activity (Blanchard et al., 2013).

[13] The simulation results shown below cf. (Section 4) are robust to the inclusion of counter-cyclical price-cost margins in equation 5 in line with the empirical evidence (Olivero, 2010).

2.3.3 Bank net worth, failure and bailout policies

The profits of bank k ($\Pi^b_{k,t}$) can be computed as follows:

$$\Pi^b_{k,t} = \sum_{cl=1}^{Cl_k} r^{deb}_{cl,t} * Deb_{cl,t} + r^{res} Cash_{k,t} + r^{bonds}_t Bonds_{k,t} - r^D Dep_{k,t} - BadDebt_{k,t} \quad (6)$$

where $Deb_{cl,t}$ represents the debt of client cl, $Cash_{k,t}$ is the liquidities, $Bonds_{k,t}$ is the stock of government bonds, and $BadDebt_{k,t}$ captures non-performing loans. Banks experience loan losses whenever one of their clients goes bankrupt and exits the market with positive debt. Banks' profits net of taxes[14] ($Net\Pi^b_{k,t} = (1 - tr) * \Pi^b_{k,t}$) are then added to their net worth ($NW^b_{k,t}$), which is equal to the difference between assets and liabilities. Banks' assets are composed of their liquidity stock ($Cash_{k,t}$), their stock of Government bonds ($Bonds_{k,t}$) and their stock of loans ($Loans_{k,t}$), while firms' deposits ($Dep_{k,t}$) are the only liabilities. Accordingly the net-worth of the bank reads as:

$$NW^b_{k,t} = Loans_{k,t} + Cash_{k,t} + Bonds_{k,t} - Depo_{k,t} + Net\Pi^b_{k,t} \quad (7)$$

Loan losses represent a negative shock to bank profits, which can become negative. If the net worth of the bank is not sufficient to cover such losses, the bank goes bankrupt. Whenever, a bank fails ($NW^b_{k,t} < 0$), the Government steps in and bails it out providing fresh capital. The cost of the public bail out ($Gbailout_{t,k}$) is the difference between the failed bank's equity before and after the public intervention.[15]

2.4 Consumption and the Government sector

The consumption of workers is naturally linked to their wage. We assume that the wage rate (w_t) is determined by institutional and market factors, with both indexation mechanisms upon the inflation gap, average productivity, and the unemployment rate:[16]

$$\frac{\Delta w_t}{w_{t-1}} = \pi^T + \psi_1(\pi_{t-1} - pi^T) + \psi_2 \frac{\Delta \overline{AB}_t}{\overline{AB}_{t-1}} - \psi_3 \frac{\Delta U_t}{U_{t-1}} \quad (8)$$

with $\psi_{1,2,3} > 0$ and where $\overline{AB_t}$ is the average labour productivity at time t. The labour market does not feature any Walrasian clearing mechanism. Accordingly, involuntary unemployment and labour rationing naturally emerge.

Unemployed workers — computed as the difference between the fixed labour supply (L^S) and firms' total labour demand (L^D_t) — receive a public subsidy (w^u_t) which is a fraction of the current wage, i.e. $w^u_t = \varphi w_t$, with $\varphi \in [0, 1]$. The total amount of unemployment subsidies to be paid by the Government (G_t) is therefore:

$$G_t = w^u_t (L^S - L^D_t) \quad (9)$$

[14]Banks pay taxes provided their current profit is positive.

[15]We assume that the bank's equity after the bailout is a multiple of the smallest incumbent's equity, provided it respects the capital adequacy ratio. Mirroring the entry rule in the real sector, this value is a random draw from a Uniform distribution with support $[\phi_1, \phi_2], 0 < \phi_1, < \phi_2 \leqslant 1$.

[16]For empirical investigations of the wage equation, see e.g. Blanchard and Katz (1996).

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

$$C_t = w_t L_t^D + G_t \tag{10}$$

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 ($Debt_t^{cost}$), the bank bailout cost ($Gbailout_t = \sum_{k=1}^{B} Gbailout_{k,t}$) and the unemployment subsidies (G_t). Public deficit is then equal to:

$$Def_t = Debt_t^{cost} + Gbailout_t + G_t - Tax_t. \tag{11}$$

If $Def_t > 0$, the Government has to issue new bonds, which are bought by banks according to their share in the total supply of credit.[17] If the demand for bonds from the Government is higher than what banks are able to buy, the central bank steps in and buys the remaining debt. If $Def_t < 0$,the Government uses the surplus to repay its debt.

The debt-related expenditures at time t are therefore:

$$Debt_t^{cost} = r_t^{bonds} * Bonds_{t-1}^{stock} \tag{12}$$

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 satisfies the standard national account identities: the sum of value added of capital- and consumption goods firms (GDP_t) equals their aggregate production (in our simplified economy there are no intermediate goods. That in turn coincides with the sum of aggregate consumption, investment and change in inventories (ΔN_t):

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

2.5 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.[18] Furthermore, in the policy experiments below (cf. Section 4) we study the effect of different fiscal rules, namely the *3%-deficit rule* (mirroring the conditions in the European Stability and Growth Pact, SGP) and the *debt-reduction rule* (mirroring the "Fiscal Compact", FC).

3%-deficit rule. With a fiscal rule mimicking the SGP, the Government becomes constrained

[17] Banks buy Government bonds employing only their net profits. Simulation results do not change if Government debt is allocated to banks according to their profit shares instead of credit ones.

[18] McKay and Reis (2013) find that automatic stabilizers can strongly contribute to dampen business cycle volatility, especially through the redistribution and social-insurance channels. See also Solow (2005) and Blanchard et al. (2010) on the case for stronger automatic stabilizers as a tool for better macroeconomic policy.

in the size of its public deficit.

$$Def_t \leq def_{rule} * GDP_{t-1} \tag{13}$$

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).[19] In our experiments, we implement two versions of such a rule: the first one corresponds to the original version of the Stability and Growth Path (SGP), while the second one includes its 2005 revision allowing for more flexibility in bad times (CEU, 2005). More precisely, the fiscal rule is not binding if the output growth rate is negative. We will refer to this second case as the SGP supplemented with an "escape clause" (SGP_{ec}).

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 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 in every year.[20] If the debt-reduction rule is binding, the surplus necessary to satisfy it is:

$$Def_t = -0.05 * \left(\frac{Debt_{t-1}}{GDP_{t-1}} - 0.60 \right) \tag{14}$$

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. In the experiments that follows we will consider a Fiscal Compact rule both with (FC_{ec}) and without (FC) an "escape clause".

Bonds spread adjustment policy. Until now we did not consider any feedback mechanism going from the level of public debt to its financing costs. Several models assume a positive correlation between public debt to GDP levels and bond yields, yet the empirical debate on such a link is still not resolved (Alper and Forni, 2011). However, as a positive correlation is apparent in some extreme cases[21] we perform a battery of simulation exercises where a debt risk premium is added to the interest rate on sovereign bonds. This introduces a positive feedback effect on the sovereign bond interest rate stemming from excessive public debt:

$$r_t^{bonds} = (1 + \mu^{bonds}) r_t \left(1 + \rho \frac{Debt_{t-1}}{GDP_{t-1}} \right) \tag{15}$$

Following empirical evidence (Alper and Forni, 2011), we set the ρ parameter to 0.04.

[19] 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.

[20] 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 FC as we jointly consider the debt reduction and the 3%-deficit rules, and we also consider the escape clause in case of recession.

[21] De Grauwe and Ji (2013) 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.

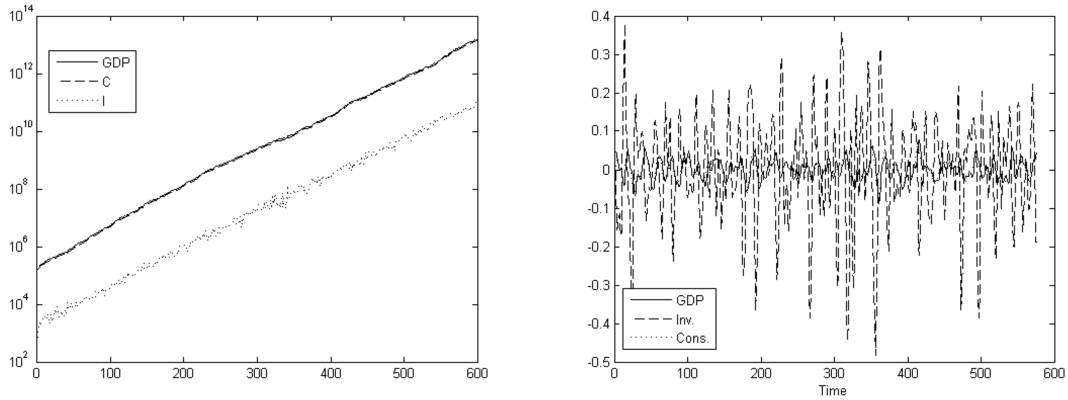


Figure 1: Output, investment and consumption time series; *left:* logs; *right:* bandpass-filtered series

3 Empirical Validation

We resort to computer simulations for the analysis of the properties of the model. In what follows, we perform extensive Montecarlo simulations to wash away across-simulation variability. Consequently, all results below refer to across-run averages over several replications.[22] The benchmark parametrization is presented in Table 7 in the Appendix. Before addressing policy questions, we first study whether in the "benchmark" setup the model is "empirically validated", i.e. it is able to reproduce a wide spectrum of macroeconomic and microeconomic stylized facts, possibly a higher number than those replicated in Dosi et al. (2006, 2008, 2010, 2013).

Let us start considering how the model fares as to *macroeconomic* empirical regularities. 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), e.g. investment is more volatile than GDP while consumption is less. Considering the co-movements between macroeconomic variables at the business cycle frequencies, we find that, in line with the empirical evidence, consumption is procyclical and coincident, net investment, changes in inventories, productivity, nominal wages and inflation are procyclical; unemployment, prices and mark-ups are countercyclical, real wage is acyclical (for the empirics and discussion cf. Stock and Watson, 1999; Rotemberg and Woodford, 1999).[23] Finally, the output growth-rate distribution generated by the model exhibits fat tails well in tune with the empirical evidence (Fagiolo et al., 2008).[24]

The model also matches the major business cycle stylized facts concerning credit (as reported

[22]All the simulation results refers to MC=100 Montecarlo iterations. Extensive tests show that the results are robust to changes in the initial conditions for the microeconomic variables of the model. In addition, they show that, for the statistics under study, Montecarlo distributions are sufficiently symmetric and unimodal. This justifies the use of across-run averages as meaningful synthetic indicators. All our results do not significantly change if the Montecarlo sample size is increased.

[23]Due to space constraints, we do not report all the results related to the empirical validation of the model. The results are available from the authors upon request.

[24]Note that DSGE models are not able to match such empirical regularity even if they are fed with fat-tailed shocks (Ascari et al., 2013).

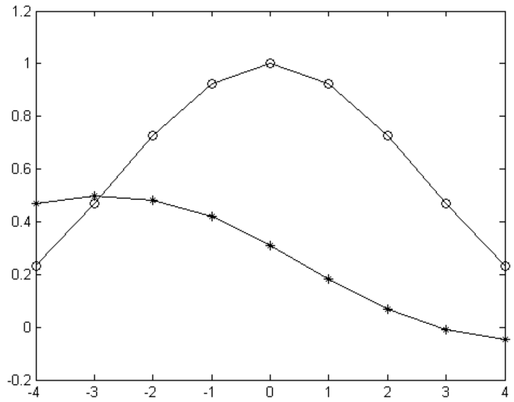


Figure 2: Average cross-correlations of bad debt with private debt at different leads and lags (circles) together with average bebt autocorrelation (diamonds)

for instance by Bikker and Metzemakers, 2005). Indeed, firms' total debt and bank profits are procyclical, while loan losses are countercyclical. 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 in tune with the Minskyan evolution of firms' financial health over the cycle. At the onset of an expansionary phase firm profit and cash flow improve. This increases production and investment expenditures, thus inducing a rise in firm debt. In turn, the rise in debt costs gradually erodes firms' cash flows and savings, paving the way to higher bankruptcy ratios and setting the stage for the incoming recession phase. In line with such a dynamics we find that higher levels 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 economic and banking crises generated by the model match the empirical distributional properties of recessions and fiscal costs of banking failures. In line with Ausloos et al. (2004), the large majority of crises are short-lived, lasting only one year. Moreover, the distribution of recession durations is exponential (Wright, 2005) and the distribution of banking crisis duration closely tracks the empirical one (see Figure 3). 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 tune with the empirical literature, that the distributions of the ratio between fiscal costs of banking crises and GDP is characterized by excess kurtosis, with tails heavier than those resulting from a normal distribution.

Finally, the model is also able to replicate a large array of *microeconomic* empirical regularities (see e.g. Bartelsman and Doms, 2000; Dosi, 2007). More specifically, firm size distributions are right skewed; firm growth-rate distributions are fat tailed; firms are heterogeneous in terms of productivities and such differences are persistent over time; firms invest in a lumpy fashion. Note that this is one of the major advances of agent-based models vis-à-vis DSGE ones, which by building on the representative agent cannot account for any persistent heterogeneity at the

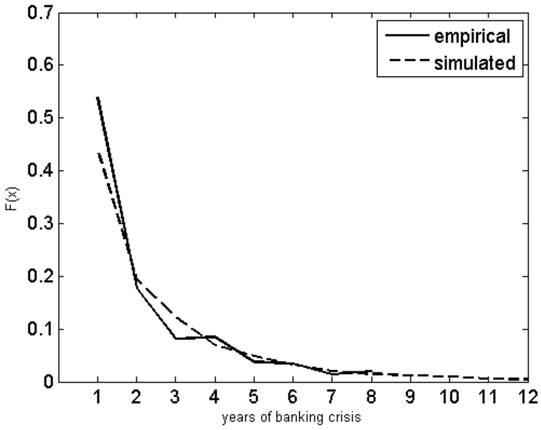


Figure 3: Distribution of banking crisis duration; empirical data: Reinhart and Rogoff (2009)

microeconomic level.[25]

4 Policy experiments

As the results described in the previous section show that the model is able to robustly account for a wide set of empirical regularities, we now turn to policy experiments. All along this section we study the impact of different combinations of fiscal and monetary policies on a set of target variables.[26] These include the GDP growth rate and the public debt to GDP ratio which catch the long term structural impact of such policies. Others, such as GDP volatility, the unemployment rate and the occurrence of economic crises (defined as the number of periods in which the fall in GDP is higher than 3%) allow to evaluate the effect of policies at 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 explore the possible interactions between fiscal and monetary policies for a given level of income distribution. *Second,* we generalize the previous analysis by conditioning the impact of different policy combinations to different income inequality scenarios.

4.1 Fiscal and monetary policy interactions

In the baseline scenario, fiscal policy is not constrained (*norule*): automatic stabilizers can fully dampen business cycles fluctuations without being limited by Government deficit. At the same time, the central bank pursues price stabilization only by following a Taylor rule indexed just upon inflation (TR_π). How do alternative combinations of fiscal and monetary policies affect the dynamics of the economy? The results of such analysis are reported in Tables 1-6. Each entry in the tables is the ratio between the Monte Carlo average of the macroeconomic

[25]See Kirman (1992) for a sharp critique of the representative agent assumption.
[26]On the possible interactions between fiscal and monetary policies see Leith and Wren-Lewis (2000); Woodford (2011); Ascari and Rankin (2013).

	TR_π	$TR_{\pi,U}$	LLR_π	$LLR_{\pi,U}$	*spread*
norule	1	1.019**	1.001*	1.016**	0.994**
		(37.326)	(2.028)	(32.689)	(10.169)
SGP	0.527**	1.014**	0.716**	0.970**	0.794**
	(68.935)	(11.487)	(51.914)	(11.002)	(39.823)
FC	0.572**	0.958**	0.676**	0.954**	0.765**
	(64.993)	(12.958)	(53.769)	(14.183)	(48.628)
SGP_{ec}	0.995**	1.013**	0.996**	1.017**	0.991**
	(5.509)	(25.733)	(6.918)	(33.244)	(16.653)
FC_{ec}	0.992**	1.021**	0.995**	1.017**	0.997**
	(13.881)	(41.713)	(7.763)	(34.634)	(5.242)

Table 1: Normalized values of average GDP growth rates across experiments. Absolute value of simulation t-statistic of H_0: "no difference between baseline and the experiment" in parentheses; (**) significant at 1% level, (*) significant at 5% level.

	TR_π	$TR_{\pi,U}$	LLR_π	$LLR_{\pi,U}$	*spread*
norule	1	0.865**	1.015**	0.874**	1.011**
		(60.202)	(5.428)	(57.889)	(3.842)
SGP	14.645**	2.760**	11.365**	2.950**	12.873**
	(74.659)	(24.015)	(66.776)	(43.700)	(81.029)
FC	16.204**	3.172**	12.085**	3.201**	14.009**
	(78.478)	(41.733)	(64.514)	(47.155)	(90.877)
SGP_{ec}	1.408**	1.027**	1.341**	0.999	1.487**
	(58.560)	(4.501)	(52.802)	(0.292)	(80.512)
FC_{ec}	1.624**	0.980**	1.543**	0.997	1.530**
	(71.660)	(6.338)	(64.215)	(0.655)	(69.624)

Table 2: Normalized values of average GDP volatility across experiments. Absolute value of simulation t-statistic of H_0: "no difference between baseline and the experiment" in parentheses; (**) significant at 1% level, (*) significant at 5% level.

variable (e.g. output growth rate, the unemployment rate, etc) under a given fiscal and monetary policy mix and the one generated by the scenario with the baseline fiscal and monetary policies $(norule, TR_\pi)$.

Fiscal rules. Let us start by examining the impact of different fiscal policies[27] (see Section 2.5) under the baseline monetary policy. The *SGP* and *FC* fiscal rules have a strong and negative impact on short-run performance of the economy by increasing unemployment, output volatility and the likelihood of economic crises (cf. the second column of Tables 1-6). Such depressing effects spill into the long-run, considerably reducing GDP growth. The deterioration

[27] Our agent-based model allows us to study the effects of fiscal-consolidation policies in a framework where policy activations as well as the outcomes (on e.g. the sovereign debt to GDP ratio) are fully endogenous. This is in line with empirical observations suggesting that the effects of fiscal policies change according to the state of the economy (see e.g. Auerbach and Gorodnichenko, 2012) or of credit markets (Ferraresi et al., 2013). On the contrary, austerity policies have only been studied so far in DSGE models by imposing exogenous policy changes to the Debt to GDP ratio target (Coenen et al., 2008; Clinton et al., 2011) or exogenous demand or supply shocks (Creel et al., 2013).

	TR_π	$TR_{\pi,U}$	LLR_π	$LLR_{\pi,U}$	*spread*
norule	1	0.322**	1.217**	0.290**	1.068**
		(59.033)	(13.879)	(64.093)	(4.681)
SGP	5.692**	0.909**	4.844**	1.312**	4.201**
	(80.950)	(5.549)	(75.711)	(10.270)	(68.422)
FC	5.706**	1.383**	4.430**	1.395**	4.963**
	(75.846)	(13.505)	(63.259)	(12.561)	(74.429)
SGP_{ec}	1.419**	0.343**	1.563**	0.334**	1.680**
	(20.881)	(55.275)	(25.356)	(57.573)	(34.949)
FC_{ec}	1.948**	0.317**	1.746**	0.331**	1.679**
	(39.284)	(58.856)	(32.536)	(57.257)	(31.392)

Table 3: Normalized values of average unemployment rate across experiments. Absolute value of simulation t-statistic of H_0: "no difference between baseline and the experiment" in parentheses; (**) significant at 1% level, (*) significant at 5% level.

	TR_π	$TR_{\pi,U}$	LLR_π	$LLR_{\pi,U}$	*spread*
norule	1	0.587**	1.032**	0.613**	1.031**
		(225.287)	(14.873)	(218.896)	(14.603)
SGP	1.983**	0.813**	1.803**	0.882**	1.647**
	(417.028)	(102.498)	(355.643)	(57.326)	(408.125)
FC	1.880**	0.934**	1.623**	0.931**	1.798**
	(361.540)	(32.051)	(277.603)	(32.499)	(504.052)
SGP_{ec}	1.505**	0.672**	1.472**	0.699**	1.777**
	(225.563)	(179.190)	(222.064)	(162.997)	(356.379)
FC_{ec}	1.953**	0.675**	1.683**	0.691**	1.836**
	(452.426)	(179.393)	(319.376)	(168.617)	(373.843)

Table 4: Normalized values of average likelihood of economic crisis across experiments. Absolute value of simulation t-statistic of H_0: "no difference between baseline and the experiment" in parentheses; (**) significant at 1% level, (*) significant at 5% level.

of the macroeconomic conditions lead to an explosion of the ratio between public debt and GDP (see Table 1). As a consequence, austerity policies appear to be *self-defeating*. The puny performance of fiscal rules is due to the fact that these rules constrain Government deficit especially during recessions when the smoothing effects of automatic stabilizers are mostly needed (McKay and Reis, 2013). This further depresses aggregate demand and exacerbates the fall of output, ultimately increasing the ratio between sovereign debt and GDP. In line with the empirical works of Poterba (1995), and Guajardo et al. (2011), our results contradict the "expansionary austerity" hypothesis (see e.g. Giavazzi and Pagano, 1996; Alesina and Ardagna, 2010).

Fiscal rules with escape clauses. Many escape clauses suspending the implementation of fiscal rules in case of "exceptional circumstances" have been introduced in recent years (Schaechter et al., 2012). Nevertheless the debate about the importance of taking into account such extraordinary events is still open. We now study what happens if we add escape clauses in case of recessions to the fiscal rules so that they better proxy the European Stability and Growth Pact and the Fiscal compact.

	TR_π	$TR_{\pi,U}$	LLR_π	$LLR_{\pi,U}$	$spread$
$norule$	1,000	1,140**	0,964**	1,145**	0,984**
		62,056	11,762	65,162	5,311
SGP	0,956**	1,128**	0,935**	1,117**	0,951**
	14,816	56,759	21,356	49,783	16,623
FC	0,975**	1,103**	0,992**	1,113**	0,932**
	8,510	42,740	2,830	47,242	22,733
SGP_{ec}	0,992*	1,142**	0,999	1,139**	0,939**
	2,493	48,671	0,244	61,739	19,614
FC_{ec}	0,962**	1,142**	0,981**	1,141**	0,023**
	12,054	62,848	6,387	62,509	9,056

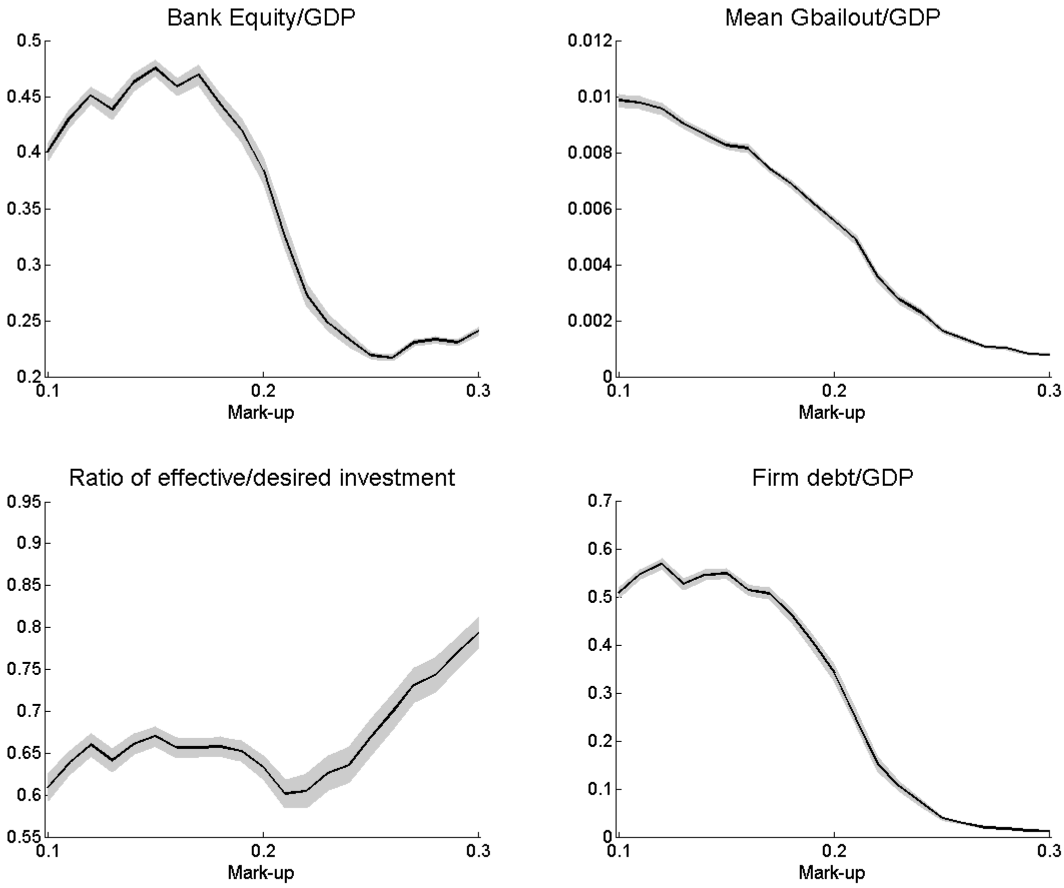
Table 5: Normalized values of average inflation rate across experiments. Absolute value of the simulation t-statistic of H_0: "no difference between baseline and the experiment" in parentheses; (**) significant at 1% level, (*) significant at 5% level.

	TR_π	$TR_{\pi,U}$	LLR_π	$LLR_{\pi,U}$	$spread$
$norule$	1,000	-50,648**	1,294**	-53,064**	1,361**
		303,770	3,627	320,025	4,265
SGP	$+\infty$	-45,545**	$+\infty$	$+\infty$	$+\infty$
		90,107			
FC	$+\infty$	-30,529**	$+\infty$	31,939**	$+\infty$
		32,790		6,419	
SGP_{ec}	1,763**	-53,955**	1,500**	-51,714**	2,958**
	7,744	289,835	5,184	288,370	19,334
FC_{ec}	4,078**	-51,369**	2,205**	-52,081**	2,590**
	24,715	318,570	11,405	299,681	14,832

Table 6: Normalized values of public debt over GDP across experiments. Absolute value of the simulation t-statistic of H_0: "no difference between baseline and the experiment" in parentheses; (**) significant at 1% level, (*) significant at 5% level. $+\infty$ denotes cases of debt explosion (normalized value > 100).

Simulation results show that the introduction of escape clauses (SGP_{ec} and FC_{ec}) considerably reduce the harm of fiscal rules (SGP and FC) to the performance of the economy (see Tables 1-6). In particular, the average GDP growth rate becomes closer to the one observed with the benchmark fiscal policy ($norule$). However, even in presence of escape clauses, the fiscal rules are still responsible for higher GDP volatility, unemployment and occurrence of economic crises and they lead to higher sovereign debt to GDP ratio vis-à-vis the unconstrained fiscal policy case. These results confirm the relevant role of countercyclical fiscal policies in supporting demand thus considerably dumping the costs of business cycle fluctuations.

Fiscal rules under the bond spread adjustment scenario. The evidence on the link between sovereign bonds rates and debt to GDP levels is inconclusive (De Grauwe and Ji, 2013). However, in some extreme cases such as Greece, Portugal and Ireland during the current crisis, a reduction in public debt levels was considered by supporters of expansionary austerity a necessary condition for limiting sovereign risk premia thus jumpstarting the economy. Would the results on the

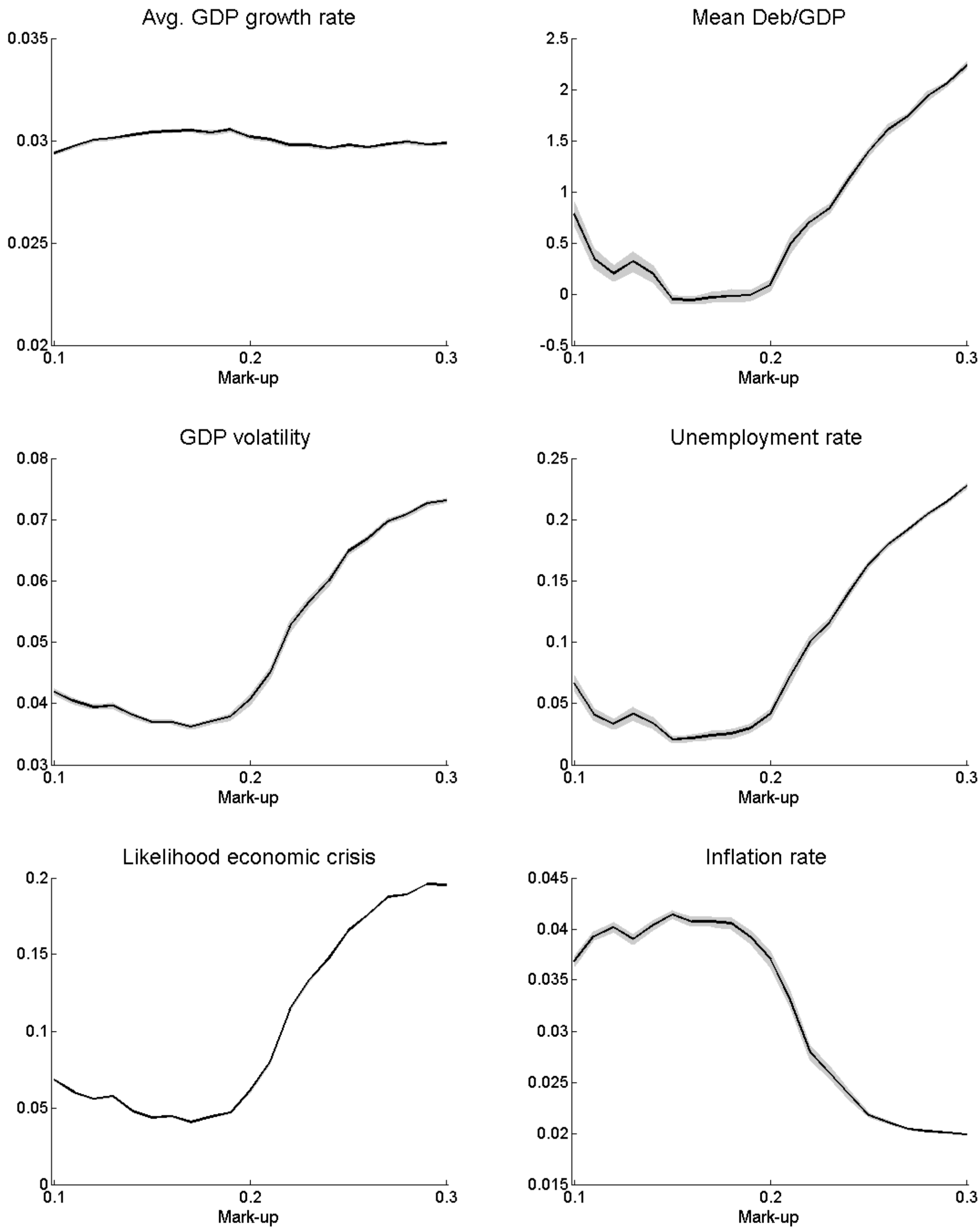


Note: Confidence interval bands are shown in a lighter color, they are computed as plus or minus twice the standard error. Average value over 100 Montecarlo iterations.

Figure 4: Income distribution and the banking sector

effects of fiscal rules change if we took into account the impact of rising public debt on the spread cost paid by the Government on sovereign bonds (cf. equation 15)? We implement this scenario (*spread*) for the five types of fiscal policies under study (cf. last column of Tables 1-6). Simulation results show that the introduction of the "spread" channel slightly worsens the performance of the economy in the baseline scenario as well as the ratio between sovereign debt and GDP. However, the results of our previous experiment are robust to the inclusion of a debt premium: the benchmark fiscal rule still outperforms the four fiscal-discipline rules.

Alternative monetary policy rules. Until now the central bank has applied a Taylor rule which adjusts the baseline interest rate only to the inflation gap (TR_{π}, see Eq. 4). We now let the central bank follow a dual-mandate monetary policy ($TR_{\pi,U}$) by including an adjustment to the unemployment gap ($\gamma_U > 0$) in the Taylor rule (with a 5% unemployment rate target). When fiscal policy is unconstrained (*norule*) and the central bank commits to both price and output stabilization, monetary policy positively affects only the short-run performance of the economy (see the third column of Tables 1-6). Indeed, GDP volatility, unemployment, likelihood of crises and the sovereign debt to GDP ratio are lower in the $TR_{\pi,U}$ vis-à-vis TR_{π} scenarios, while the average GDP growth rates do not significantly increases. On the contrary, when



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 and macroeconomic dynamics

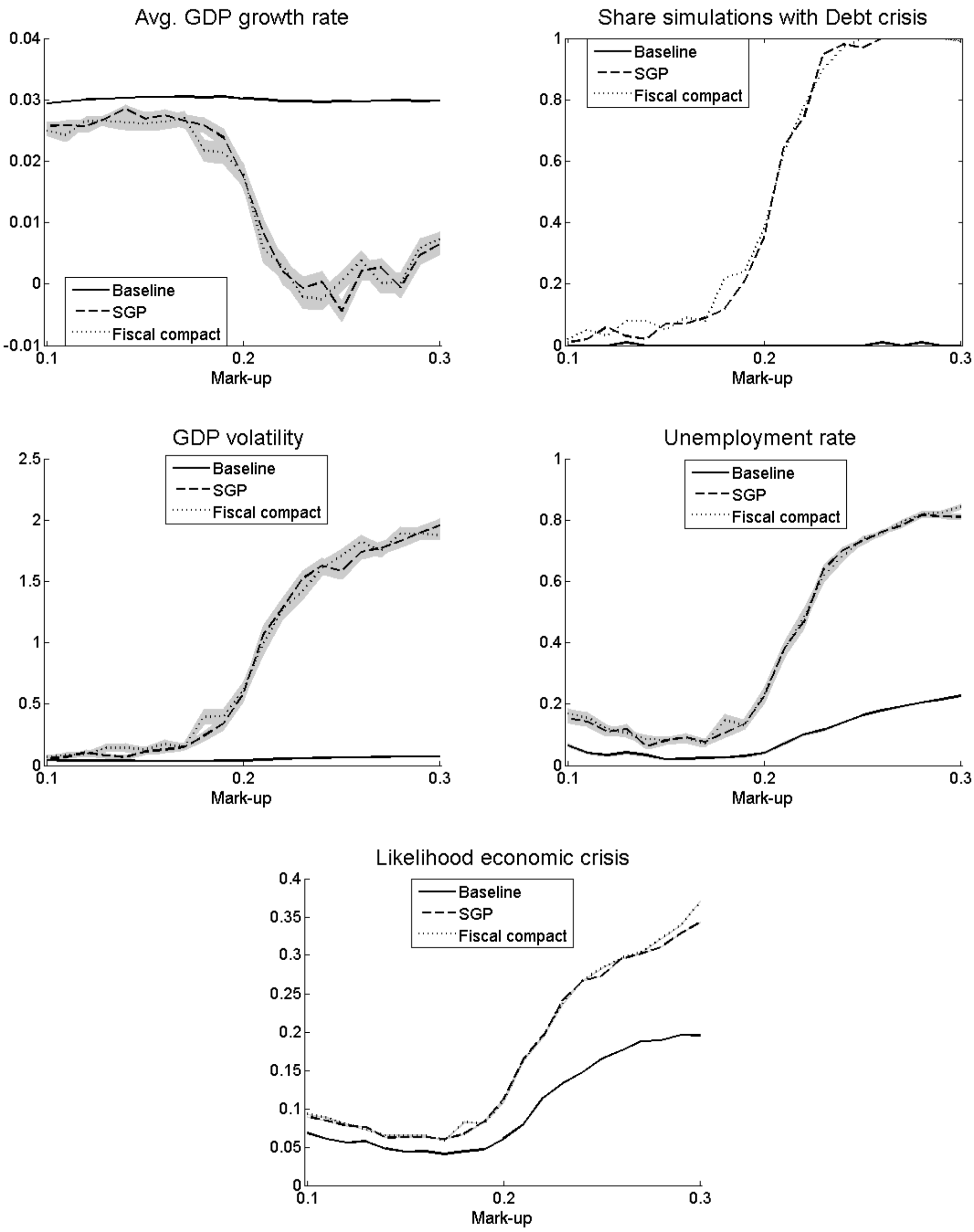
fiscal rules are activated, the dual-mandate monetary policy strongly impacts on both the short- and long-run dynamics of the economy, contributing to alleviate the pains caused by fiscal-consolidation policies and helping to stabilize public finance. For every type of fiscal policy, the dual-mandate Taylor rule slightly increases the inflation rate, but it does not put the economy on a high inflation path as the average inflation level in the benchmark scenario is quite small. The presence of bank-based and balance-sheet transmission channels of monetary policy (see e.g. Bernanke et al., 1999; Boivin et al., 2010; Borio and Zhu, 2012) appear to be responsible for the better performance of the $TR_{\pi,U}$ rule over the TR_{π} one (more on that in Section 4.2).

In the last battery of policy experiments, we complement both types of Taylor rule policies by letting the central bank also act as a "lender of last resort" (LLR_{π} and $LLR_{\pi,u}$): the central bank commits to buy an unlimited quantity of Government bonds in order to keep the interest rate bounded to 1%. This policy is supposed to reduce the financing costs of public debt. The results of the last battery of simulation results are reported in the fourth and fifth columns of Tables 1-6. For the baseline fiscal policies, we find that, for both types of Taylor rules, the LLR policies do not improve the performance of the economy, and it reduces the ratio between sovereign debt and GDP only when the central bank follows a dual-mandate Taylor rule. On the contrary, when the SGP and FC fiscal rules are activated, the LLR policy positively affects the dynamics of the economy under a Taylor rule that pursues just price stabilization (LLR_{π}), whereas it contributes to increase the instability of the economy when the dual-mandate Taylor rule is in place ($LLR_{\pi,u}$). For all the fiscal rules, "lender of last resort" policies appear to not increase the average inflation rate. Overall, the results suggest that LLR policies do not help to stabilize the economy.

Taking stock of policy interactions. The simulation results show that there are strong interactions between different types of fiscal and monetary policies. The appropriate policy mix for stabilizing the economy requires an unconstrained fiscal policy, where automatic stabilizers are free to dampen business cycles fluctuations, and a monetary policy targeting both price and output stability. Note that such policy combination achieves lower unemployment, output volatility and likelihood of crises *without* spurring the inflation rate or the sovereign debt to GDP ratio. Fiscal rules always depress the economy without improving the ratio between sovereign debt and GDP. In that, austerity policies are *self-defeating*. Moreover, the painful effects of fiscal rules are almost neutralized by the introduction of escape clauses, which let Government run deficits during recessions, and a dual-mandate monetary policy, which is more effective in stabilizing the economy than a "conservative" Taylor rule focused only on inflation stabilization.

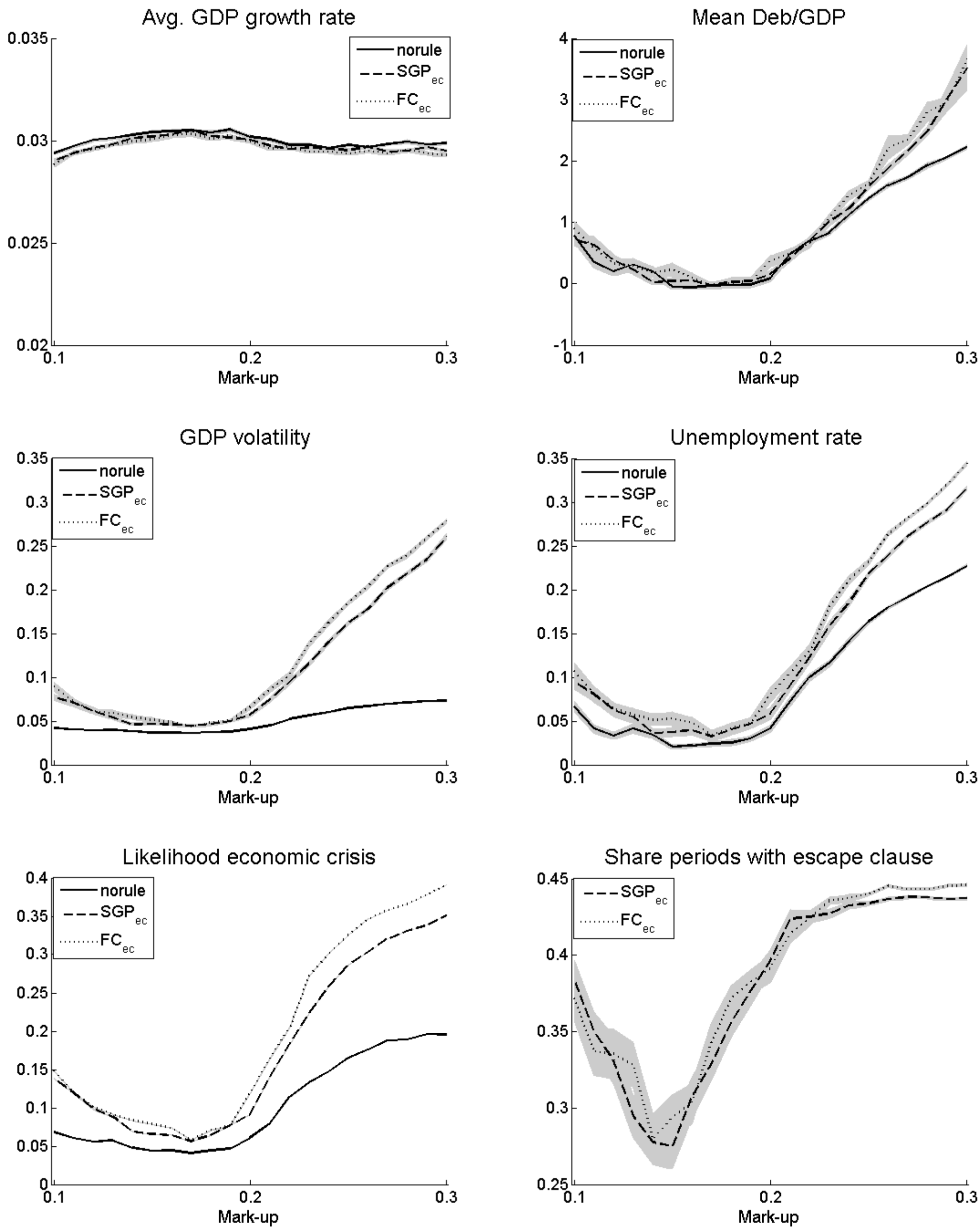
4.2 Inequality and macroeconomic policies

The policy experiments performed until now have been carried out for a given level of income inequality (the mark-ups of consumption-good firms fluctuate around the initial peg, cf. equations 20 and 21). However, a growing number of works have conjectured that the increasing levels of inequality have contributed to depress aggregate demand and to weigh down private indebtedness thus setting the stage for the Great Recession (Fitoussi and Saraceno, 2010; Kumhof



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 rules without escape clauses



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 rules with escape clauses

and Rancière, 2010; Stiglitz, 2012).[28] Such hypotheses were supported by the direct antecedent of this model (Dosi et al., 2013), where we found that a higher level of inequality increases the effects of fiscal policies. Given these premises, we explore how different levels of income inequalities affect the dynamics of the banking sector and the results produced by the different mixes of fiscal and monetary policies spotlighted in the previous section. These experiments will also contribute to explain the dynamics of the banking sector and its role in generating crises.

The impact of the mark-up rate. Let us begin by analyzing how our target variables evolve when we modify the income distribution under the benchmark scenario (*norule*, TR_{π}). The results are reported in Figures 4 and 5. First, the size of the banking sector is negatively associated with the mark-up rate (Fig. 4 top left). Indeed, when the mark-up is low, firms have a reduced ability to finance their investment with their own accumulated profits and thus they rely more on credit, boosting banks' profits and equity. This in turn increases the size of banks and the cost of banking crises.

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". When mark-ups are low, firms' higher failure rates weaken the banking sector thus curbing the supply of credit. As a consequence, a higher proportion of financially constrained firms reduces production and investment leading to higher unemployment rates. When firms have high profit rates, they do not invest because expected demand is too low. This, — in line with the findings in Dosi et al. (2013) — spurs GDP volatility and unemployment.

Fiscal and monetary policy interactions. Why should the impact of fiscal rules change along with the income distribution? As bailout costs are high when firms are credit constrained (see Figure 4), tighter limits on budget deficits can further depress aggregate demand thus amplifying the effects of financial constraints. On the other side, Dosi et al. (2013) have shown that when income inequality favors firms' higher margins, fiscal policy is more needed to sustain an (otherwise low) consumption demand. We test here the corollary, that fiscal discipline is *more harmful* when the income distribution is more biased towards firms' profit. For every level of income inequality, we find that the SGP and FC fiscal rules increase the instability of the economy (see Figure 6) and they are self-defeating as they considerably inflate the ratio between public debt and GDP. Moreover, fiscal discipline appears to be *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, which in turn reduces the average GDP growth rate and it leads to the explosion of the public debt to GDP ratio.[29] When the escape clauses are in place, they prevent the activation of fiscal rules up to 40% of the periods (Fig. 7, bottom right), thus reducing their negative impact on the dynamics of the economy. Nonetheless, in line with our previous results,

[28] For the empirical evidence about the long-run dynamics of income inequality, see Atkinson et al. (2011).

[29] In Figure 6 we report the share of simulations that end in a debt crisis, identified as an average public debt to GDP ratio above five.

the economy keeps on being more unstable and we keep on observing a self-defeating effect of fiscal rules on public debt.[30]

Let us conclude observing how monetary policy interact with income inequality. The dual-mandate Taylor rule performs better than the "conservative" one for every level of inequality without leading to inflation spirals (cf. Figure 8). Which mechanisms are responsible for such dynamics? Figure 9 helps to understand the forces at play: with a dual-mandate Taylor rule, the banking sector performs better, as shown by a higher share of investment projects that are financed and implemented (Fig 9, top left), as well as by a lower rate of banking failures. Both results stem from higher bank profitability when interest rates are high. A negative feedback loop is indeed at play: lower unemployment pushes interest rates up, which strengthens bank's profitability, while reducing firms' incentives to invest. The increase of the interest rate cools down aggregate demand, while improving the net worth of the banks leading to higher supply of credit when the economy will experience a downturn. Finally, the results about the LLR policy observed in Section 4.1 are robust to changes in the income distribution.

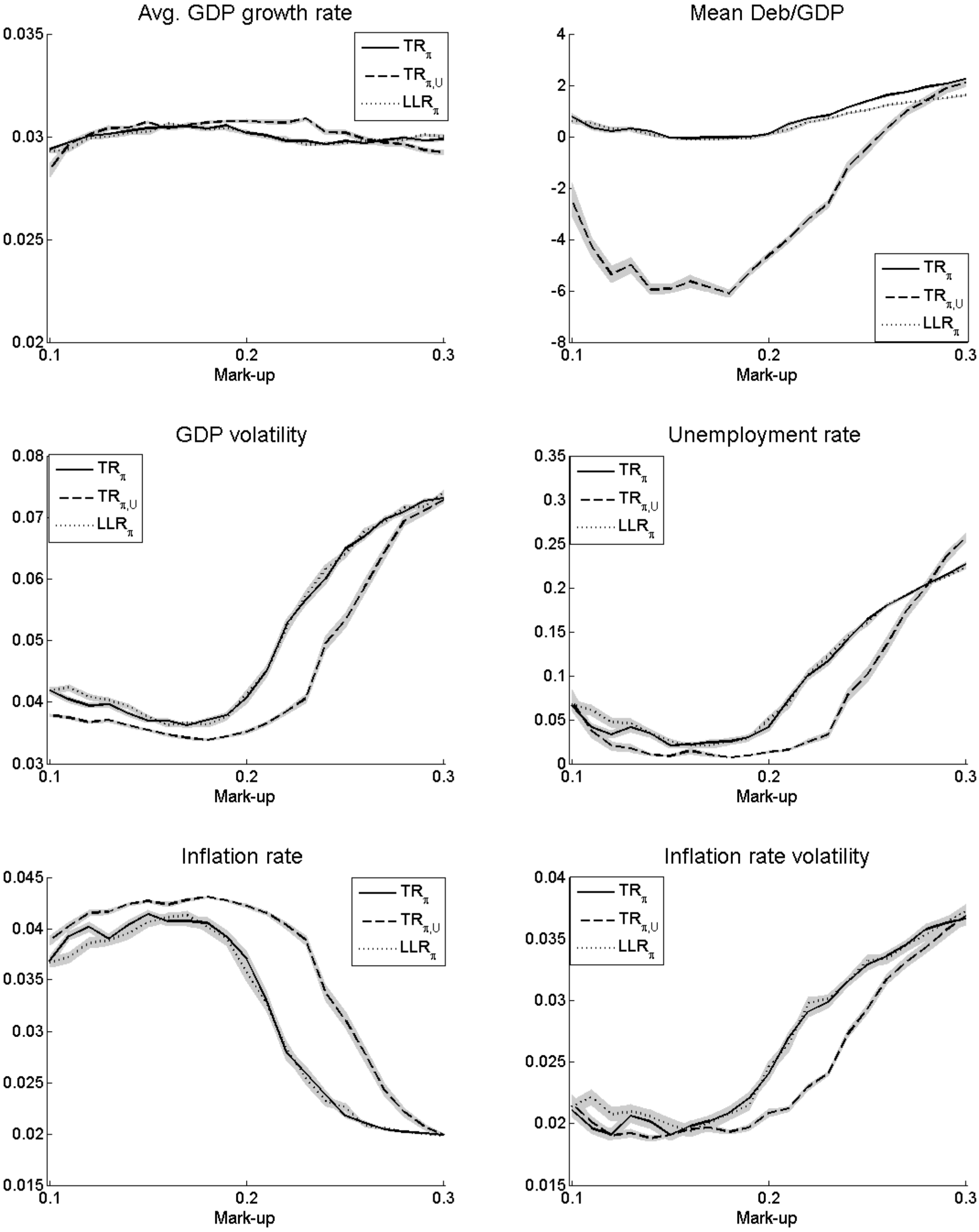
5 Concluding remarks

Building on previous works (Dosi et al., 2010, Dosi et al., 2013), we have studied the effects of alternative fiscal and monetary policies in an agent-based model with both a real and a 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.

Simulation results reveal that the choice of the macroeconomic policy mix significantly affects the dynamics of the economy. If policy makers aim at stabilizing both macroeconomic fundamentals (i.e. GDP growth, output volatility, unemployment and inflation rate) and public finances they should opt for an unconstrained fiscal policy coupled with a dual-mandate monetary policy. Jointly the two policies guarantee the lowest output fluctuation, unemployment rate, likelihood of economic crises stabilizing at the same time the inflation rate and the sovereign debt to GDP ratio. We find that the introduction of fiscal rules mimicking the Stability and Growth Pact or the Fiscal Compact worsen the performance of the economy as well as public finances. In that, austerity policies appear to be *self-defeating*. The presence in the model of bank-based and balance-sheet transmission mechanisms of monetary policy implies that the depressive effects of fiscal-consolidation rules are exacerbated when the central bank follows a "conservative" Taylor rule focused only on inflation stabilization. Finally, the impact of monetary and fiscal policy combinations is magnified by the level of income inequality in the economy. In particular, the recessionary effects of austerity fiscal rules are stronger when the income distribution is more biased toward profits.

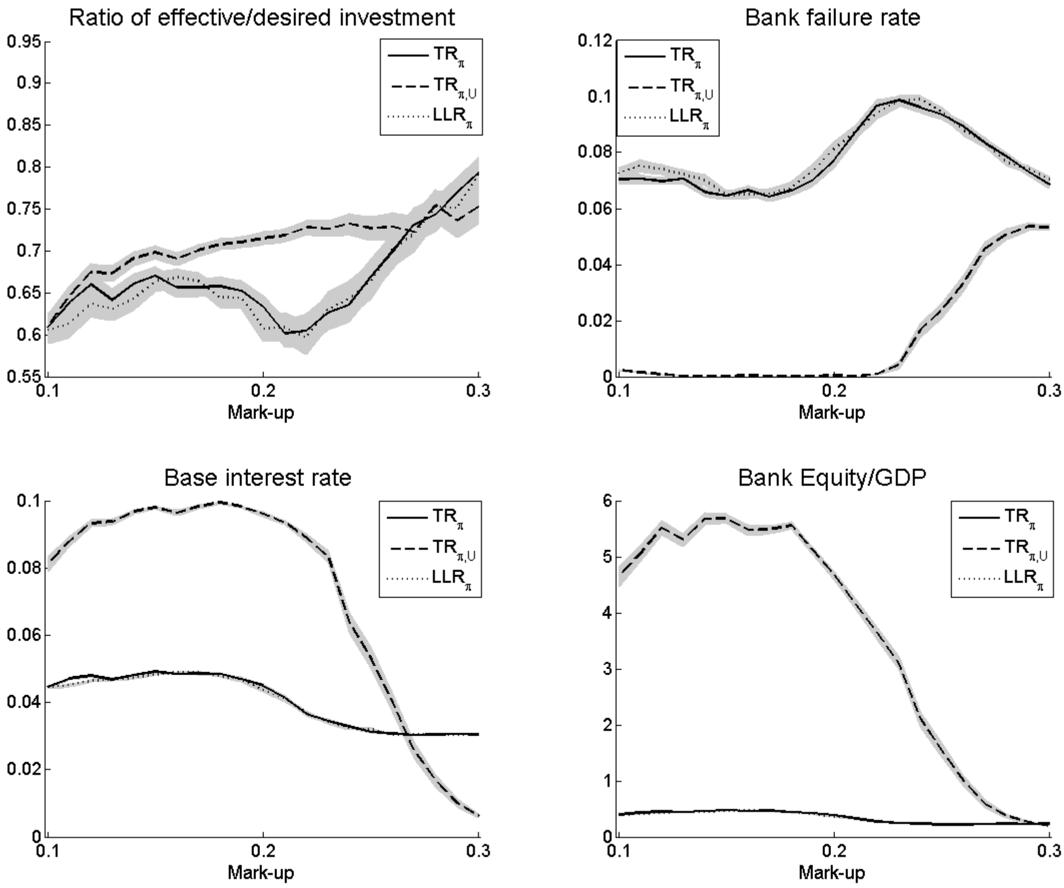
The present model could be expanded according to several research routes. First, we could better study how the banking sector structure may affect Government's bail-out costs and more generally the performance of the economy. Second, different ensembles of macroeconomic policies should be analyzed considering e.g. the possible interactions between fiscal and monetary policies

[30]The results of our previous analysis are confirmed also in the bond spread adjustment scenario and are available from the authors upon request.



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 8: Monetary policy - macroeconomic dynamics



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 - the banking sector

and Schumpeterian policies (building upon Dosi et al., 2010) and structural reforms (e.g. the Abenomics experiment, Patrick, 2013). Finally, the impact of fiscal policies (for any type of monetary rule) could be better assessed by computing the size of the fiscal multipliers according to the state of the economy along the lines of Auerbach and Gorodnichenko (2012) and Ferraresi et al. (2013).

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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 2. 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.

A.1 The Capital-Good Industry, complements

Capital-good firms' labour productivity is defined by A_i^τ, the labour productivity of the machine tool produced by firm i[31] and B_i^τ, the labour productivity of firm i itself, with τ the technology vintage. Firms define their price by applying a fixed mark-up ($\mu_1 > 0$) on their unit cost of production defined by the nominal wage w_t and productivity level ($c_{i,t} = \frac{w_t}{B_i^\tau}$). Capital-good firms can increase both their process (B_i^τ) and product (A_i^τ) technology levels via (costly) innovation and imitation. Indeed, R&D expenditures, defined in each period as a fraction $\nu \in [0,1]$ of past sales[32] are split between both activities according to the parameter $\xi \in [0,1]$.

The innovation process comprises two steps: first a random draw from a Bernoulli distribution of parameter $\theta_{i,t}^{in} = 1 - e^{-\zeta_1 IN_{i,t}}$ determines whether firm i innovates or not, with $\zeta_1 \leqslant 1$.[33] If it does innovate, the firm draws the technology associated with the new labour productivity levels (A_i^{in}, B_i^{in}) such that:

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

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

where x_i^A and x_i^B are two independent draws from a Beta(α_1, β_1) distribution over the support $[\underline{x}_1, \overline{x}_1]$[34] with $\underline{x}_1$ belonging to the interval $[-1, 0]$ and $\overline{x}_1$ to $[0,1]$. The imitation process is similarly performed in two steps. A Bernouilli draw ($\theta_{i,t}^{im} = 1 - e^{-\zeta_2 IM_{i,t}}$) defines access to imitation given the imitation expenditures $IM_{i,t}$, with $0 < \zeta_2 \leqslant 1$. In the second stage, a competitor technology is imitated, based on an imitation probability which decreases in the technological distance[35] between every pair of firms. Note that the innovative and imitation processes are not always successful as the newly discovered technology might not outperform firm i's current vintage. The comparison between the new and incumbent generations of machines is made taking into account both price and efficiency. The selected machine is chosen as follows:

$$\min \left[p_{i,t}^h + bc^h(A_{i,t}^h) \right], \qquad h = \tau, in, im, \tag{16}$$

where b is a positive payback period parameter for consumption-good firms (see Eq. 19 below). Next, capital-good firms advertise their machine's price and productivity by sending a "brochure" to potential customers (both to historical – $HC_{i,t}$– clients and to a random sample of potential new customers –$NC_{i,t}$;[36]) consumption-good firms thus have access to imperfect information about the available machines.

[31] Consumption-good firms' unit labour cost associated with the machine of vintage τ is $c(A_i^\tau, t) = \frac{w(t)}{A_i^\tau}$.

[32] The R&D propensity is fixed across time and firms.

[33] Note that higher amounts of R&D expenditures allocated to innovation $IN_{i,t}$ increase the probability to innovate.

[34] The shape and support of the Beta distribution define the extent of technological opportunities available to firms. The role of 'Schumpeterian" technology policies impacting these opportunities has been studied in depth in Dosi et al. (2010).

[35] We use Euclidean metrics to compute such technological distance.

[36] The random sample is proportional to the size of $HC_{i,t}$, i.e., $NC_{i,t} = \varpi HC_{i,t}$, with $0 < \varpi < 1$.

A.2 The Consumption-good industry, complements

Consumption-good firms produce a homogeneous good using two types of inputs (labor and capital) with constant returns to scale. The desired level of production Q_j^d depends on adaptive demand expectations (D_j^e,[37]), desired inventories (N_j^d) and firm j's stock of inventories (N_j):

$$Q_{j,t}^d = D_{j,t}^e + N_{j,t}^d - N_{j,t-1}, \tag{17}$$

with $N_{j,t}^d = \iota D_{j,t}^e$, $\iota \in [0,1]$.

Consumption-good firms' production is limited by their capital stock ($K_{j,t}$). Given the desired level of production firms evaluate their desired capital stock ($K_{j,t}^d$), which, if higher than their current capital stock, calls for desired expansionary investment ($EI_{j,t}^d$):[38]

$$EI_{j,t}^d = K_{j,t}^d - K_{j,t}. \tag{18}$$

Each firms' stock of capital is made of a set of different vintages of machines $\Xi_{j,t}$, with heterogeneous productivity. Machines with technology $A_i^\tau \in \Xi_{j,t}$ are scrapped according to a payback period routine which considers their technology obsolescence and new machines' prices:

$$RS_{j,t} = \left\{ A_i^\tau \in \Xi_{j,t} : \frac{p_t^*}{c(A_{i,\tau}, t) - c_t^*} \leq b \right\}, \tag{19}$$

where p^* and c^* are the price of and unit cost of production upon the new machines. Total replacement investment is then computed at firm level as the number of scrapped machines satisfying Equation 19, and those with age above η periods, $\eta > 0$. Firms compute the average productivity of their current capital stock ($\pi_{j,t}$) and unit cost of production ($c_{j,t}$), then setting prices by applying a variable mark-up ($\mu_{j,t}$) on unit costs of production:

$$p_{j,t} = (1 + \mu_{j,t})c_{j,t}. \tag{20}$$

mark-up differences are linked to changes in firms' market shares (f_j):[39]

$$\mu_{j,t} = \mu_{j,t-1}\left(1 + \upsilon \frac{f_{j,t-1} - f_{j,t-2}}{f_{j,t-2}}\right), \tag{21}$$

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

Consumers access to imperfect information regarding the final product (see Rotemberg, 2008, for a survey on consumers' imperfect price knowledge) as they cannot instantaneously switch to the most competitive producer. Still, a firm's *competitiveness* ($E_{j,t}$) directly relates to its price, but also to the amount of unfilled demand ($l_{j,t}$) inherited from the previous period:

$$E_{j,t} = -\omega_1 p_{j,t} - \omega_2 l_{j,t}, \tag{22}$$

where $\omega_{1,2} > 0$.[40] At the aggregate level, the *average competitiveness* of the consumption-good sector is computed as the competitiveness of each consumption-good firm weighted by its past

[37] With $D_j^e = f(D_{j,t-1}, D_{,t-2}, \ldots, D_{j,t-h})$ where $D_{j,t-1}$ is the demand addressed to firm j at time $t-1$.

[38] Following the empirical literature on firm investment patterns (e.g. Doms and Dunne, 1998), firms' expansion in production capacity is limited by a fixed maximum threshold. Moreover, as described in Section 2.2, credit-constrained firms' effective investment does not reach the desired level.

[39] Such assumption relates to "customer market" models as originally described by Phelps and Winter (1970).

[40] Such unfilled demand is due to the difference between expected and actual demand, firms defining their production level according to the former. Inventories accumulate if the firm's expected demand was too high and it produced too much. On the contrary firm j's competitiveness is negatively affected if it cannot satisfy its demand.

market share (f_j):

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

Following a "quasi" replicator dynamics, firms' competitiveness drive the dynamics of their market shares:

$$f_{j,t} = f_{j,t-1}\left(1 + \chi \frac{E_{j,t} - \overline{E}_t}{\overline{E}_t}\right), \tag{23}$$

with $\chi > 0$.[41]

Description	Symbol	Value
Benchmark parameters		
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
Capital-good firm mark-up rule	μ_1	0.04
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^T	0.03
Target inflation rate	$dcpi^T$	0.02
Banks deposits interest rate	r^D	0
Bond interest rate mark-down	μ^{bonds}	-0.33
Loan interest rate mark-up	μ^{deb}	0.30
Bank capital adequacy rate	τ^b	0.08
Shape parameter for the distribution of banks' clients	$pareto_a$	0.08
Scaling parameter for interest rate cost	k_{const}	0.10
Capital buffer adjustment parameter	β	1
R&D investment propensity	ν	0.04
R&D allocation to innovative search	ξ	0.5
Firm search capabilities parameters	$\zeta_{1,2}$	0.3
Beta distribution parameters (innovation process)	(α_1, β_1)	(3,3)
Beta distribution support (innovation process)	$[\underline{x}_1, \overline{x}_1]$	[-0.15,0.15]
New customer sample parameter	ϖ	0.5
Desired inventories	ι	0.1
"Physical" scrapping age	η	20
Payback period	b	3
Mark-up coefficient	υ	0.04
Competitiveness weights	$\omega_{1,2}$	1
Policy experiment parameters		
Inflation adjustment parameter ($TR_\pi, TR_{\pi,U}$)	γ_π	1.1
Unemployment adjustment parameter ($TR_{\pi,U}$)	γ_U	1.1
Fiscal rule max deficit to GDP (SGP, FC)	def_{rule}	0.03
Fixed interest rate on bonds (LLR)	$\overline{r_{bonds}}$	0.01

Table 7: Parameters

[41] Contrary to a canonic replicator dynamics, market shares may becomes negative. In that case the firm exits the market.