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Multi-Agent models for policy analysis: evaluation of coordination issues

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The current global crisis has revealed the inadequacy of standard neoclassical models both as description of the economic systems and as forecasting tools. Therefore we propose two agent-based models where interaction and heterogeneity concur in determining emerging aggregate phenomena. The models are then used as computational laboratories that allow performing both monetary and fiscal policy experiments in a controlled environment. In general, simulations show Keynesian features in the policy effects together with a strong departure from usual findings by mainstream economists.

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MONETARY AND FISCAL POLICY EXPERIMENTS IN AN AGENT-BASED MACRO MODEL WITH FINANCIAL FRICTIONS

By

Leonardo Bargigli, Domenico Delli Gatti, Saul Desiderio

1 Introduction

The current global crisis has deeply challenged the apparently established view of monetary policy as being elevated to the status of science (Clarida et al., 1999; Woodford, 2003). Relevant deviations from the standard prescriptions of a rule-based approach during the crisis include the adoption of a zero-interest rate policy in view of inflation levels exceeding the implicit or explicit targets of many Central Banks, as well as a whole array of unconventional measures such as quantitative easing, credit easing, foreign exchange intervention, currency SWAPS. On the other hand, fiscal policy played a major role in the most dramatic months of the crisis, providing a fundamental source of demand, contrary to neoclassical theory's main tenet of fiscal policy being at best ineffective if not harmful as a stabilization tool.

Regarding monetary policy, public authorities have become more wary of standard prescriptions and tools in the aftermath of the crisis. In the words of J.-C. Trichet, president of the European central bank, “Macro models failed to predict the crisis and seemed incapable of explaining what was happening to the economy in a convincing manner. As a policy-maker during the crisis, I found the available models of limited help. In fact, I would go further: in the face of the crisis, we felt abandoned by conventional tools ” (Trichet, 2010).

The current mainstream approach may be labeled, following Delli Gatti et al. (2004), as inflation-forecast targeting. According to this view, the goal of monetary policy is to stabilize inflation around a given target by employing the Taylor principle of a more than proportional increase of the policy rate in response to an increase of the inflation rate, while at the same time minimizing the output gap. Since the effects of monetary policy are lagged, the monetary authority must also be forward looking, i.e. it must rely on macroeconomic forecasts. Both these pillars may be questioned, since on the one hand the scale and timing of policy rate adjustment, today more than ever, look like a matter of judgment, while on the other hand economic forecasts are subject to a great uncertainty. In particular, the financial crisis delivered a stress test for the main macro-forecasting tool, namely DSGE models, which failed to deliver a correct prediction for the incoming economic contraction (Caballero, 2010).

A throughout critique of the DSGE approach is presented by Fagiolo and Roventini (2010) both on theoretical and on empirical grounds. Regarding theory, DSGE models turn out to be nothing more than a juxtaposition, whereby money, monopolistic competition (with price mark-ups) and nominal price rigidities are added to a real business cycle (RBC) 'core' (Caballero, 2010). Since the former ingredients make monetary policy again effective, contrary to the main tenet of the original RBC theory, the model is closed by a monetary policy rule, often under the form of a simple Taylor rule. In addition, other sources of frictions must be frequently introduced (such as fixed price and expenditure decisions, rigid wages, adjustment costs, consumption habits) in order to account for the higher amount of persistence found in real data with respect to theoretical predictions. These addition don't change the Walrasian nature of the core, since the latter still relies on the hypothesis of general equilibrium, requiring to introduce the notion of the rational representative agent (RRE) in order to obtain stable and unique equilibria.

While the main assumptions underlying the RRE hypothesis today look more unrealistic than ever, heterogeneity of agents has become a key ingredient in order to explain many important stylised facts of financial markets, such as fat tails, clustered volatility and long memory - see e.g.
LeBaron (2006) or Hommes (2006). In particular, heterogeneous expectations coupled with bounded rationality and adaptive learning provide valuable tools, which have been recently extended to a stylised macro model (Anufriev et al., 2009) with the goal to investigate how an ecology of different forecasting rules may affect the stabilizing properties of a simple Taylor rule. The reference to ecology is justified since agents adopt alternative forecasting rules according to an evolutionary fitness measure, which takes into account costly information gathering on part of rational agents. Under these hypotheses, alternative expectations may arise even with a Taylor type interest rule – i.e. the stabilizing solution is surrounded by other, destabilizing, equilibria. This result depends from the fact that it is convenient for a stable fraction of the population of agents to adopt ‘naive’ forecasting rules, even if a rational forecast is available.

Regarding fiscal policy, Ricardian equivalence states that with lump-sum taxes, perfect capital markets, and dynastic households, any fiscal policy satisfying an inter temporal budget constraint, cannot affect either the level of production or the price level, since households’ optimal consumption decisions are indifferent to the decision of the fiscal authority (Barro, 1974). In other terms, Ricardian theory predicts that any time paths for taxation implying the same total present value for tax revenue are equivalent in terms of prices and allocations. Unfortunately, this theory is at odds with empirical evidence, which shows a relevant impact of deficit spending on consumption. As a consequence, closing the gap between Ricardian theory and evidence has become a serious concern for mainstream macroeconomists who, more and more, have to concede that the only viable route for this purpose is to introduce heterogeneity between agents.

In fact, alternative models have been devised for which some of the Ricardian assumptions do not hold, mostly by adopting alternative taxation schemes, capital market imperfections or imperfect intergenerational altruism (Heatcote, 2005). In all these models, heterogeneity is a key ingredient. For example, when dealing with capital imperfections, the standard hypothesis is to introduce an heterogeneous population structure, where consumers differ in wealth and face idiosyncratic income/productivity shocks against which they cannot fully insure. In particular, the Standard Incomplete Markets (SIM) model, described as the ‘main workhorse for studying heterogeneity in macroeconomics’ (Storesletten et al., 2009), includes a continuum of maximising agents hit by idiosyncratic shocks on individual wage/productivity. On the other hand, if the only source of heterogeneity is idiosyncratic risks, which cannot be fully insured, the aggregate behaviour of the model is almost identical to that of a representative-agent model (Krusell and Smith, 2006). In order to obtain different results, the additional hypothesis of credit constraints must be introduced. In fact, the combination of idiosyncratic uncertainty, imperfect insurance markets and liquidity constraint generate a powerful motive for precautionary saving which leads to a higher saving rate above the so-called golden rule and eventually to an excess level of capital.

Heatcote (2005) finds that a combination of distortionary taxation, capital market imperfections and borrowing constraints can produce substantial departures from Ricardian equivalence. This result is consistent with the evidence provided by panel data on the behaviour of low-income households (Heatcote, 2005: p. 4-5). While most of the response of aggregate consumption to tax changes in these models is attributable to the fact that flat-rate taxes are non neutral, the asset market structure is important for both the magnitude and the composition of aggregate responses to tax shocks. Consumption is most reactive when the distortionary effects of proportional taxes are coupled with the liquidity effects that arise with incomplete-markets.

These models are useful not only because their implications are closer to the findings of the applied microeconomic literature studying consumption and labour supply decisions, which emphasizes the existence of precautionary savings and liquidity or borrowing constraints, but also because macroeconomic forces influence inequality, which on its part influences the evaluation of stabilization policies. In fact, business cycles affect the rich and the poor quite differently, and consequently macroeconomic policy has also important distributional implications, which should be taken into account. For example, Afonso and Furceri (2008) detect a positive relationship between business cycles, economic growth and wage/income dispersion. In Storesletten et al. (2001),
instead, liquidity constrained households are particularly hard hit by aggregate productivity shocks. As a consequence of inequality, the welfare cost of business fluctuations can be much larger than expected under the representative agent hypothesis, making a much stronger case in favour of stabilization policies than in the standard RBC framework. Even inflation has potentially large distributitional consequences, since the poor hold a larger share of their wealth in cash than the rich, and are therefore more vulnerable to high (expected) inflation.

For similar reasons, it is important to understand the welfare distribution effects of any policy program. And many important issues, like social security system, aging problems, or wage dispersion, cannot be modelled without heterogeneity. On the other hand, we must observe that mainstream models with heterogeneous consumers don't produce unequivocal results. For example, in the standard neoclassical paradigm, a permanent increase in government consumption affects production through a negative wealth effect, which raises labour supply. With incomplete markets, on the other hand, the increased government consumption impairs private investment, triggering a reduction in capital intensity, productivity, and wages which contributes towards lower employment and output (Angeletos and Vasia, 2007). This effect reduces further the scope for fiscal policy, making it harder to reconcile these models with empirical evidence, especially in the aftermath of the financial crisis. These implications are not completely surprising, since these models still accept most of the main building blocks of standard RBC models, like inter-temporal optimisation or rational expectations.

A third and distinct issue regards the coordination of monetary and fiscal policy. Historically, we may say that the need to coordinate monetary and fiscal policy arose because they were separated in the first place at the beginning of the Eighties. The twin principles of inflation targeting and central bank independence introduced a potential clash with fiscal policy, as central banks got charged with pursuing price stability as their primary goal, with stabilization of cyclical movements becoming at best a secondary goal (Niemann and von Hagen, 2008). In the longer run, historians have recorded clear shifts in the configuration of monetary and fiscal policy during the post-war era in US. These shifts suggest that an encompassing model should include evolving combinations of active and passive policy rules, according to which monetary policy may or may not satisfy the Taylor principle, and fiscal policy may or may not be Ricardian (Eusebi and Preston, 2008). The process of establishing EMU is partly responsible for renewed interest in these issues, since the coexistence of a single monetary authority with many national fiscal authorities created an institutional asymmetry, whereby policy spillovers could become potentially damaging; all the more so, since the monetary union was established between countries with a long tradition of monetary and fiscal discipline and others more prone to fiscal unsustainability. This situation created the pre-conditions for an “unpleasant monetarist” fiscal dominance over monetary policy (Sargent and Wallace, 1981), which needed to be contrasted as rapidly as possible.

Even if we accept the now established view that leaving both monetary and fiscal policy in the hands of the government leads to inflationary outcomes, and thus we maintain the case for separating monetary and fiscal policy, the coordination issue remains at stake. In fact, if externalities between policies are strong, a lack of coordination may lead to inefficiency, and authorities could achieve better outcomes by taking into account these externalities. For example, a significant stock of government debt may constrain the path of monetary policy. Since the largest part of government debt is in nominal terms, monetary policy can affect its real value and therefore the tax burden required to finance it. Then, in presence of excessive debt levels, central banks may be forced to pursue a looser monetary policy than otherwise, in order to reduce the interest rate burden on public debt. On the other side, there are various channels of influence of tight monetary policy upon the budget deficit, most of which lead to an increase of it (Dahan, 1998), while the reaction of the government to recession might be an increase in the budget deficit that may affect overall policies’ credibility. In all these situations, a coordinated outcome leads the economy closer to the planned target as compared to the non-cooperative game (Tabellini, 1986). When agents are not perfectly informed about the policy regime, the need for policy coordination becomes stronger:
the choice of monetary policy limits the set of fiscal policies consistent with macroeconomic stability, and simple Taylor-type rules frequently lead to expectations-driven instability. In contrast, non-Ricardian fiscal policies combined with an interest rate peg promote stability (Eusepi and Preston, 2008).

The most pronounced view on this issue is provided by the so-called fiscalist theory, according to which fiscal policy may influence the price level, and in some circumstances fiscal variables can fully determine the price level independently of monetary variables (Evans and Honkapohja, 2002). Although this result involves an explosive price level, Leeper (1991) has shown that different policy combinations are possible around an unique steady state. Indeed, both a passive fiscal policy combined with an active monetary policy and its vice versa yield an unique stationary equilibrium. And, when fiscal policy is active, the price level is not determined anymore uniquely by monetary policy. Even if this result rests on the admissibility of non-Ricardian fiscal policies, and moreover the validation of the fiscalist argument turns out to be problematic (Kocherlakota and Phelan, 1999), the probability that monetary authorities resort to surprise inflation may still be an increasing function of the government’s nominal debt burden under alternative settings. Then, with rational expectations, agents will predict a positive inflation bias related to the stock of debt (Niemann and von Hagen, 2008), something which seems indeed to be the case according to Campillo and Miron (1997), who find a significant effect of debt levels on cross-country inflation variation.

Regarding the coordination mechanism, most models suggest a solution based on the property of the fiscal policy process being lengthy, complex, and not easily reversible while, on the contrary, monetary policy decisions can be implemented in a very short time and are easily reverted. Hence, the fiscal authority will emerge as the Stackelberg leader in the macroeconomic policy game. This situation is indeed desirable as long as the government sets fiscal policy according to the minimization of the all-inclusive social welfare function. In other words, the fiscal stance should take into account also the goals of monetary policy (Lambertini and Rovelli, 2003).

All the models described above don't have the ambition to provide an alternative framework with respect to mainstream macroeconomics, with which they share most of their basic assumptions. Most scholars in this field explicitly declare that their goal is to perform a “robustness check” on the standard representative-agent macroeconomic model, the only relevant difference being, for example, that “the SIM model incorporates shocks at the individual instead of (or in addition to) the aggregate level” (Storesletten et al., 2009). Further, the introduction of heterogeneity is only partial, turning these models into a theoretical juxtaposition, like for example in Aiyagari (1994), where we find the SIM model embedded in a neoclassical production economy, with a representative firm operating with a constant-returns-to-scale technology. On the other hand, very few attempts have been made to deal with the issue of policy coordination from a full-blown agent based perspective (Haber, 2008). Westerhoff and Hohnisch (2010) have recently developed a simple Keynesian-type model where consumers are either optimistic or pessimistic. A change in the proportion of consumers that are optimistic will then influence the aggregate propensity to consume. Opinion waves grow through mutual influence between consumers and also through the effect of prevailing economic conditions. In this model, fiscal policy influences output not only through the usual Keynesian multiplier process, but also through movements in the consumer sentiment, which are supported by fiscal policy itself. In fact, if fiscal policy manages to increase national income, then it becomes likely that consumers will become more optimistic, which, in turn, should give the economy a further boost. However, according to this model, the interplay between individual consumer attitudes, national income and fiscal policy is quite complex, and it may be quite difficult to bring the economy to the desired target.

Here we pursue the alternative approach provided by micro-to-macro agent-based models, in which the behavioural, often adaptive, rules of all the relevant heterogeneous agents in the economy (workers-consumers, firms, banks, fiscal and monetary authorities) are specified in order to build a realistic representation of the whole economic system. In this paper we are going to follow this
route, by presenting two AB macroeconomic models which belong to a series of computational investigations of macroeconomic processes conceived as complex adaptive systems (CATS). Other exemplifications of the CATS approach can be found in Delli Gatti et al. (2005, 2008), Gaffeo et al. (2007) and Russo et al. (2007). These models, though able to replicate many stylized facts related to business cycles and growth, were not suited to simulate the implementation of policy interventions. Thus, our main goal is to extend these models in order to perform policy experiments adopting a representation of the economy that is richer than that offered by DSGE models. In particular, we want to evaluate the effects of different monetary and fiscal policy regimes on the macroeconomy taking into account the potential impact of heterogeneity and of the interactions occurring among the elements of its microstructure. Since in this framework firms are price setters and equity constrained, monetary policy acts through the credit channel (Bernanke and Gertler, 1995), and leverage cycles are endogenously generated. In fact, production costs must be sustained before the proceeds from sales are collected, which implies that firms must recur to borrowing in order to finance their working capital. Since credit market is not frictionless because of persistent uncertainty and asymmetric information, borrowing conditions depend on firms’ leverage. Then movements of the policy rate affect the production plans of firms both because production costs depend directly on nominal interest rates, and because the cost of external finance affects the demand for loans expressed by firms. So, combining heterogeneous financial conditions and interaction we get the following results: (i) endogenous business cycles generated by the interplay between real activity and financial conditions; (ii) the non-neutrality of monetary policy and (iii) the assessment of the performance of a monetary policy based on the Taylor principle (Taylor, 1993). Finally, we assess (iv) the behaviour of fiscal policy under different financing schemes.

The rest of the paper is organized as follows. Section 2 describes the accounting system of the models and their temporal structure; section 3 presents the basic model without financial frictions and shows results from simulations; section 4 introduces a second model with frictions and its simulation; section 5 is devoted to the assessment of diverse monetary policy experiments; section 6 contains fiscal policy experiments; finally, section 7 concludes.

2 General features

In this paper we are going to present two models sharing the same basic economic structure, except for the credit demand function that characterize the firms. We will see that this only discrepancy is sufficient to produce very different results.

The artificial economy presented in the two models runs sequentially for T periods and is populated by I firms/capitalists, J workers, one commercial bank and the Central Bank (CB). Capitalists and workers together come to form I+J households/consumers.

From a microscopic point of view, as in any agent-based model our simulated economy is based on networks of agents that continuously interact according to local search-and-matching market protocols, while from the macroscopic standpoint it follows a balance sheet approach. With this label we mean the introduction of a correct accounting system, which is aimed at ensuring the consistency of not only aggregate flows as in standard macroeconomics, but also of stocks of assets and liabilities. This consistency implies a fortiori model closure, in the sense that no external resource is unduly added to the system and no internal resource is lost, both for financial and real variables. Moreover, balance sheets summarize past history and are an important source of path dependence.

The importance of the balance sheet approach in our case can be well appreciated for at least two reasons: (i) from an economic perspective, the stock-flow consistency provides the model with an external coherence since it increases the degree of realism of the model and its adherence to real economies; (ii) it offers a powerful and practical way to check the correctness of the model implementation (internal coherence). In both cases the balance sheet approach serves as a validation tool.
2.1 The balance sheets

Agents are characterized by different state variables that are summarized by their balance sheets as shown below by the double-entry table (1). We even could push ourselves to say that the economy as a whole can be viewed as a system of the balance sheets of all its agents (Allen et al., 2002).

<table>
<thead>
<tr>
<th></th>
<th>Households</th>
<th>Firms</th>
<th>Banks</th>
<th>Central Bank</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deposits</td>
<td>$D_h$</td>
<td>$D_f$</td>
<td>$-(D_h + D_f)$</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Reserves</td>
<td>$H$</td>
<td>-</td>
<td>$-H$</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Loans</td>
<td>-$L$</td>
<td>$L$</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$W$</td>
<td>$A$</td>
<td>$E$</td>
<td>$-H$</td>
<td>0</td>
</tr>
</tbody>
</table>

Table 1. Balance sheets.

In aggregate assets and liabilities must sum to zero, thus the following fundamental time-invariant macroeconomic accounting identity holds:

$$W + A + E = H,$$  \hspace{1cm} (1)

where $W$ stands for households’ total savings, $A$ and $E$ respectively for firms and bank’s total equity and $H$ is the monetary base that at the beginning of the story the CB grants to firms and bank. The meeting of this condition is therefore essential in order to validate our models.

The dynamics of stocks is determined by agents’ behavior, which substantiates in market transactions producing flows of funds as illustrated by table (2):

<table>
<thead>
<tr>
<th></th>
<th>Households</th>
<th>Firms</th>
<th>Banks</th>
<th>Central Bank</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goods</td>
<td>-$Y$</td>
<td>$Y$</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wages</td>
<td>$w*N$</td>
<td>-$w*N$</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New loans</td>
<td>$B$</td>
<td>-$B$</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Principal</td>
<td>-$R$</td>
<td>$R$</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loan interests</td>
<td>-$r*L$</td>
<td>$r*L$</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New deposits</td>
<td>-$ND_h$</td>
<td>-$ND_f$</td>
<td>$+ND_h + ND_f$</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Dividends</td>
<td>$Div$</td>
<td>-$Div$</td>
<td>$S_b$</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>$S_h$</td>
<td>$S_f$</td>
<td>$S_b$</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Flow of funds.

From table (2) we argue that in aggregate, given that firms do not make investments, the flow of current savings must sum to zero and, therefore, the following identity holds true:

$$S_h + S_f + S_b = 0.$$ \hspace{1cm} (2)

This last condition entails that if someone increases his savings someone else must be reducing his or must be increasing his debt, and this is precisely what we need in order to have model closure. Since flows represent stock dynamics, it is very easy to show the relationship between (2) and (1). In fact, by taking the difference of both sides of (1) and considering that by assumption $\Delta H = 0$, we get exactly identity (2).
A peculiar hypothesis we made is the absence of currency: firms and households keep at any point in time all their liquid assets as bank deposits, which are used as credit money. This assumption, in line with a well-honored tradition (Keynes, 1930; Schumpeter, 1954), allows us to state a causal relation going from loans to deposits. In fact, every payment between firms and households (wages, purchases and dividends) happens through their bank accounts without involving any actual monetary flow outside the bank. Hence, whenever a new loan is granted and is used by firms to execute a payment, the amount of monetary base flowing from bank’s reserves to payment beneficiaries’ pockets instantaneously is dropped back into the bank and is totally translated in new deposits. Our assumption can be well considered a good approximation of today’s economic activity, where most of loans generate deposits and increase the total stock of money.

The above assumptions together lead to another identity. Adding total loans $L$ to both sides of (1) we get the relationship

$$ (D_h+D_f)+E=H+L \quad (3), $$

which simply states that the sum of private sector deposits and bank’s equity must be equal to the total amount of debt (monetary base plus total loans). As a consequence, higher liquidity levels can only stem from higher levels of debt.

2.2 The sequence of events

Having defined the general framework, we are now ready to introduce the time structure characterizing the models, limiting ourselves to give the general idea and omitting the details that will be treated in the next section.

The economy is an iterative system where agents repeat the same groups of operations at each time step. The time unit is conveniently to be interpreted as one month since this is the frequency at which wages are paid. Within the same time lapse a credit market, a labor market and a consumption goods market open sequentially as the following sequence of events can make clear:

1. Each operating firm decides on the amount of output to be produced (hence, the amount of labor to be hired) and the price to be charged according to expected demand for consumption goods. Expectations of future demand are updated adaptively, i.e. they are formed on the basis of the firm’s past experience.

2. If internal financial resources (net worth) are in short supply with respect to the wage bill – i.e. if there is a financing gap – the firm can access a credit market represented by a commercial bank that supply credit unlimitedly. Bank and firm sign a long-term debt contract that provides for a fixed-rate principal repaying schedule and a contractual interest rate calculated applying a mark-up (which is itself a function of financial viability) on an exogenously determined baseline interest rate. In Model 1 firms borrow all the needed money regardless of the interest rate level, while in Model 2 this last assumption will be removed.

3. A fully flexible labor market opens. In first place, firms having more workers than necessary fire the excess workforce. Secondly, firms with open vacancies hire new workers picking them from the pool of unemployed people. Firms then pay wages, which are exogenously given and uniform across firms.

4. Production takes one time period, regardless of the scale of production/firm’s size. After production is completed, the market for goods opens. Firms post their offer price, and consumers contact a given number of randomly chosen firms to purchase goods, starting from the one which posts the lowest price. If a firm ends up with excess supply, it gets rid of the unsold goods at zero costs. The good in fact is perishable and cannot be stored in a warehouse to be sold in the future.
5. Firms collect revenues and calculate profits. If profits are high enough, they “validate debt commitments”, i.e. pay back principal and interest to the bank. Moreover, if net profits are positive, firms pay dividends to the owners.

6. Earnings after interest and dividends are retained profits, which are employed to increase net worth. Net worth at the end of a period, in fact, is the sum of all retained profits accumulated in the past. Firms are financially viable – and therefore survive – if they are able to serve their debt commitments. If this is not the case they go bankrupt, shut down and exit the market. The bank, therefore, has to register a bad debt (non-performing loan).

7. A string of new firms equal in number to the bankrupt ones enters the market. Their size at entry is smaller than the average size of surviving firms, and their initial liquidity is provided by owners’ personal funds.

3 Model 1: baseline

In what follows we describe the behavioral rules adopted by the agents, which are common to both models except for the individual credit demand function.

3.1 The labor market

The i-th firm carries on production by means of a constant return to scale technology, with labour \( N_{it} \) as the only input:

\[
Y_{it} = \alpha N_{it}, \quad \alpha > 0 \tag{4}
\]

where \( \alpha \) is labor productivity. We will deal with productivity as if it were a given and constant parameter. From equation (4) follows that the desired workforce, i.e. the demand for labor \( N_{it}^d \) is simply given by:

\[
N_{it}^d = \frac{Y_{it}^d}{\alpha}, \tag{5}
\]

where \( Y_{it}^d \) is the “desired” level of production\(^1\). In other words, the desired workforce is the labor requirement that must be fulfilled to reach the desired scale of production. We will later show how the latter is determined.

At the beginning of time \( t \), each firm is endowed with an operating workforce equal to \( N_{it}^o \), hence vacancies are:

\[
V_{it} = (N_{it}^d - N_{it}^o).
\]

In case the desired labor force is larger than the actual one, vacancies are positive and the firm will seek to hire new workers picking them from the reservoir of unemployed people, otherwise vacancies are negative and the firm will disband the excess workforce without incurring in firing costs.

We assume that workers supply inelastically one unit of labor per period and that nominal wages are fixed and uniform across firms. In spite of these assumptions may appear too restrictive, actually the labor market operates in complete absence of any kind of real frictions since firms can fire and hire without costs, and workers can freely flow from an employer to another. Hence, adjustments totally take place on quantities. Only two instances of rationing may occur: firms may

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\(^1\) Since labor is a discrete variable, in the simulations we always approximate it by excess.
end up with unfilled vacancies when the economy is at full employment, and unemployed workers may be unable to find a job if labor demand is low.

3.2 The credit market

At the beginning of period $t$ the firm is endowed with liquid resources $D_n$. In case the wage bill $W_n$ she expects to pay is larger than liquidity, the firm looks for a bank loan $B_n = W_n - D_n$. The demand for credit therefore is simply given by:

$$B_n = \max(W_n - D_n, 0)$$  (6)

We suppose that credit demand could in principle be finalized without distinction both to finance current production plans and to expand the productive capacity, but we exclude the possibility for firms to borrow in order to cover previous debt commitments. Moreover, we assume absence of credit rationing such that the actual lending is always equal to current credit demand.

The bank offers to firm $i$ a long-term debt contract, which allows the firm to pay back debts at a constant rate $0 < \tau < 1$ and determines the future profile of financial outflows. Consequently, total debts at the end of each period amount to

$$L_n = L_{n-1} + B_n - \tau L_{n-1}$$  (7),

where $R_n = \tau L_n$ represents principal repayments.

The contractual interest rate offered by bank to firm $i$ is determined as a mark-up over a policy rate set by the central monetary authority ($r$):

$$r_n = r(1 + \phi_i \mu(\ell_n))$$  (8)

The mark-up in turn is a function

- of random variations in banks’ operating costs, captured by the random variable $\phi$, an idiosyncratic shock uniformly distributed on the interval $(0, h_\phi)$;
- of the financial fragility of the borrower, captured by the term $\mu(\ell_n), \mu' > 0$ where

$$\ell_n = \frac{L_{n-1} + B_n}{D_n}$$ is the borrower’s leverage.

The mark-up the bank charges over the policy rate reflects a risk premium that increases with the financial fragility of the borrower. Equation (8) can be interpreted in the light of the theory of the “external finance premium” pioneered by Bernanke and Gertler (1989, 1990). In the presence of ex post asymmetric information and costly state verification, the higher the borrower’s financial fragility, the more frequent should be (in the optimum) the auditing activity of the bank and the higher the interest rate charged to the borrower.

Interests paid at the end of each period are equal to $Int = r_n L_n$. As it will be explained below, the higher is the service of debt, the higher are average costs and prices. Hence, a link between financial activity and real activity exists through the cost channel.

3.3 The market for consumption goods

At the beginning of each period, the $i$-th firm adjusts the control variables, i.e. the price or the quantity supplied, to adapt to changing business conditions. In spite of the good being homogeneous, asymmetric information and search costs imply that consumers may end up buying from a firm even if its price is not the lowest. It follows that the conditions for perfect competition are not satisfied, and the law of one price does not apply (Stiglitz, 1989).
For simplicity, we assume that the firm can change either the price or the quantity but not both at the same time. In other words the strategies consisting in “changing the price” and in “changing the quantity” are mutually incompatible. This assumption is based on the evidence of survey data on price and quantity adjustment of firms over the business cycle (Kawasaki et al., 1982; Bhaskar et al., 1993).

For expositional simplicity we assume that each strategy is ex-ante equally likely. In principle, however, we could attach a probability to each strategy which could be calibrated on real data. For instance, the available evidence suggests that liquidity constrained firms – i.e. firms with a limited cash-flow – quantity adjustments are more likely during recessions than during booms, whereas the reverse is true for price adjustments; i.e. constrained firms are less likely to cut prices in recessions.

In our model the adaptation of each strategy depends on signals coming from the internal condition of the firm and/or from the market environment. Each firm has a certain degree of market power on its own market. The information set relevant for price or quantity adjustment of the \(i\)-th firm in \(t\) consists of

- the level of excess demand/supply in the previous period. Excess supply is signaled by the accumulation of an inventory of unsold goods \((S_{it-1}>0)\). Since the good is perishable, this inventory cannot be carried over to \(t\) and therefore it is temporary. Moreover, we assume that the firm can get rid of the inventory at no cost. If demand happens to be equal to supply or if there is excess demand, there will be no inventory \((S_{it-1}=0)\). In the former case, in principle, the firm has an incentive to reduce the price or reduce the quantity – we will be more precise momentarily – while in the latter case there is room for a price increase or an increase in quantity. There is a lower bound to a reduction of the price which is represented by the minimum price the firm has to charge to cover average costs.

- the deviation of the individual price from the average price \(P_{it-1} - P_{t-1}\) during the last transaction round. If this deviation is positive (negative), the firm recognizes that it is charging a price higher (lower) than its competitors and therefore may be induced to reduce (increase) the price or the quantity to avoid (facilitate) a massive migration of consumers in favor of (from) its rivals. Also in this case a reduction of the price is bounded from below: the price cannot be lower than the minimum price the firm has to charge to cover average costs.

Internal conditions (i.e. the level on the temporary inventory or the individual price) are private knowledge, while the aggregate price is common knowledge.

In principle we have four cases. As we said above, we assume that price changes and quantity changes cannot occur simultaneously. Therefore we associate either a price change or a quantity change to each cell.

- In case inventories are positive (excess supply) and the individual price is high with respect to the average, the firm will reduce the price (until the lower bound is reached) keeping the quantity unchanged;
- In case inventories are zero (excess demand) and the individual price is low with respect to the average, the firm will increase the price keeping the quantity unchanged;
- In case inventories are positive (excess supply) and the individual price is low with respect to the average, the firm form an expectation of lower demand today (in \(t\)) than yesterday (in \(t-1\)) and therefore will reduce the quantity supplied keeping the price unchanged;
- In case inventories are zero (excess demand) and the individual price is high with respect to the average, the firm forms an expectation of higher demand today than yesterday and will increase the quantity keeping the price unchanged.

In cases a) and b) the firm has an unambiguous incentive to change the price in the suggested direction. In case c) the firm could in principle cut the price to allure consumers instead of cutting production but this move would reduce profitability. In case d) the firm could in principle increase the price to reduce demand instead of increasing production but this move would induce a loss of.
customers. The strategy of changing prices in cases c) and d) moreover is based on the implicit assumption that the firm is able and willing to manipulate demand through price changes, a situation that we can rule out on the ground of bounded rationality. In fact, since the model is characterized by true uncertainty, firms are not able to discern the demand function for their product not even in probabilistic terms and, consequently, price adjustments are destined to bear unpredictable effects.

Cases a) and b) are incorporated in the following price rule:

\[
P^i_t = \begin{cases} 
\max[P^i_{t-1}, P_{t-1}(1 + \eta_t)] & \text{if } S_{t-1} = 0 \text{ and } P_{t-1} < P \\
\max[P^i_{t-1}, P_{t-1}(1 - \eta_t)] & \text{if } S_{t-1} > 0 \text{ and } P_{t-1} \geq P
\end{cases} \quad (9)
\]

where \( \eta_t \) is an idiosyncratic random variable uniformly distributed on the support \((0, h_\eta)\), and \( P^i_t \) is the lowest price at which firm is able to cover its average costs:

\[
P^i_t = \frac{W_t + r_a L_a}{Y_t}. \quad (10)
\]

Cases c) and d) trigger quantity adjustments. In this case, the level of production planned or “desired” at the beginning of period \( t \) (\( Y^d_{t-1} \)) is equal to expected demand, \( Y^d_{t-1} = De^e_{t-1} \). Expectations on future total orders – and therefore the scale of production – are revised adaptively according to the following rule:

\[
De^e_t = \begin{cases} 
Y^d_{t-1}(1 + \rho_t) & \text{if } S_{t-1} = 0 \text{ and } P^i_{t-1} \geq P_{t-1} \\
Y^d_{t-1}(1 - \rho_t) & \text{if } S_{t-1} > 0 \text{ and } P^i_{t-1} < P_{t-1}
\end{cases} \quad (11)
\]

where \( \rho_t \) is an idiosyncratic shock uniformly distributed on the support \((0, h_\rho)\). Thus, expectations are revised upward if a manager observes excess demand for its output and its price is already above the average price on the market, and downward when the opposite holds true.

Total consumers’ income is the sum of the wage bill paid to workers employed in \( t \) and of dividends distributed to shareholders. Since profits are realized at the end of period \( t-1 \), also dividends are distributed in the same period.

The marginal propensity to consume out of wealth (accumulated savings plus current income) \( c < 1 \) is assumed to be constant and equal across consumers. These savings, in turn, are due to a typical precautionary motive in the face of income uncertainty: households hold assets to smooth their consumption in case of unpredictable declines in income associated with spells of unemployment. Hence, before the market opens households allocate a consumption budget proportional to their wealth.

Given the absence of a market-clearing mechanism, consumers have to search for satisfying deals on a fully decentralized goods market. The information acquisition technology affects the number \( Z \) of firms a consumer can visit without incurring transaction costs. In other words, transaction costs are equal to zero if the consumer does not cross the border of her local market of size \( Z \), but they become prohibitively high as soon as a consumer tries to search outside it. The identity of the \( Z \) firms associated to a generic consumer \( j \) at any time period \( t \) is determined by chance. The search mechanism in fact works as follows.

- Consumers enter the market sequentially, the picking order being determined randomly at any time period \( t \).
- Each consumer \( j \) is allowed to visit \( Z \) firms to assess the price posted by each one of them.
• Posted prices (and the corresponding firms) are then sorted in ascending order, from the lowest to the highest. Consumer \( j \) tries to spend her entire budget in goods of the firm charging the lowest price in his local market.
• If the cheapest firm has not enough output to satisfy \( j \)'s needs, the latter tries to spend her remaining income buying from the firm with the second lowest price, and so on.
• If \( j \) does not succeed in spending her whole income after she visited \( Z \) firms, she saves (involuntarily) what remains for the following periods. For the sake of simplicity, the interest rate on savings is assumed to be equal to 0.

The search and matching process described above is based upon an evolving network structure; the links connecting firms and consumers are in fact continuously changing over time. The firm posting the lowest price in fact attracts a large fraction of consumers and crowds out competitors, gaining the ability to stay on the market in a predominant position also in the future. Profitable and more liquid firms experience in general a lower need of external funds and, thus, incur in lesser financial costs. Other things being equal, therefore, profitable firms charge lower average costs and prices that generate higher profits. As showed below, this typical rich-getting-richer mechanism helps in generating fat-tailed distributions and endogenous business cycles.

After the market for consumption goods has closed, the \( i \)th firm has sold \( Y_{it} \), at the price \( P_{it} \). Accordingly, \( i \)'s revenues are \( R_{it} = P_{it}Y_{it} \). Due to the decentralized buying-selling process among firms and consumers, it is possible that a firm remains with unsold quantities (\( S_{it} > 0 \)). In the following period, the variable \( S \) will be used as a signal in adjusting firms’ prices or quantities, as explained above.

3.4 Bankruptcy, exit and entry

At the end of period \( t \), each firm computes profits \( \pi_{it-1} \): should they be positive, firm’s shareholders receive dividends \( Div_{it-1} \), which are computed as a fixed fraction \( \delta \) of profits. The residual, i.e. retained profits, are added to equity \( A_{it} \). The law of motion of equity of a profitable firm, therefore, is:

\[
A_{it} = A_{it-1} + \pi_{it-1} - Div_{it-1} = A_{it-1} + (1 - \delta) \pi_{it-1} \quad (12)
\]

At the end of each period bankruptcy happens whenever insufficient cash flows do not allow the firm to honor her debt commitments with the bank – that is to pay principal and interests. As showed by a large literature on capital market imperfections, net worth is the key variable to assess the firm’s viability. Hence, if the stock of debt is high in comparison to net worth – i.e. leverage is high – bankruptcy becomes a likely event because of elevated financial costs, ceteris paribus. When a firm is not viable any more, i.e. when it goes bankrupt, it exits the market. Bankruptcy, therefore, is the most straightforward mechanism to model exit. Consequently, the interaction between the stock of outstanding debt and the dynamics of operating cash flows drives the selection mechanism inside the firm population.

Of course, new firms are also entering the market. We assume that a new entrant, whose initial conditions relative to production scale and price are set below the average size of incumbent firms, replaces each bankrupt firm\(^2\). Moreover, debts are set back to zero and new liquid assets are provided by firm’s owner financial resources.

This one-to-one replacement of bankrupt firms with entrant firms is essentially a working hypothesis, which allows to keep total firms’ population constant. We can offer a rationale for the assumption, however, based on two, widely accepted stylized facts (Sutton, 1997). First, in each established (mature) industry, there is a tendency for the number of firms to settle down around a roughly constant level, below the maximum recorded in that sector’s history. Second, the inflow

\(^2\) To be precise, to compute the average size of the incumbent firms we use the truncated mean at 10%. This means the lower and upper 5% of the firms’ population are ruled out.
and outflow of firms are highly correlated: Geroski (1991), for example, reports a correlation coefficient of 0.796 for a sample of 95 industries in United Kingdom in 1987. Implicitly we are assuming a correlation equal to 1.

Due to firms’ bankruptcies, the bank will record non-performing loans (bad debt). Bad debt $BD$ on bank’s book is equal to exiting firm’s outstanding debt minus liquid cash the bank is able to reclaim from her. Consequently, a law of motion for banks’ equity can be defined as well:

$$E_t = E_{t-1} + \sum_{i \in \Theta} r_{it-1} L_{it-1} - BD_{t-1},$$

where $\Theta$ is bank’s performing loans portfolio, $r_{it-1}$ is the interest rate charged to firm $i$ at time $t-1$ and $BD_{t-1} \leq \sum_{i \in \Theta} L_{it-1}$ represents bank’s bad debt. As for firms, it may happen that bank’s equity becomes negative; in this case the Government bails the bank out.

3.5 Simulations

In all the simulations we start with the following setup for parameters and initial conditions:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$I$ Number of workers</td>
<td>650</td>
</tr>
<tr>
<td>$J$ Number of firms</td>
<td>100</td>
</tr>
<tr>
<td>$B$ Number of banks</td>
<td>1</td>
</tr>
<tr>
<td>$T$ Number of time periods</td>
<td>1000</td>
</tr>
<tr>
<td>$c$ Propensity to consume</td>
<td>0.8</td>
</tr>
<tr>
<td>$\rho$ Minimum interest rate</td>
<td>0.02</td>
</tr>
<tr>
<td>$\alpha$ Productivity</td>
<td>0.1</td>
</tr>
<tr>
<td>$\tau$ Rate of debt repayment</td>
<td>0.05</td>
</tr>
<tr>
<td>$w$ Wage</td>
<td>1</td>
</tr>
<tr>
<td>$H_\eta$ Maximum growth rate of prices</td>
<td>0.1</td>
</tr>
<tr>
<td>$H_\rho$ Maximum growth rate of quantities</td>
<td>0.1</td>
</tr>
<tr>
<td>$H_d$ Maximum amount of banks’ costs</td>
<td>0.1</td>
</tr>
<tr>
<td>$Z$ Number of trials in the goods market</td>
<td>2</td>
</tr>
<tr>
<td>$H$ Initial monetary base</td>
<td>1500</td>
</tr>
<tr>
<td>$A$ Initial firm’s equity</td>
<td>10</td>
</tr>
<tr>
<td>$E$ Initial bank’s equity</td>
<td>500</td>
</tr>
</tbody>
</table>

Table 3. Parameters.

In figure (1) time series relative to aggregate production and consumption price index are reported. The model clearly settles down around a full-employment steady state where rather small fluctuations are the fruit of the combination of idiosyncratic shocks and heterogeneity. This quite
dumb and little-interesting aggregate dynamics along the upper bound is ascribable to an inherent lack of frictions, which are merely confined in the consumption good market where a modest degree of imperfect competition is at work.

Though, self-reinforcing mechanisms driven by the interplay between balance sheets and individual decisions are sufficient conditions to make emerge realistic firms’ size distributions. In fact, in spite of an initial homogeneity among firms, quickly each agent experiences an individual story differentiating from each other. In figure (1) we also report two rank-size diagrams (in logarithmic scale) relative to different measures of size: equity and liquid assets (cash). Both distributions display high positive skewness with the bulk of the firms roughly matching a lognormal distribution, and with a long tail tending to a power-law density function. As it is notorious at least from Gibrat (1931), lognormal distributions can emerge from additive processes with proportional increments, while power-laws generally need some non-linear mechanism in order to appear, as it happens with multiplicative processes. Our model is able to assume both of these kinds of dynamics without recurring to ad-hoc mechanisms by simply relying on the self-reinforcing relationship between balance sheet conditions, financial costs and average prices. As above explained, low levels of leverage allow to keep prices low and, therefore, to sustain profit margins and positive cash flows, which on their turn can limit in future periods the resort to external financing sources. Conversely, high degrees of leverage will tend to further impair balance sheet soundness because of high costs. This mechanism is strictly interrelated with the productive activity of the firm and affects its overall financial conditions. As a result, in regions where equity and cash are low, roughly erratic variations of these stock variables will confer a lognormal-like shape to their size distribution. On the contrary, in regions where equity and cash are high an approximate power-law emerges thanks to the working of self-reinforcing dynamics.

In spite of heterogeneous financial conditions, the absence of true financial constraints and risk aversion allow firms to always carry on their production plans, hence business fluctuations become an unimportant phenomenon. Therefore, in order to generate interesting endogenous business cycles we need to introduce some sort of friction in the credit market, and this is precisely what we are doing in the next paragraph.
Figure 1. Emergent properties of Model 1 after 4000 iterations. (a) Real GDP; (b) price level; (c) firms’ equity; (d) firms’ liquid assets.
Figure 2. Emergent properties of baseline model after 4000 iterations. (a) Total savings, including bank’s; (b) total firms’ debts; (c) firms’ leverage (debt to net worth ratio); (d) number of bankrupted firms.

4 Model 2

The aim of this section is to introduce a simple microeconomic non-linearity in the baseline model by bringing to it a change that concerns firms’ credit demand. As it will be clear later, this unique credit market friction is sufficient to generate endogenous business cycles through a financial accelerator mechanism.

4.1 Elastic credit demand

In Model 1 firms requesting new loans to the bank do not respond to the interest rate – the elasticity of credit demand is zero. We remove this hypothesis by supposing firms to have a step-wise decreasing credit demand. In practice, firms are supposed to share a common “reservation” interest rate $i_i$ that works as a threshold driving demand contractions: whenever actual interest rates are higher than $i_i$, a reduction in loan request is triggered. Effective credit demand ($EB_i$) of firm $i$, therefore, becomes as follows:

$$EB_i = \begin{cases} B_i & \text{if } r_i \leq i_i \\ \phi \delta B_i & \text{if } r_i > i_i \end{cases}$$

(13)

where $B_i$ is the original loan demand given by equation (6), $r_i$ is the rate proposed by the bank and $\phi$ is a positive parameter less than one that captures the degree of demand contraction.

The reservation interest rate is treated as the sum of an exogenous parameter plus past inflation rate. As a consequence, in periods of high inflation the threshold is relaxed and demand reductions become less probable. The logic underlying such a mechanism is that firms perceive borrowing to be more convenient in case of high inflation, and this because they can expect to return in future periods devaluated money.

We now illustrate the possible effects generated by the interaction between the baseline model and the just proposed step-wise decreasing demand function. The basic insight is that we are establishing two different linkages: a self-reinforcing connection between individual balance sheets and individual micro-behaviors, and a downward causation from the macro level to the micro level. As far as the former is concerned, the mechanism is straightforward: balance sheet conditions, namely leverage, affect the interest rates proposed by the bank according to equation (8). If the firm is characterized by elevated financial fragility, it is therefore likely that the proposed interest rate is higher than the threshold, and that a demand reduction may trigger.

The second kind of link represents a mean-field type interaction between an environmental variable as the inflation rate and individual decisions. According to the macroeconomic conditions,
the mechanism can work both as a stabilizing and a reinforcing device. In general, four macroeconomic configurations are imaginable according to the dynamics of prices \( P \) and production \( Y \):

(i) both are growing: the mechanism is reinforcing because inflation stimulates borrowing, thus pushing \( Y \) further up;

(ii) both are decreasing: the mechanism is reinforcing because deflation discourages borrowing, thus pushing \( Y \) further down;

(iii) production is growing and prices decreasing: the mechanism is stabilizing because deflation discourages borrowing, thus inhibiting the growth of \( Y \);

(iv) production is decreasing and prices growing: the mechanism is stabilizing because inflation stimulates borrowing, thus favoring the growth of \( Y \).

As one can argue, in a hypothetical phase diagram where the time derivatives of \( Y \) and \( P \) are set on the axes, the model would admit the existence of a saddle path describing the joint dynamics of the couple \( (Y, P) \). But the analogy with canonical dynamical systems stops here. In fact, our model is driven by the complex dynamics of a multitude of dispersed and non-linear interactions among heterogeneous agents buffeted by idiosyncratic shocks, whose behaviors generate aggregate dynamics that can be barely summarized in a canonical phase diagram. At most we could state that the micro-behaviors of the agents continuously change position and slope of the hypothetical saddle path producing, therefore, a multiplicity of ever-changing equilibria. Hence, in our model dynamics is associated not only to single variables, but also to the equilibrium set itself, and the joint presence of these two kinds of variability is a sufficient condition in order to generate endogenous cycles.

4.2 Simulations

As above explained, Model 2 introduces two additional parameters, whose values have been set as follows: \( \phi = 0.8, i_t = 0.05 + \pi_{t-1} \). Other parameters and initial conditions are still set according to table (3).

Business cycles in mainstream interpretation, as in popular DSGE models, are nothing else that the optimal response of a Representative Firm to exogenous aggregate shocks, arguing that individual shocks average out with the characteristic \( \sqrt{N} \)-speed. Consequently, large fluctuations can be only caused by large shocks and small shocks can trigger small fluctuations only. Such a strict proportionality between causes and effects, typical of scientific reductionism, has been extensively criticized from several corners. In particular, from a complex systems perspective (Delli Gatti et al., 2008; Delli Gatti et al., 2010) aggregate fluctuations must be conceived as the result of composition effects of idiosyncratic shocks hitting the whole agents’ population and not as the effect of an aggregate shock upon an average macro-agent. An appealing theory based on this view is that of the “granular” origin of aggregate fluctuations (Gabaix, 2009), which can find a rationale in the concept of auto-catalyticity\(^3\). Its basic intuition is that the \( \sqrt{N} \)-averaging argument breaks down if the distribution of firm sizes is fat-tailed – namely a power-law distribution – and that aggregate dynamics is dominated by what happens to the largest firms and not to the representative element.

Even though the granular theory constitutes an attractive critic and alternative to neoclassical interpretation, both share an unpleasant feature: their implied business cycles are still essentially determined by exogenous shocks and, thus, are unexplained. On the contrary, besides endorsing the complex system paradigm, our model provides an endogenous explanation for aggregate fluctuations.

In panel (a) of picture (3) aggregate real production is reported. The introduction of mechanism (13) reveals to be a sufficient condition in order to get large fluctuations; in fact we can observe a quite stable behaviour for long periods, which a prolonged phase of declining economic

\(^3\) A variable is said to display auto-catalytic behavior whenever its variations are proportional to its current value through stochastic factors.
activity follows to. Eventually, the system is able to recover to full employment, until a new crisis breaks out.

Of course, our results must not be taken as the attempt to quantitatively reproduce real business cycles. Richer and more realistic versions of the present model have already been proved to be able to challenge – and even to outperform – DSGE methodology (Gaffeo et al., 2008; Delli Gatti et al., 2010). What here matters is simply to understand the importance of heterogeneity and non-linearity in order to generate endogenous aggregate fluctuations.

In the present stylised setting, cycles are determined by the interaction among different levels of economic activity. As in the financial instability hypothesis put forth by Minsky, during prosperous times our artificial economy is only apparently stable; under the quiet surface of the full employment, in fact, microscopic dynamics and varying distributional configurations put the basis for the endogenous formation of a break point. When eventually the system reaches the critical state, macroeconomic dynamics changes its direction and a crisis sets in. The key variable driving the whole dynamics is individual leverage that interacts with mechanism (13) and with the prices, as below we can see in more details.

Aggregate production is given by \( Y = \sum \nabla_i Y_i \) and, therefore, its time variation is

\[
\Delta Y = \sum \Delta Y_i = \sum \nabla_i Y_i, \tag{14}
\]

where the \( \nabla_i \) are individual, partly random, shocks. As in “granular” theory, the aggregate variation depends on the size distribution of individual productions \( Y_i \), but here a peculiar role is also played by the factors \( \nabla_i \). Positive and negative variations are \textit{ex ante} equally likely; but it is here that financial fragility enters into play. We first look at how aggregate and individual financial fragility take place in the economy, and then we examine how they affect output dynamics.

From the aggregate viewpoint, in prosperous periods households accumulate savings and the bank increases its equity as long as firms are able to pay wages and interests and do not go bankruptcy. Since by identity (2) the total savings must sum to zero, firms’ liquidity decreases and production must be more and more financed through credit, as picture (4) shows. Thus, total leverage increases because firms’ liquidity goes down and debt stock boosts. From the microeconomic perspective, leverage size does not distribute equally across firms but, as explained in paragraph (3.5), it self-reinforces into highly right-skewed distributions with power-law tail (picture 5). Consequently, a group of firms will start to experience increasing financial costs both because of an enlarging financing gap and because of an increasing external finance premium that pushes interest rates up. So, according to equation (13), a reduction in credit demand becomes a likely event. If this is the case, then, firms will tend to revise downward their production plans and negative variations of individual output will prevail on the positive ones both in magnitude and in frequency.

If composition effects are strong enough, the economy enters in recession. Moreover, our endogenous fluctuations show positive autocorrelation as in real data: this is because the percentages \( \nabla_i \) depend not only upon random and stationary factors, but on path-dependent individual balance sheets and on distributional characteristics too. It is therefore probable that, in contiguous time periods, variations \( \Delta Y \) of the same sign could occur and that, in case of a recession, to a negative variation of total production follows another negative variation. A crisis is then characterized to be a self-organizing criticality (Bak, 1997).

In picture (3) we can also observe how aggregate financial fragility and firms’ population composition change along the business cycle\(^4\). While the recession unfolds, bad debt increases (as

\(^4\) The taxonomy of firms has been defined as follows: hedge firms are those with a leverage below 50%; speculative firms are those with a leverage between 50% and 150%; ponzi firms are those with a leverage above 150%.
also witnessed by the decreasing bank’s equity in picture 4) and fragile firms are wiped out of the system. This sort of natural selection among firms eventually allows the economy to start a new expanding phase from financially more sound bases, because lower debts and interest rates widen firms’ profit margins and rarefy the reductions in credit demand.

![Emergent properties of Model 2 after 4000 iterations.](image)

Figure 3. Emergent properties of Model 2 after 4000 iterations. (a) Real GDP; (b) price level; (c) firms’ leverage (debt to net worth ratio; recessions in grey bands); (d) number of hedge, speculative and ponzi firms; (e) bad debt.
Figure 4. Emergent properties of Model 2 after 4000 iterations. (a) Firms’ liquidity; (b) total firms’ debts; (c) bank’s equity (bank’s savings); (d) households’ total savings.
5 Monetary policy experiments

The last section is devoted to the exercise of monetary policy experiments, which basically translate into a sensitivity analysis over interest rate values. Using Model 2 as a computational laboratory, we are going to simulate two different scenarios of policy intervention: in the first one (par. 5.1) the Central Bank is called to induce exogenous changes on the minimum interest rate charged to the commercial bank; in the second one (par. 5.2), the monetary policy by the Central Bank becomes endogenous since it is conducted by means of a Taylor Rule. In both cases balance sheets, coupled with individual decreasing demand functions, play a crucial role in determining the external finance premium and in giving an explanation for the “black box” of the transmission mechanism of the monetary policy (Bernanke and Gertler, 1995).

5.1 Exogenous interest rates

We start by imposing an exogenous increase of the minimum interest rate $\bar{r}$ from 0.02 to 0.05 at time 300 after a transient phase. Then, we consider two scenarios: in experiment A the value of $\bar{r}$ is decreased back to 0.02 at time 600, while in experiment B its decrement is anticipated at time 500.

A. Results are shown in figure (6) and (7). As expected, the negative impact of a restrictive monetary policy on total production is evident, while its apparently counter-intuitive effects on prices can be explained considering that the restriction goes to directly and primarily weaken the supply side of the economy through the cost channel and the credit demand channel. In fact, a rise
in interest rates has, as a first effect, that of producing a transfer of wealth from firms to bank. Rising costs shrink firms’ profits and reduce their cash; as a consequence larger financial gaps have to be compensated by additional borrowing. In figure (7) we can see increasing corporate debts and falling levels of liquidity: their combined action produces a level of leverage that, after period 300, rises faster than in the baseline simulation. Increasing leverage on its turn pushes interest rates further up, starting a financial acceleration through the balance sheets, which operate as propagation mechanism of the initial monetary policy impulse. At this point more and more firms will tend to reduce their credit demand and production; eventually, debt stock also shrinks as the recession pushes fragile and indebted firms outside of the economy and the surviving ones are able to heal their balance sheets.

In the present experiment the economy does not totally collapse but it is not able to recover to full employment after the shock on the interest rate has been removed at time 600, even though overall financial conditions have improved. This is simply due to excessive granularity and indivisibility that characterize our model, as one may figure out by looking at equation (14): when the levels $Y_i$ become too small, positive variations in productions are not able to trigger a raise of the employment since the coefficients $v_i$ are limited by an upper bound. Compositions effects are then always too small. Confirmations come from experiment B, where nothing such this happens.

![Graphs](image.png)

**Figure 6.** Experiment A after 1000 iterations. (a) Real GDP; (b) real GDP in baseline Model 2; (c) price level; (d) price level in baseline Model 2.
Figure 7. Experiment A after 1000 iterations. (a) Firms’ leverage; (b) firms’ leverage in baseline Model 2; (c) total savings; (d) total savings in baseline Model 2; (e) total debts; (f) total debts in baseline Model 2.

B. Results are shown in figure (8). As anticipated, if the monetary shock is removed not “too” late, the economy is able to recover to full employment since indivisibility is still a minor problem.
5.2 Endogenous interest rates by Taylor Rule

Now we turn to a different kind of exercise: in both experiments C and D we simulate a shock on the demand side by lowering at time 300 the marginal propensity to consume to 0.3. Then, at time 600, we raise it back to 0.8. The difference is that in experiment D, during the period of low demand, the Central Bank is allowed to manipulate the minimum interest rate following a standard Taylor Rule, which is aimed at pursuing the targets of zero inflation and of an unemployment rate of about 7.5%. In practice, in experiment C the minimum interest rate remains fixed to a value of 0.02 for the whole simulation, while in D it is determined according to the following rule:

\[
\bar{r}_t = r + \pi_{t-1} + 0.5(y_{t-1} - y_n) + 0.5(\pi_{t-1} - \pi_n) = 0.02 + 1.5\pi_{t-1} + 0.5(y_{t-1} - y_n),
\]

(14)

where the real interest rate \(r\) is equal to 0.02 and the “natural” log-output \(y_n\) has been set to that production level attainable with an unemployment rate of 7.5%. The comparison between the two is shown in figures (9, 10, 11, 12).

In experiment E we perform another exercise involving the same kind of Taylor Rule applied, from the beginning of the simulations, to the basic Model 2 from paragraph (4). Finally, we conclude our assessment of TR by conducting experiments F and G: in the former the same kind of shock is fronted by a reduction of the minimum interest rate from 2% to 1%, while in the latter the minimum interest rate is lowered to the average value produced by the TR in experiment D.
C-D. The influence of the Taylor rule is evident: output falls dramatically without intervention by the CB (panel a of figure 9), while with the help of an active monetary policy it remains around a sufficiently high level (panel b). The Taylor rule is also able to stabilize inflation: in panel (c) the price level is always higher than in panel (d).

A quick deleveraging is at the root of the poor economic performance in the experiment where the Taylor rule is absent (fig. 10 and 11). Without Taylor rule firms’ liquidity is lower at any point in time. On the contrary, the presence of an adjusting interest rate induces firms not to reduce their credit demand. We have two consequences: first, as long as firms do not reduce their credit demand they are able to sustain production and employment; second, as made clear by identity (3), since debt levels do not drop the ‘revolving fund’ (Keynes, 1937) of aggregate money stock does not shrink, and households’ purchasing power and firms’ cash flows are preserved⁵.

Although TR is able to sustain the economy, we have also to point out that of the two pursued targets of 7.5% of unemployment and 0% of inflation only the latter has been reached.

![Figure 9](image)

**Figure 9.** Experiments C and D after 1000 iterations. (a) Real GDP (C); (b) real GDP (D); (c) price level (C); (d) price level (D).

⁵ Admittedly, this is also a consequence of a constant marginal propensity to consume, which implies linearity between nominal wealth and nominal spending.
Figure 10. Experiments C and D after 1000 iterations. (a) Aggregate financial fragility (C); (b) aggregate financial fragility (D); (c) number of hedge, speculative and ponzi firms (C); (d) number of hedge, speculative and ponzi firms (D).
Figure 11. Experiments C and D after 1000 iterations. (a) Firms’ total debts (C); (b) firms’ total debts (D); (c) firms’ liquid assets (C); (d) firms’ liquid assets (D).
E. An active monetary policy conducted by means of a Taylor rule can also calm down endogenous fluctuations: figure (13) shows results from experiment E, where the same Taylor rule is employed for 4000 time steps. If we compare the outcome of experiment E with the basic simulation of Model 2 in paragraph (4.2), we can observe the disappearing of the large fluctuations characterizing the production, and also a more stable price level.

F-G. With the same kind of shock in F we lower the minimum rate to 1%, getting a better performance than that obtained by the TR in experiment D. But the Taylor Rule determined during the period of the shock an average value for the minimum rate of about 1.76%. Consequently, in G we set the minimum rate at the constant value of 1.76%, getting a poorer economic performance than that we got with the TR. From the comparison of the experiment outcomes we draw the following conclusion about the effectiveness of the Taylor principle as a policy instrument. First, it clearly displays the capacity to positively affect the economy and to outperform a simple rule fixing the minimum policy rate at the average value generated by the Taylor rule. This means that its adaptive behavior is ‘smarter’ than a constant rate policy. But at the same time it implies that the TR is not smart enough to achieve a lower interest rate that would have got a better economic performance, as experiment F illustrates. Our explanation is the following. At the beginning, being both inflation and output gap components negative, the rule ‘understands’ to rapidly lower the policy rate below the long run average value, immediately boosting the economy. But then the rule raises the rate too quickly (above the long run average value) because of the inflation element,
which forces it to a more than proportional rise. That is, the negative output gap and the positive inflation rate constitute two disaccording signals preventing the policy rule to keep on doing the right thing, that is maintaining the policy rate low. In other words, a single policy instrument cannot achieve two targets unless they are positively correlated.

![Graphs](a) (b) (c)

**Figure 13.** Experiment E after 4000 iterations. (a) Real GDP; (b) price level; (c) minimum interest rate.

### 6 Fiscal policy experiments

In this section we are going to simulate two typologies of shocks, one on the side of demand and one on the supply side. Besides, we also imagine a Government striving to contrast the effect of the shocks by resorting to two different instruments of fiscal policy: public purchases and transfers. The consequences of employing different forms of financing sources are also explored. The major finding is the non-irrelevance of Policy because of the presence of a multiplier mechanism. We also argue that the presence of a multiplier implicitly casts doubts on the scientific status of rational expectations hypothesis. Finally, we get the intuition that Government should help the sector or class not affected by the shock; for example, if it is households to decrease their propensity to consume, then it is firms to have to receive subsidies.

Before entering in deeper details, a cautionary note upon our methodology is needed. The outcome of simulations depends upon the particular values assumed by the parameters and by the seed of the random-number generator. In order to have clear and monotonic patterns in the relationship between parameters and simulated economic data, extensive Montecarlo experiments should be performed according to the lines presented, for example, in Fagiolo et al. (2008). We leave such a task for future works. Nonetheless, below we will show results for selected
simulations. With that we do not mean we are going to choose *ad hoc* simulations, but that we show simulated data whenever we believe, through a qualitative inspection of a small Monte Carlo experiment, they are sufficiently representative of the model data-generating process.

### 6.1 Demand-side shock

As in section 5, we simulate the occurrence of a transitory market saturation by reducing households’ spending attitude: at time 300 marginal propensity to consume $c$ is lowered to 0.3 and at time 600 it is set back to 0.8. The behaviors of public purchases and inter-class transfers are separately examined. The economic variable used to compare simulations will be the average along 1000 periods of aggregate production.

During the period of crisis, before the opening of the consumption good market the Government intervenes by spending at each time period a fixed amount $G$ in buying goods. $G$ is allotted to firms proportionally to their relative production: for example, if firm $i$ is producing the 10% of total output, then it receives the 10% of $G$ under the shape of public purchases. Therefore, the quantity Government actually purchases from firm $i$ is $q(i) = 0.1G/P(i)$.

We first show results relative to balanced-budget purchases, then we conclude with a scenario of monetization of public expenditures, which can be interpreted as a case of coordination between fiscal and monetary policies.

#### 6.1.1 Balanced budget

We start with a setting where $G$ is endogenous and fully financed by means of taxes applied to labour income before the opening of the good market. Government then immediately uses collected tax revenues at time $t$ as public purchases.

Picture 14 displays aggregate production relative to a tax rate of 1%. Performance is worse than that without any public intervention (same price levels but lower average production). The explanation is that, on one side, public purchases simply substitute themselves to the private ones without increasing aggregate demand, and that on the other side we lose some of the efficiency usually provided by market selection. In fact, while households use to spend in the attempt of following the information conveyed by prices, Government purchases are carried out without any economic efficiency consideration. As a result, largely indebted firms may end up to be financed even though they are charging high prices. Thus, this kind of balanced-budget Government intervention does not sustain aggregate demand but only microeconomic inefficiency. Simulations with higher tax rates reinforce our argument: in fact, when taxes increase, economic performance gets worse and worse because the public sector acquires greater importance relative to the private one, and consequently more and more purchases are carried out in an economically inefficient way.

![Figure 14. Aggregate production.](image)

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6 Actually, this seems to be true only in a first phase, when leverage is higher than in the normal case; then it settles around a level very similar to that of the normal case. Though, it is sufficient to determine a poorer economic performance.
Above experiments do not imply the possibility for a multiplying mechanism to trigger since what Government adds to aggregate demand is simultaneously subtracted from households’ purchases. Therefore, in the next policy exercises we keep on retaining the hypothesis of a balanced Government budget, but we investigate the consequences of different financing schemes.

The new experiment unfolds like the previous one, with the difference that, in each period of crisis, public spending $G$ is always equal to 10, while the tax rate on labour income is endogenously chosen in each $t$ such that tax revenues are always equal to $G=10$. As a consequence, Government budget is in equilibrium in each period.

As expected, and in analogy with the first experiment, the result is poor. However, if we postpone taxing of 24 periods\(^7\), during which Government is supposed to monetize its spending, economic performance neatly improves, even though in the end public expenditures are the same and the budget is balanced. This result reveals the presence of an income multiplier activated by public expenditures between $t=300$ and $t=324$: during this stage, fiscal policy increases aggregate demand well beyond public expenditures $G$ because it starts a virtuous cycle that induces a reprise in private expenditures also. Therefore, the total effect of $G$ on total output is greater than the depressing effect exerted by taxes.

The actual existence of an income multiplier is confirmed by the next set of experiments. As before, in each period $t$ between 300 and 600 Government spends a fixed amount $G=10$. At the same time labour income is taxed at a fixed rate $Tx$. The difference between $G$ and current tax revenues, if any, is supposed to be covered by emission of monetary base. While public purchases are carried out only during the periods of crisis, taxation continues until Government has totally withdrawn the money emitted during the crisis. We run simulations with different values for the tax rate and with different timing of taxation: one starting at $t=300$, and one at $t=324$. The result, as summarized by table 4, favours simulations with taxation starting later, thus confirming the presence of a multiplier.

\begin{center}
\begin{tabular}{cccc}
$Tx=1\%$ & 55.15 & 48.77 & 62.44 \\
$Tx=2\%$ & 51.56 & 40.49 & 59.70 \\
$Tx=5\%$ & 50.05 & 36.88 & 56.74 \\
$Tx=10\%$ & 29.64 & 29.22 & 13.38 \\
\end{tabular}
\end{center}

Table 4: timing at $t=300$. Col. 1: tax rates; col. 2: average production; col. 3: average production during crisis; col. 4: average production after crisis.

\begin{center}
\begin{tabular}{cccc}
$Tx=1\%$ & 57.00 & 54.52 & 62.73 \\
$Tx=2\%$ & 54.87 & 47.37 & 62.78 \\
$Tx=5\%$ & 53.83 & 42.27 & 62.14 \\
$Tx=10\%$ & 52.92 & 41.94 & 61.99 \\
\end{tabular}
\end{center}

Table 4: timing at $t=324$. Col. 1: tax rates; col. 2: average production; col. 3: average production during crisis; col. 4: average production after crisis.

We can immediately see that economic performance is better both when taxation starts later (at $t=324$) and when the ‘velocity’ of taxation is slower (lower tax rates). This is especially evident during the period of crisis, as the large gap between the two columns ‘3’ can witness. Thus, also these experiments show the importance of multiplicative effects.

As a corollary to our results, we conclude with a comment on rational expectations hypothesis. Modern macroeconomics states fiscal policy ineffectiveness on the presumption of the

\(^7\) Of course the choice of 24 periods is not strictly necessary for the outcome of the experiment and is based on considerations of realism only. In fact, in our fictitious world we interpret a single period as one month, thus 24 periods correspond to two years, a reasonable length for a phase of deficit spending.
validity of the Ricardian equivalence theorem. Consequently, if agents are supposed to have rational expectations, they reduce their consumption today in order to pay higher taxes tomorrow, offsetting the positive effects of public purchases. On the contrary, if an income multiplier exists – as in our model – it would be more convenient not to reduce consumption today, and rational agents should not anticipate future taxes. Thus, policy would be effective also in the case of rational expectations. But this result is also a confirmation that rational expectations are basically self-fulfilling prophecies. In fact, if agents believe in the Ricardian equivalence, they anticipate future taxes and reduce present consumption, preventing the multiplier to work. Therefore, the total effect of fiscal policy would be null, confirming the validity of the initial hypothesis of Ricardian equivalence. On the contrary, if they believe in a multiplying mechanism activated by fiscal policy, then they do not reduce present consumption and allow the multiplier to trigger.

6.1.2 Monetization

We conclude with a last experiment of perfectly coordinated macro policies, where public purchases are totally financed by emission of monetary base. The public intervention actually enhances economic performance: monetized public expenditure is additional to private purchases by households and is able to sustain aggregate demand and firms’ profits. Interestingly enough, prices are practically not affected by Government intervention. This result contrasts with the monetarist belief of a direct and mechanical relationship between commodity prices and money.

![Figure 15. Effects of monetization. On the left, total output; on the right, price level.](image)

6.2 Supply-side shock

In this paragraph we simulate the occurrence of a shock on the supply side of the economy from time $t=300$ to time $t=600$. It is supposed that all the firms are hit by the same shock on their willingness to invest caused by increased risk aversion. In practice, the upper bound of the stochastic increment of individual production is reduced from 10% to 5%. Figure 16 shows simulation results.
Consistently with a canonical supply-demand scheme, the supply-side shock causes output to go down and prices to rise. Besides, in accordance with empirical evidence, aggregate leverage is procyclical, with the exception of the initial phase of the crisis, where the presence of a certain degree of inertia makes leverage to keep on going up when production starts shrinking. This is to be ascribed to firms’ heterogeneity: in fact, in the short run the shock hits only firms that, in absence of it, would have increased their production. As a consequence, these firms can reduce their debt stock and, in addition, their behavior causes a negative externality on the other firms through a reduced aggregate demand. Thus, the first group of firms reduces both production and debt, while the second group of firms does not modify their production plans and has to increase its debt because of reduced sales. But in the long run all firms revise downward their production plans according to the decline of aggregate demand and aggregate leverage eventually shrinks.

In order to contrast the effects of the supply-side shock we have implemented the same battery of policy experiments already used above: public purchases financed through different types of taxation.

Results are qualitatively very similar to those of paragraph 6.1 and confirm the relevance of multiplicative effects activated by public expenditures when they are not financed at the same time by taxes of the same amount. But simulations also reveal that this kind of public intervention has stronger effects in the case of the shock on the side of demand, and this seems to be due to the negative effect of taxes on consumption. In fact, in the case of demand-shock households increase savings, thus taxation on labour income partly offsets the effects of the shock by drawing accumulated wealth back into the economy. On the contrary, when it is firms to reduce their propensity to spend, taxes on labour income have perverse effects because they insist on private wealth already made poor by the crisis. The negative effect of taxation is made even clearer by the case of monetization: when the tax rate is null and public purchases are totally financed by emission of money, Government intervention is more effective in the case of the supply-side shock, as figure 17 can show if compared to figure 15.
By the comparison of the effects of the same policies on different kinds of shocks we can therefore draw the following simple conclusion: income taxation is more efficient when the shock comes from households’ spending attitude, while in general it has depressing effects when the shock is caused by a reduced willingness to invest by firms.

6.3 Transfers

In the last section we conclude our assessment of fiscal policy by implementing balanced-budget transfers from households to firms and vice versa with both kinds of shocks.

If we sustain households’ purchasing power by an initial deficit spending and postponing taxation at the end of the crisis, the overall result is univocally positive regardless of the type of shock because of relevant multiplicative effects by public expenditures. On the contrary, if transfers are balanced period by period, we get mixed results.

In the case of demand-side shock, transferring resources from firms to households has depressing and inflationary effects. Besides, after the removal of the shock recovery is slow. This is because transfers further impair firms’ balance sheets already put under stress by households’ high saving propensity. On the contrary, transfers from households to firms in general make the economy to perform better because they help sustaining firms’ cash flows and financial soundness. But the tradeoff between firms’ financial fragility and aggregate demand causes transfers to have non-linear effects: in fact, when transferring rates become higher, the depressing effect on aggregate demand operated by taxes reduces economic performance. However, recovery after the crisis is always fast because of the high liquidity of firms.

Turning to the case of a shock on firms’ propensity to invest, we discover that the non-linear behavior of transfers is even more marked. In fact, results are very similar if transfers flow from households to firms, and in addition we have a non-linear trajectory also in case of transfers from firms to households. As long as tax rates on firms are low, they do not impair their balance sheets and sustain households’ consumption. But when tax rates exceed a certain threshold, the negative effect on balance sheets overcomes the positive one on consumption and eventually the economy worsens its performance.

In conclusion, and partly in contrast with the insight from previous experiments with public purchases, our simulations suggest that transfers in favor of households and consumption are more effective when the shock comes from firms’ investing attitude that when it comes from households’ consumption propensity.

7. Final remarks

In this work we presented two macroeconomic models inspired to the complexity approach where heterogeneity and interaction play a primary role. The adopted agent-based microfoundations allowed us to set the stage for the continuous interactions among bounded rational agents such as workers/consumers, firms and one commercial bank. In particular, we gave relevance to the interplay between credit market conditions and firms’ balance sheet quantities, which together concur in determining firms’ production decisions and the macroeconomic performance. The presence of financial acceleration mechanisms in conjunction with the productive activity of adaptive firms determines the emergence of endogenous credit and business cycles as non-equilibrium phenomena.

The models served us as simulation platforms by which we performed several experiments of monetary and fiscal policy. Simulations showed a clear non-neutrality of monetary policy, which finds its transmission mechanism in the credit channel – namely in the balance sheet channel. In our case, a tightening in monetary policy induces firms to reduce their borrowing attitude, while a loosening makes them increase their loan demand. As one may expect, the overall effect on the macroeconomy is negative and positive respectively.
Besides, we also evaluated the performance of a monetary Authority whose response function was modelled according to a standard Taylor principle. The main conclusion is that while a Taylor rule is able to attain some positive results if compared to an inactive monetary policy, at the same time it is not fully able to reach the goals it is supposed to pursue.

Finally, fiscal policy experiments showed how monetary policy coordination is important: when it was accommodating, as in the case of debt monetization, the fiscal stimulus got its best results. Moreover, we also found that balanced budget fiscal measures are not able to foster economic performance, while an initial deficit spending, through the activation of multiplying mechanisms, is.

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