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Abstract

Starting from the agent-based decentralized matching macroeconomic model proposed in Riccetti et al. (2012), we explore the effects of banking regulation on macroeconomic dynamics. In particular, we study the overall credit exposure and the lending concentration towards a single counterparty, finding that the portfolio composition seems to be more relevant than the overall exposure for banking stability, even if both features are very important. We show that a too tight regulation is dangerous because it reduces credit availability. Instead, on one hand, too loose constraints could help banks to make money and to increase their net worth, thus making the constraints not binding. However, on the other hand, if bank profits are tied to higher payout ratio (as it really happened along the deregulation phase of the last 20 years), then the financial fragility increases causing a weaker economic environment (e.g., higher mean unemployment rate), a more volatile business cycle, and a higher probability of triggering financial crises. Accordingly, simulation results support the introduction of the Capital Conservation Buffer (Basel 3 reform).

Keywords: financial regulation, agent-based macroeconomics, business cycle, crisis, unemployment, leverage.
JEL classification codes: E32, C63.

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1 Introduction

In this paper we explore the effects of banking regulation on financial and macroeconomic dynamics, using the agent-based decentralized matching macroeconomic model proposed in Riccetti et al. (2012), according to which the macroeconomy is a *complex system* populated by two policy makers, the government and the central bank, and many heterogeneous agents (households, firms and banks) which directly interact in different markets (goods, labor, credit, and bank deposits). In this context, aggregate regularities emerge from the "bottom up" (Epstein and Axtell, 1996) as statistical properties at the meso and macro levels that derive from the (simple and adaptive) individual behavioral rules and the interaction mechanisms which describe the working of markets (Tesfatsion and Judd, 2006; LeBaron and Tesfatsion, 2008).

Many papers in the field of agent based computational economics investigated the role of interaction in a heterogeneous agents setting, exploring the properties of a methodological alternative to neoclassical Walrasian microfoundations, based on the Representative Agent (RA) hypothesis (for a comprehensive review, see Fagiolo and Roventini, 2009, 2012).

In particular, Riccetti et al. (2012) developed a model with decentralized interactions, along the lines already traced in the literature (for instance, Fagiolo et al., 2004, Delli Gatti et al., 2005, 2009, 2010, Russo et al., 2007, Gaffeo et al., 2008). Nevertheless, a peculiar aspect of the model developed in Riccetti et al. (2012) is that the decentralized matching process presents common features across markets. This framework has many useful characteristics among which: (i) it is stock-flow consistent, (ii) it endogenously creates business cycles in which real and financial aspects interact, (iii) it is well suited to perform computational experiments about policy interventions.

- Stock-flow consistency is a very important feature (see Godley and Lavoie, 2006) that economists are applying also in the field of agent-based macroeconomics as, for instance, in Cincotti et al. (2010, 2012), Kinsella et al. (2011), Seppecher (2012).

- The second characteristic is that the recent financial turmoil has stressed the importance of the relatioship between financial factors and the real economy. It means that models should catch the possibility of firm and bank defaults (financial contagion) and the fundamental role of leverage cycles in shaping the macroeconomic dynamics. Accordingly, many recent contributions try to understand the leverage process both for firms and banks: Adrian and Shin (2008, 2009, 2010), Brunnermeier and Pedersen (2009), Flannery (1994), Fostel and Geanakoplos (2008), Geanakoplos (2010), Greenlaw, Hatzius, Kashyap and Shin (2008), He, Khang and Krishnamurthy (2010), Kalemli-Ozcan et al. (2011). Many of these papers find that the leverage pattern for financial firms (especially investement banks and large commercial banks) is pro-cyclical. The behaviour of the leverage level is a component of a more general discussion on firm and bank capital structure, such as in Booth et al. (2001), Diamond and Rajan (2000), Gropp and Heider (2010), Lemmon, Roberts and Zender (2008), Rajan and Zingales (1995). See Riccetti et al. (2013) for a more detailed literature review on this topic. To address the procyclicality issue, in this paper we use the model of Riccetti et al. (2012), in which firms' capital structure is based on the Dynamic Trade-Off theory (this capital structure is also investigated in the agent-based model proposed by Riccetti et al., 2013). According to this theory, we assume that firms have a "target leverage" (Graham and Harvey, 2001, conduct a survey where 81% of firms affirm to consider a target debt ratio or range when making their debt decisions), that is a desired ratio between debt and net worth, and they try to reach it by following an adaptive rule governing credit demand. The Dynamic Trade-Off theory has a relevant role in influencing the leverage cycle, with a strong impact on macroeconomic evolution. For this reason, Riccetti et al.(2012) analyze in details the dynamics of financial variables, firms' leverage and banks' exposure, and their interplay with the business cycle.

- The last feature of the model, fundamental for this paper, is the possibility to perform some computational experiments about regulatory issues. In general, agent-based models are often a useful tool for analyzing policy interventions. For instance, some recent contributions have proposed an analysis of economic policy issues: Delli Gatti et al. (2005) and Cincotti et al. (2010, 2012) study the role of monetary policy, Russo et al. (2007) analyze the fiscal policy and its effect on R&D dynamics, the combination of Keynesian management of aggregate demand and Schumpeterian policies aimed at promoting technological progress is studied by Dosi et al. (2010), while Dosi et al. (2012) consider the interplay between income distribution and economic policies, Haber (2008) investigates the effects of fiscal and monetary policies, Neugart (2008) examines labor market policies, Westerhoff and Dieci (2006) and Mannaro et al. (2008) analyze the effects of introducing a Tobin-like tax, Westerhoff (2008) analyzes the role of regulatory policies on financial markets, and Westerhoff and Franke (2012) analyze the effectiveness of various stabilization policies, and so on. Hence, agent-based models represent an alternative formulation of microfoundations suited for a complex macroeconomic system; following this different approach may have important implications for policy advice (Dawid and Neugart, 2011). For a comprehensive review, see Fagiolo and Roventini (2009, 2012). Recently, also the debate on banking regulation was faced by agent-based models, as in Neuberger and Rissi (2012) who find that both unregulated financial systems and too restrictive regulations have destabilizing effects.

With the present paper we add some results to the analysis of policy issues in an agent based macroeconomic framework. Summarizing our finding, we show that: (i) for banking stability, the portfolio composition seems to be more relevant than the overall exposure, even if both features are very important; (ii) a too tight regulation is dangerous because it reduces credit

availability; (iii) too loose constraints could help banks to make money and to increase their net worth, thus making the constraints not binding, but if banks profits are associated with a higher payout ratio (as really happened in the last 20 years), then the financial fragility increases causing a weaker economic environment (higher mean unemployment rate), a more volatile business cycle, and a higher probability of triggering crises.
The methodology used to address the financial regulation issue is to perform two sensitivity analyses on two parameters of the model of Riccetti et al. (2012), that constrain the banking activity: the overall credit exposure and the lending concentration towards a single counterparty. Moreover, we analyze what happens if both parameters are changed jointly, calling this case the "deregulation" one. We slightly modify the cited agent-based model to allow banks to extend a higher dividend, to address the fact that, in the last decades, financial sector obtains a deregulation process coupled with a growing payout policy. For a brief literature review and discussion on the payout policy, see Subsection 4.3.
With our finding we try to give a contribution to the discussion on the Basel III reforms of the banking sector. Indeed, the overall credit exposure is related to the First Pillar of the reform on Capital requirements, in which there are many rules concerning this topic. We now report the ones that are more directly related with our paper:

- the *common equity* has to be larger than the 4.5% of risk-weighted assets;
- above the already mentioned 4.5%, there is an addictional 2.5% of equity (for an overall value of 7%) called *Capital Conservation Buffer*; constraints on a bank's payout and other discretionary distributions are imposed if the common equity falls below this 7%;
- a maximum for the non-risk-based *Leverage Ratio* (including off-balance sheet exposures) is set in order to avoid too large leverage ratio based on risk-based measures. The equity has to be above 3% of total assets value (thus bank's leverage ratio has to be below about 33).

In particular, the Capital Conservation Buffer is also related to our discussion on the payout policy. About the possible implications related to the introduction of the *Leverage Ratio* see, for instance, Elliott (2009, 2010), Hellwig (2010), Kiema e Jokivuolle (2010). Instead, the analysis on the lending concentration parameter is associated with the debate on the Second Pillar, about "Risk management and supervision", which also contains the topic of managing risk concentrations. In general, in the recent years, numerous studies have analyzed in detail the various regulatory reforms and the impacts both on the economy and on profitability and management of the banks, deriving from the strengthening of the capital requirements (Jokipii and Alistair, 2008, 2011; Hanson et al., 2010; King, 2010; Al-Darwish et al., 2011; Andersen, 2011; Carlson et al., 2011; Agenor and Pereira da Silva, 2012; Allen et al., 2012; Francis and Osborne, 2012; Mora and Logan, 2012; Tutino et al., 2012; Agur, 2013; Vollmer and Wiese, 2013; Zhou, 2013).

The paper is organized as follows. Section 2 presents the model setup and, in particular, Subsection 2.1 reports the characteristics of the four markets (credit, labor, goods, and bank deposits) which composes our economy; the evolution of agents' wealth is described in subsection 2.2, while the behavior of policy makers is discussed in subsection 2.3. Section 3 summarizes the model dynamics and the simulation results found in the baseline setting of the model reported in Riccetti et al. (2012). We provide the regulatory analyses in Section 4, in which we perform sensitivity and Monte Carlo experiments, comparing these findings with the baseline model outputs and highlighting the implications for financial regulation. Section 5 concludes.

2 The model

This paper, as already explained, is based on the model reported in Riccetti et al. (2012). Our economy evolves over a time span $t = 1, 2, ..., T$ and is composed by households ($h = 1, 2, ..., H$), firms ($f = 1, 2, ..., F$), banks ($b = 1, 2, ..., B$), a central bank, and the government. Agents are boundedly rational and live in an incomplete and asymmetric information context, thus they follow simple rules of behaviour and use adaptive expectations.
Agents interact in four markets: (i) credit market; (ii) labor market; (iii) goods market; (iv) deposit market. The interaction between the demand (firms in the credit and labor markets, households in the goods market, and banks in the deposit market) and the supply (banks in the credit market, households in the labor and deposit markets, and firms in the goods market) sides of the four markets follows a common decentralized matching protocol, even if each agent in the demand side observes a list of potential counterparts in the supply side and chooses the most suitable partner according to some market-specific criteria. In particular, the interaction develops in the following way: a random list of agents in the demand side is set, then the first agent in the list observes a random subset of potential partners, whose size depends on a parameter $0 < \chi \leq 1$ (which proxies the degree of imperfect information), and chooses the cheapest one. After that, the second agent on the list performs the same activity on a new random subset of the updated potential partner list. The process iterates till the end of the demand side list. Subsequently, a new random list of agents in the demand side is set and the whole matching mechanism goes on until either one side of the market (demand or supply) is empty or no further matchings are feasible because the highest *bid* (for example, the money till available to the richest firm) is lower than the lowest *ask* (for example, the lowest wage asked by till unemployed workers).

Now, we briefly explain the main features of the four markets. However, for a detailed description of the markets, we refer to Riccetti et al. (2012).

2.1 Markets

2.1.1 Credit market

In each period, at first firms and banks interact in the credit market. Firm's f credit demand at time t depends on its net worth A_{ft} and the leverage target l_{ft}. Hence, required credit is:

$$B^d_{ft} = A_{ft} \cdot l_{ft} \tag{1}$$

The evolution of the leverage target changes according to expected profits and inventories: if expected profits are above expected interest rate and there are few inventories, the firm enlarges its target leverage, and viceversa.

Banks set their credit supply B^d_{bt} depending on their net worth A_{bt}, deposits D_{bt}, and the quantity of money provided by the central bank m_{bt}. However, we add some regulatory constraints:

$$B^d_{bt} = min(\hat{k}_{bt}, \bar{k}_{bt}) \tag{2}$$

where $\hat{k}_{bt} = \gamma_1 \cdot A_{bt}$, $\bar{k}_{bt} = \gamma_2 \cdot A_{bt} + D_{bt-1} + m_{bt}$, with parameters $\gamma_1 > 0$ and $0 \leq \gamma_2 \leq 1$. Parameter γ_1 represents the maximum exposure in risky assets (corporate lending) as a multiple of bank capital. Instead, parameter γ_2 represents the maximum percentage of capital that can be invested.

Morever, in order to reduce risk concentration, only a fraction $0 < \beta \leq 1$ of the total amount of the credit B^d_{bt} can be lent to a single firm.

Bank b charges an interest rate on the firm f at time t according to the following equation:

$$i_{bft} = i_{CBt} + \hat{i}_{bt} + \bar{i}_{ft} \tag{3}$$

where i_{CBt} is the nominal interest rate set by the central bank at time t, $\hat{i}_{bt}$ is a bank-specific component, and $\bar{i}_{ft} = \rho^{\,l_{ft}}/100$ is a firm-specific component, that is a risk premium on firm target leverage l_{ft} (with parameter $\rho > 0$).

The bank-specific component decreases if the bank did not manage to lend to firms all the credit supply. Indeed, at the end of the interaction mechanism, each firm ends up with a credit $B_{ft} \leq B^d_{ft}$ and each bank lends to firms an amount $B_{bt} \leq B^d_{bt}$. The difference between desired and effective credit is equal to $B^d_{ft} - B_{ft} = \hat{B}_{ft}$ and $B^d_{bt} - B_{bt} = \hat{B}_{bt}$, for firms and banks respectively.

Moreover, we hypothesize that banks ask for an investment in risk free government securities equal to $PD^d_{bt} = \bar{k}_{bt} - B_{bt}$. If the sum of desired government bonds exceeds the amount of outstanding public debt then the effective investment PD_{bt} is proportionally rescaled. Instead, if public debt exceeds the banks' desired amount, then the central bank buys the difference.

2.1.2 Labor market

Government, firms and households interact in the labor market. On the demand side, first of all, the government hires a fraction g of households. The remaining part is available for working in the firms. Firm's f labor demand depends on available funds, that is net worth and bank credit: $A_{ft} + B_{ft}$.
On the supply side each worker posts a wage w_{ht} which increases if he/she was employed in the previous period and viceversa. Moreover, the required wage has a minimum related to the price of a good.
As a result of the decentralized matching between labor supply and demand, each firm ends up with a number of workers n_{ft} and a residual cash (insufficient to hire an additional worker) and a fraction of households may remain unemployed. The wage of unemployed people is set equal to zero.

2.1.3 Goods market

Subsequently, households and firms interact in the goods market. On the demand side, households set the desired consumption on the basis of their disposable income and wealth. Firms produce consumption goods on the basis of hired workers as follows:

$$y_{ft} = \phi \cdot n_{ft} \tag{4}$$

where $\phi \geq 1$ is a productivity parameter. They put in the goods market their current period production and previous period inventories $\hat{y}_{ft-1}$. The selling price increases if in the previous period the firm managed to sell all the output, while it reduces if it had positive inventories. Moreover, the minimum price at which the firm want to sell its output is set such that it is at least equal to the average cost of production, that is *ex-ante* profits are at worst equal to zero.
As a consequence of the interaction between the supply and demand sides in the goods market, each household ends up with a residual cash, that is not enough to buy an additional good and that she will try to deposit in a bank. At the same time, firms may remain with unsold goods (inventories), that they will try to sell in the next period.

2.1.4 Deposit market

Banks and households interact in the deposit market. Banks represent the demand side and households are on the supply side. Banks offer an interest rate on deposits according to their funds requirement: if a bank exhausts the credit supply by lending to private firms or government then it decides to increase the interest rate paid on deposits, so to attract new depositors, and viceversa. However, the interest rate on deposits can increase till a maximum given by the policy rate r_{CBt} which is both the rate at which banks could refinance from the

central bank and the rate paid by the government on public bonds.
Households determine their savings to be deposited in banks as the desired savings plus the residual cash at the end of the interaction in the consumption market. Moreover, they set the minimum interest rate they want to obtain on bank deposits as follows: a household that in the previous period found a bank paying an interest rate higher or equal to the desired one decides to ask for a higher remuneration. In the opposite case, she did not find a bank satisfying her requirements, thus she kept her money in cash and now she asks for a lower rate. We hypothesize that a household deposits all the available money in a single bank that offers an adequate interest rate.

2.2 Profits, dividends and wealth dynamics

2.2.1 Firms

At the end of the interaction in the credit, labor and goods markets, every firm f calculates its profit/loss:

$$\pi_{ft} = p_{ft} \cdot \bar{y}_{ft} - W_{ft} - I_{ft} \tag{5}$$

where p_{ft} is the price set by the firm f on its goods, $\bar{y}_{ft}$ are the sold goods, W_{ft} is the sum of wages paid to employed workers, and I_{ft} is the sum of interests paid on bank loans.
Firms pay a proportional tax τ on positive profits; however, firms can subtract previous negative profits in the calculation of the tax base. After taxes, we indicate net profits with $\bar{\pi}_{ft}$.
Finally, firms pay a percentage δ_{ft} as dividends on positive net profits. The fraction $0 \leq \delta_{ft} \leq 1$ goes down if in the previous period the firm produces and sells all the goods (no inventories), then it wants to retain a larger share of profits to enlarge the production, and viceversa.
The profit net of taxes and dividends is indicated by $\hat{\pi}_{ft}$. In case of negative profits $\hat{\pi}_{ft} = \pi_{ft}$. Thus, the evolution of firm f's net worth is given by:

$$A_{ft} = (1 - \tau') \cdot [A_{ft-1} + \hat{\pi}_{ft}] \tag{6}$$

where τ' is the tax rate on wealth (applied only on wealth exceeding a threshold $\bar{\tau'} \cdot \bar{p}$, that is a multiple of the average goods price).

If $A_{ft} \leq 0$ then the firm goes bankrupt and a new entrant replaces the bankrupted agent according to a one-to-one replacement. Banks linked to defaulted firms lose a fraction of their loans, but recovers the remaining part; analytically, $(A_{ft} + B_{ft})/B_{ft}$ is the recovery rate.
The new entrant starts with an initial net worth equal to a multiple of the average goods price and the money needed to finance entrants is subtract from households' wealth. We set to one the leverage of the new firm. Moreover, the entrant sets an initial price for its gooods equal to the mean price of survival firms.

2.2.2 Banks

As a result of interaction in the credit and the deposit markets, the bank b's profit is equal to:

$$\pi_{bt} = int_{bt} + i_t^{\Gamma} \cdot \Gamma_{bt} - i_{bt-1}^{D} \cdot D_{bt-1} - i_{CB}^{t} \cdot m_{bt} - bad_{bt} \tag{7}$$

where int_{bt} represents the interests gained by bank b on lending to non-defaulted firms, i_t^{Γ} is the interest rate on government securities Γ_{bt}, i_{bt-1}^{D} is the interest rate paid on the sum of deposits D_{bt-1}, i_{CB}^{t} is the interest rate paid on the amount of money m_{bt} required to the Central Bank, and bad_{bt} is the amount of "bad debt" due to bankrupted firms. Bad debt is the loss given default of the loans to bankrupted firms, that is a fraction 1 less the recovery rate (see the previous subsection) of the loans.

Banks pay a proportional tax τ on positive profits; however, they subtract previous negative profits in the calculation of the tax base. We indicate net profits with $\bar{\pi}_{bt}$.

Finally, banks pay a percentage $\hat{\delta_{bt}}$ as dividends on positive net profits. The fraction $0 \leq \hat{\delta_{bt}} \leq 1$ evolves according to the following rule (that is different from the one used in Riccetti et al., 2012, because here we add the parameter $0 \leq \bar{\delta_b} \leq 1$):

$$\hat{\delta_{bt}} = \bar{\delta_b} + \delta_{bt} \tag{8}$$

where:

$$\delta_{bt} = \begin{cases} \delta_{bt-1} \cdot (1 - \alpha \cdot U(0,1)), & \text{if } B_{bt} > 0 \text{ and } \hat{B}_{bt} = 0 \\ \delta_{bt-1} \cdot (1 + \alpha \cdot U(0,1)), & \text{if } B_{bt} = 0 \text{ or } \hat{B}_{bt} > 0 \end{cases} \tag{9}$$

That is, if the bank does not manage to lend the desired supply of credit then it decides to distribute more dividends (because it does not need high reinvested profits), and viceversa.

The profit net of taxes and dividends is indicated by $\hat{\pi}_{bt}$. In case of negative profits $\hat{\pi}_{bt} = \pi_{bt}$.

Thus, the bank b's net worth evolves as follows:

$$A_{bt} = (1 - \tau') \cdot [A_{bt-1} + \hat{\pi}_{bt}] \tag{10}$$

where τ' is the tax rate on wealth (applied only on wealth exceeding a threshold $\bar{\tau'} \cdot \bar{p}$, that is a multiple of the average goods price).

If $A_{bt} \leq 0$ then the bank is in default and a new entrant takes its place. Households linked to defaulted banks lose a fraction of their deposits (the loss given default rate is calculated as $1 - (A_{bt} + D_{bt})/D_{bt}$). The initial net worth of the new entrant is a multiple of the average goods price. Moreover, the initial bank-specific component of the interest rate ($\hat{i}_{bt}$) is equal to the mean value across banks.

2.2.3 Households

According to the operations in the labor, goods, and deposit markets, the household h's wealth evolves as follows:

$$A_{ht} = (1 - \tau') \cdot [A_{ht-1} + (1 - \tau) \cdot w_{ht} + div_{ht} + int^D_{ht} - c_{ht}] \qquad (11)$$

where τ' is the tax rate on wealth (applied only on wealth exceeding a threshold $\bar{\tau'} \cdot \bar{p}$, that is a multiple of the average goods price), τ is the tax rate on income, w_{ht} is the wage gained by employed workers, div_{ht} is the fraction (proportional to the household h's wealth compared to overall households' wealth) of dividends distributed by firms and banks net of the amount of resources needed to finance new entrants (hence, this value may be negative), int^D_{ht} represents interests on deposits, and c_{ht} is the effective consumption. Households linked to defaulted banks lose a fraction of their deposits as already explained.

2.3 Government and central bank

Government's current expenditure is given by the sum of wages paid to public workers (G_t) and the interests paid on public debt to banks. Moreover, government collects taxes on incomes and wealth and receives interests gained by the central bank. The difference between expenditures and revenues is the public deficit Ψ_t. Consequently, public debt is $\Gamma_t = \Gamma_{t-1} + \Psi_t$. The presence of the government as an acyclical sector is a very important feature of the model. Indeed, hiring public workers, the government provides a fraction of the aggregate demand. In this way it partially stabilizes the economy by reducing output volatility.

Central bank decides the policy rate i_{CBt} and the quantity of money to put into the system in accordance with the interest rate. In order to do that, the central bank observes the aggregate excess supply or demand in the credit market and sets an amount of money M_t to reduce the gap in the subsequent period of time.

3 Baseline model results

We explore the dynamics of the model by means of computer simulations. We refer to Riccetti et al. (2012) for the details about the parameter setting, the initial conditions and the results of the baseline model that we will sum up now.

With the baseline setting we perform two Monte Carlo analyses with two different time span. The first analysis exploits 1000 Monte Carlo simulations over a "short" time horizon of 150 periods, of which we examine the results for the last 50, because the first 100 periods are used to initialise the model. The second study regards 100 Monte Carlo simulations over a "long" time span of 500 periods (again, the first 100 are used to initialise the model). However, this model analyzes the business cycle, then it performs a short/medium run analysis,

given that we do not consider the features that characterize the long run growth (tied to the productivity of both capital and labour). So, the "long" time horizon simulation is only another way to assess the business cycle fluctuations, able to show some additional features of the computational model.
In 995 out of 1000 of the "short" simulations and in 98 out of 100 of the "long" Monte Carlo simulations, we observe the emergence of endogenous business cycles with the following pattern: an increase of firms' profits determines an expansion of production and, if banks extend the required credit, this effect could be amplified resulting in more employment; the fall of the unemployment rate increases wage inflation that, on the one hand, expands the aggregate demand, while on the other hand reduces firms' profits, possibly causing the inversion of the business cycle. Then, we can notice a "real" economy engine given by the dynamic relation between the unemployment and the profit rate, enlarged by a financial accelerator mechanism. The "real" mechanism is that an increase of profits boosts the expansion of the economy and then a fall of the unemployment rate follows; the low unemployment increases wages, so firms try to save on production costs reducing labor demand. This results in a rise of unemployment that lowers the profit rate at the subsequent period due to a lack of aggregate demand. However, the presence of unemployed people decreases wages and this makes firms to hire a larger number of workers, so boosting the beginning of a new expansionary phase of the business cycle.
Firms' leverage and banks' exposure are the financial drivers that enlarge business fluctuations: growing firms ask for more credit to expand the production; subsequently, the low unemployment fosters wages that, together with the rise of interest payments on the increased debt, reduces firms' profitability. Thus, the business cycle reverses and financial factors amplify the recession, indeed the relatively low level of profits with respect to interest payments induces a deleveraging process. According to the empirical evidence (for example, Kalemli-Ozcan et al., 2011), there is a negative but modest correlation between firms' leverage and the unemployment rate, while there is a more significant negative correlation between banks' exposure and unemployment. The importance of banks' capitalization is evident because this variable determines the credit conditions, so influencing firms' leverage and the macroeconomic evolution.
Focussing on the financial sector, the model show that a more leveraged financial sector sustains the expansion of the economy, but the relation is non-linear: for low levels, an increase of bank exposure reduces the rate of unemployment; instead, for high levels of bank exposure a further increase makes the unemployment higher. In other words, if banks increase their exposure enlarging credit to firms, the latter hire more workers and the unemployment rate decreases. But, when the exposure of banks becomes "excessive" this leads to instability (more failures) and an increase of the unemployment rate follows.

The business fluctuations are mitigated by the government, representing an acyclical sector, that plays a central role to reduce the output volatility through stabilizing the aggregate demand. However, in 5 out of 1000 "short" simulations and in 2 out of 100 "long" ones, the system is characterized by large and extended crises, that is the average unemployment rate reaches values above the 20%. Differently from the usual business cycle mechanism, the reduced wages due to growing unemployment does not reverse the cycle, but generates a lack of aggregate demand that amplifies the recession in a vicious circle for which the fall of purchasing power prevents firms to sell commodities, then firms decrease production, unemployment continues to rise, and the recession further deteriorates.

4 Regulation analysis

In this section we perform some computational experiments to assess the effects of modifying the regulatory constraints to the bank activities. For this analysis, we change the parameters γ_1 and β (see Section 2.1.1)[1]. Thus, we try to address in a stylized way some banking regulation topics. Indeed, we can only implement some aspects of the Basel 3 proposals in this simplyfied framework given that, for instance, banks do not use various instruments (that is on the asset side they only lend to firms and residually to the government, while on the passive side they only have equity and deposits) and there are not different lending horizons in order to assess liquidity vs. solvency problems. However, as already explained in Section 1, studying the role of parameter γ_1 we can analyze the banking capital and leverage regulation, given that this parameter constraints the risky assets over the bank's net worth[2]. Instead, studying parameter β we can address the maximum lending concentration issue, that is included in the Second Pillar ("Risk management and supervision") of Basel III Capital regulation.

In the baseline model we set $\gamma_1 = 10$ and $\beta = 0.1$. Now we discuss the experimental settings of the additional analyses we propose; then, we will report the results in the next Subsections.

The first is on the parameter β. In particular, we perform 1000 replications of the model over a time span of T=150 organised as follows: 20 simulations for each values of β from 1% to 50% with step 1%, keeping unchanged all the other parameters. Then, we analyze the impact of the parameter β over the "long" time horizon. That is, we run 100 Monte Carlo repetitions with T=500 for $\beta = 0.50$, in order to compare these results with those emerging from the 100 simulations of the baseline model over the "long" time span.

[1] γ_1 and β can be interpreted both as behavioural parameters (for instance, when β increases the bank is more prone to concentrate the credit risk and vice versa) or regulatory constraints (according to which it is not allowed for banks to exceed a concentration threshold β).

[2] In other words, this parameter does not exactly correspond neither to the 4.5% minimum capital requirement nor to the 3% Leverage Ratio rule, because we consider that the risk comes only from the credit extended to firms, thus implying that risk-free government bonds have a risk-weighting equal to zero (because the Central Bank is committed to buy the unsold government bonds, without a spread over the policy rate).

The second analysis is on the parameter γ_1. As in the previous case, we perform both a sensitivity analysis over a time span of T=150 changing γ_1 from 1 to 50 with 50 steps of 1 (again, for each step we perform 20 simulations for an overall amount of 1000 simulations) and a study with 100 Monte Carlo repetitions on the "long" time span T=500 with γ_1=50. The third analysis concerns both parameters at the same time, that is we study a parameter setting with $\gamma_1 = 50$ and $\beta = 0.5$ with 100 Monte Carlo simulations on the "long" time horizon T=500. In this way we assess a case of wide financial "deregulation".
Last, we perform two batteries of 100 Monte Carlo repetitions each with $\bar{\delta}_b$=0.45, where the other parameters are fixed both in the baseline model setting ($\gamma_1 = 10$ and $\beta = 0.1$) and in the "deregulation" case ($\gamma_1 = 50$ and $\beta = 0.5$). In this way we analyze the "deregulation" case in a high payout ratio environment. The discussion on banking payout is strictly related with the Basel III Capital Conservation Buffer, because a constraint on banks discretionary distributions is imposed if the *common equity* falls below this threshold.

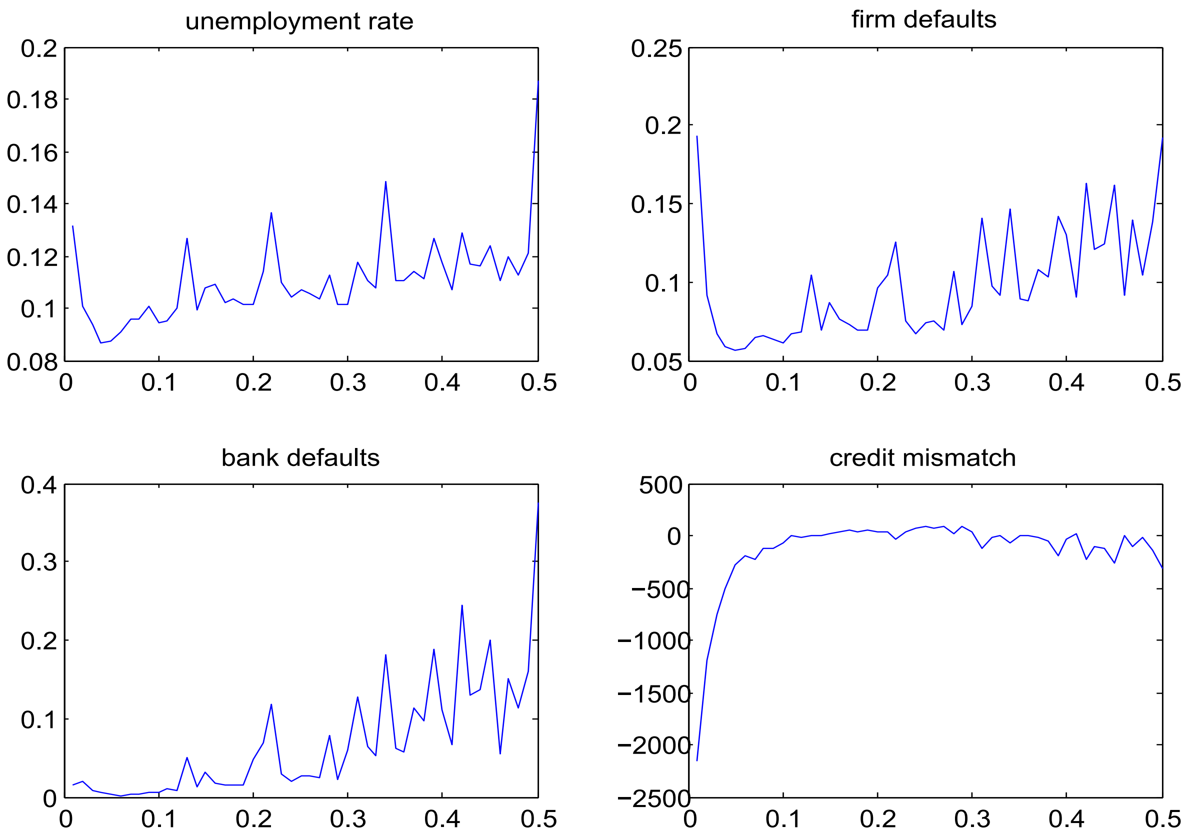
4.1 Sensitivity analysis on parameter β

We perform the sensitivity analysis on the parameter β that constrains the maximum lending concentration. Firstly, as already said, we run 1000 simulations on the "short" time horizon for 50 different values of β, from 0.01 to 0.50 with 0.01 step.

Figure 1 shows that when β is very small, that is if banking regulation is excessively tight, there is a relevant credit rationing which causes many firm defaults and high rates of unemployment, even though banks are safe and their default is very unlikely. As the parameter grows, while remaining low, the credit mismatch reduces or disappears and a reduction of firm defaults and unemployment follow. For increasing values of β, the riskiness of the financial system tends to increase, as shown by the growing number of bank defaults. This induces at first a slight increase of the mean rate of unemployment. Then, when the regulatory constraint becomes too loose, system's financial fragility is excessive and this can lead to large bankruptcy avalanches of firms and banks. As a consequence, banks' net worth collapses resulting in a strong credit constraint. At the same time, firms are not able to hire workers because their net worth also falls down and they do not receive enough credit from the banking system. Hence, the credit crunch results in a large unemployment rate. Moreover, this determines also a high unemployment volatility and a growing number of large crises (average unemployment rate above 20%): for instance, when $\beta = 0.05$ the mean unemployment rate is 8.7% and there are no large crises, while if $\beta = 0.50$ it becomes 18.73% with a large crisis scenario in 6 out of 20 simulations.

To further check for the robustness of these results and for the presence of large crises, we repeat the Monte Carlo simulations over a "long" time horizon T=500 (as usual, excluding from the analysis the first 100 time steps used to initialize the economy). We compare the findings obtained when $\beta = 0.5$, with those of the baseline case, that is $\beta = 0.1$ (see Table

Figure 1: Sensitivity analysis on the impact of the parameter β – from 0.01 to 0.50 with step 0.01 – on the following variables: (i) unemployment rate, (ii) firms default rate, (iii) banks default rate, (iv) credit mismatch (that is the difference between the money available from banks and not lent and the money required by firms and not received). All values are the average on the 20 simulations with the corresponding β value.



1). If $\beta = 0.5$, we observe 22 out of 100 simulations with large crises, a number much higher than the 2 simulations when $\beta = 0.1$. Moreover, if we consider all simulations in which the unemployment rate exceeds 20% for at least one period, we calculate 36 cases when $\beta = 0.5$ versus the 3 cases when $\beta = 0.1$. The riskiness of this setting is confirmed by the fact that, even focusing on the simulations in which the average unemployment rate is below 20%, the mean unemployment rate is larger (10.73% vs 9.73%) and the unemployment volatility higher (2.16% vs 1.84%). In other words, compared to the baseline setting, the main difference when $\beta = 0.5$ is the significantly higher frequency of large and extended crises; moreover, the level and the volatility of the unemployment rate is a bit higher even if we discard the large crisis cases (and this also one of the reasons for which large crises are more probable).

4.2 Sensitivity analysis on parameter γ_1

Now we study parameter γ_1 that represents the maximum bank exposure in risky assets (corporate lending) as a multiple of bank capital. As in the previous Section, we run 1000 simulations on the "short" time horizon for 50 different values of γ_1, from 1 to 50 with step of 1. With $1 \leq \gamma_1 \leq 3$, firms face a huge credit constraint that causes a very high number of firm defaults. A high unemployment rate follows. Instead, differently from the analysis on β, we do not detect significant changes from $\gamma_1 = 4$ to $\gamma_1 = 50$, that is a loose banking regulation does not increase the risk of financial crises. However, we see that banks do not always use their maximum possible exposure (reaching very high amount of risky assets compared to their net worth), given that this is only a theoretical upper bound. Indeed, in this paper banks do not allocate their portfolio considering a risk-return optimization, then we can not assess the issue of different banking strategies in presence of different regulatory rules.

Nevertheless, to better check for the presence of large crises, also in this case we repeat the Monte Carlo simulations over a "long" time horizon T=500. We compare the case when $\gamma_1 = 50$ to the baseline case of $\gamma_1 = 10$ (see Table 1). With a longer time span, the risk of financial crises emerges: if $\gamma_1 = 50$, we count 12 simulations with large crises, versus the 2 simulations of the baseline case. Considering all simulations in which the unemployment rate exceeds 20% for at least one period, we calculate 15 cases when $\gamma_1 = 50$ against 3 cases when $\gamma_1 = 10$. Excluding the large crisis simulations, the mean unemployment rate is quite low (9.08% vs 9.73%), but the possibility to expand the risky assets volume takes to a higher business cycle volatility (unemployment volatility equal to 2.09% vs 1.84% in the baseline setting), that can also trigger large crises.

To sum up, a too tight constraint on γ_1 seems to be more dangerous than a too loose one, but also a very high value of γ_1 is harmful, given that it increases the possibility of triggering financial crises.

Comparing these results with those on maximum lending concentration β, we note that the portfolio composition seems to be more relevant than the overall exposure, even if both features are very important for banking stability.

4.3 Deregulation case

We analyze the case of a very loose constraint on both parameters, β and γ_1, calling it banking "deregulation" case. In practice, we perform 100 Monte Carlo simulations over the "long" time horizon (T=500) fixing $\beta = 0.5$ and $\gamma_1 = 50$; in this case banks can lend to firms an amount of money till 50 times the net worth and they could even give half of this amount to a single firm. This is an overly risky regulation. However, we detect only one simulation with a large crisis and this is even the only case in which the unemployment rate goes beyond the 20%. In the other 99 simulations, the mean unemployment rate is 9.29% and it never exceeds 20%.

The reason is quite simple: banks make a huge amount of money, they become relatively large compared to the overall economic size and, in particular, to firms' size, then they are able to provide all the required credit without approaching the constraints. For instance, over the 99 simulations without a large crisis, the mean ratio between lent credit and banks net worth is below 4, even if the limit is 50.

But what happens if the large amount of profits, that banks are able to obtain in the deregulation case, are used to enrich the payout ratio[3] of banks and not to enlarge banks net worth? DeAngelo et al. (2004) and Denis and Osobov (2008) show that most profitable firms increase their dividends and, more in general, there is large literature on financialization (for example, see Stockhammer, 2004) and on corporate governance trend of maximising shareholder value (for instance, see Lazonick and O'Sullivan, 2000, that argue a shift in management strategies from "retain and invest" to "downsize and distribute" in the USA). Focusing on banks, in particular, various studies observe an increase of banks payout ratio in the last decades: Acharya et al. (2009) show the dividend amount for 10 US and 11 European large banks from 2000 to 2008, while Brogi (2010) exhibits the dividends distributed by Italian banks; for instance, the Italian banking system distributed 1.4 Euro billions (payout ratio of 27.46%) in 1990, while it distributed 14.4 Euro billions (payout ratio of 64.43%) in 2006, with an increase of both net profits and payout ratio. Brogi (2010) says: "In the period 2004-2007, immediately preceding the crisis, the Italian banking system benefited from a considerable rise in profitability (...), but it did not seize the opportunity to strengthen capital base and, on the contrary, limited allocations to reserves and opted instead for generous payout policies". Moreover, these authors (but also the Basel Commitee on Banking Supervision) highlight that even when the financial crisis started and the banking system suffered the depletion of common equity through losses, banks continued to pay dividends. Indeed, banks are reluctant to reduce dividends, also because high dividend payments signal to the market the

[3] Here we proxy the payout ratio with the percentage of dividends paid on profits, even if now repurchases are the dominant form of payout (see Brav et al., 2005, or Skinner, 2008).

soundness of the bank. Acharya et al. (2009) explain "that dividends were paid to equity holders at the expense of the debt holders (including the taxpayers who fund bailouts) (...) the inertia in bank accounting makes even a distressed bank appear healthy in terms of its book capital ratios, enabling a transfer in violation of priority of debt over equity". Brogi (2010) shows that from 2001 to 2010 new share of Italian listed banks totalled about a third of aggregate dividends paid by the system in the same period, then an early imposition of dividend distribution constraint is an important reform needed by the regulatory system. E.S. Rosengren, President & Chief Executive Officer of the Federal Reserve Bank of Boston, expresses a similar opinion at "Rethinking Central Banking" Conference held in Washington D.C. in October 2010. This debate makes the Basel Committee to introduce the so-called "Capital Conservation Buffer", explained in Section 1: if the Common Equity of a bank goes below the 7% thresholds, the bank will have a distribution constraint[4].

In light of the reported stylized facts and of the regulatory debate, we modify the parameter $\bar{\delta_b}$ from zero to 0.45. With this value we perform two times 100 Monte Carlo repetitions with the baseline setting for γ_1 and β ($\gamma_1 = 10$ and $\beta = 0.1$) and in the deregulation setting ($\gamma_1 = 50$ and $\beta = 0.5$). In this way we analyze the case of full "deregulation" in a high payout ratio environment.

When $\gamma_1 = 10$ and $\beta = 0.1$, as reported in Table 1, the number of large crisis simulations is equal to 2 as in the baseline case. However, the number of simulations in which the unemployment rate exceeds the 20% increases to 12. This is coherent with the higher mean unemployment rate (now 11.36%) and the higher unemployment volatility (2.09%). It is obviously due to the lower accumulation of bank net worth which reduces the credit supply and increases financial fragility (tied to an increased bank leverage).

Instead, now, the "deregulation" worsens the economic environment: the number of large crisis simulation is equal again to 2, but the number of simulations in which the unemployment rate exceeds the 20% is now 45, the mean unemployment rate grows to 12.42%, and the mean unemployment volatility grows to 2.62%. The deregulation causes a high business cycle volatility and it implies two features: on one hand it happens very often to reach very high unemployment levels during strong cyclical downturns, on the other hand regulatory flexibility helps the system not to remain trapped in the large crisis scenario, that is it is easier for the system to recover from large unemployment[5].

[4]This regulatory debate goes with the debate on the proper notion of regulatory capital, see for instance Acharya et al. (2009). Indeed, the Tier 2 notion used by the Basel II agreement, that is a buffer against depositors loss then including hybrid claims such as preferred equity or subordinated debt, makes the composition of bank capital change from equity to hybrid claims, increasing banking leverage relative to common equity. Moreover, the injections of bank capital from Governments, for instance through the TARP program in the United States, often took the form of preferred equity rather than common equity, further increasing leverage and not reducing the reluctance of banks to extend credit.

[5]For this reason, the idea of a countercyclical regulation, tighter during the expansionary phases and looser during recessions, such as the Basel III "Countercyclical Buffer" (that is, authorities can ask till an addictional

To conclude: if the deregulation is preparatory and associated with a growth of banks net worth, it strengthens the banking sector, making the same rules not binding. Instead, if the deregulation is tied to higher payout and not to a higher net worth, then the leverage and the credit risk really increases, causing a more fragile economy (higher mean unemployment rate) and a more volatile business cycle.

Table 1: Summary of Monte Carlo simulations. In each row there is a parameter combination for which we perform 100 Monte Carlo repetitions on a time span of T=500. We report: (i) the number of simulations in which the mean unemployment rate is above 20% (N° large crisis), (ii) the number of simulations in which the maximum unemployment rate is above 20% (Max U > 20%), (iii) the mean unemployment rate in the non large crisis simulations (Mean U %), (iv) the mean unemployment standard deviation in the non large crisis simulations (U volatility %).

parameters	N° large crisis	Max U > 20%	Mean U %	U volatility %
$\beta = 0.1$, $\gamma_1 = 10$, $\bar{\delta_b}$=0	2	3	9,73	1,84
$\beta = 0.5$, $\gamma_1 = 10$, $\bar{\delta_b}$=0	22	36	10,73	2,16
$\beta = 0.1$, $\gamma_1 = 50$, $\bar{\delta_b}$=0	12	15	9,08	2,09
$\beta = 0.5$, $\gamma_1 = 50$, $\bar{\delta_b}$=0	1	1	9,29	2,04
$\beta = 0.1$, $\gamma_1 = 10$, $\bar{\delta_b}$=0.45	2	12	11,36	2,09
$\beta = 0.5$, $\gamma_1 = 50$, $\bar{\delta_b}$=0.45	2	45	12,42	2,62

5 Concluding remarks

We present an agent-based macroeconomic model that allowed us to investigate the role of financial regulation on macroeconomic dynamics.
The model is populated by heterogeneous agents (households, firms and banks) that interact according to a fully decentralized matching mechanism. The matching protocol is common to all markets (goods, labor, credit, deposits) and represents a best partner choice in a context of imperfect information. The model is useful because it gives rise to emergent macroeconomic properties like the fluctuation of the unemployment rate, the relevance of leverage cycles and credit constraints on economic performance, the presence of bank defaults and the role of financial instability, and so on. In particular, simulations show that endogenous business cycles emerge as a consequence of the interaction between real and financial factors: when firms' profits are improving, they try to expand the production and, if banks extend the required credit, this results in more employment; the decrease of the unemployment rate leads to the rise of wages that, on the one hand, increases the aggregate demand, while on the other hand reduces firms' profits, and this may cause the inversion of the business cycle. Moreover,

2.5% of common equity when credit is growing too much), could be an important tool.

model simulations highlight that even extended crises can endogenously emerge with a strong reduction of real wages, a consequent fall of the aggregate demand that, in turn, induces firms to decrease production, so enlarging the unemployment rate, in a vicious positive feedback circle. In these cases, the system may remain trapped, without the possibility to spontaneously recover unless an exogenous intervention.

This modeling framework is useful to understand the effects of some policy or institutional changes. In this paper we perform some computational experiments on the role of the parameter governing banks' capital regulation and credit portfolio concentration. The first constraint is related to the First Pillar of Basel III Capital regulation, while the credit concentration is tied to the Second Pillar.

The analysis shows non-linear relationships between the health of the economy (proxied by the unemployment rate) and the values of the parameters. Repeated simulations show that if regulation is excessively tight then strong credit constraints emerge causing high unemployment and a further weakness of economic and financial conditions in a vicious circle. By contrast, if the regulatory constraint is too loose then an excessive financial risk follows and this may result in bankruptcies avalanches of firms and banks and large unemployment. Another interesting feature for banking stability is that the portfolio composition seems to be more relevant than the overall exposure, even if both features are very important.

An unexpected result concerns the analysis of the "deregulation" case, that is setting both regulatory parameters at very risky levels. If only one of the two parameters is set at a very risky level, then the economy is very fragile, while this is not the case when both regulations are very loose. Indeed, if the deregulation is associated with a growth of banks net worth, it strengthens the banking sector, making the same constraints not binding. However, this result is tied to a banks' profit reinvestment in net worth larger than what observed during the last 20 years, when banks did not retain the huge amount of profit made and then took all the possible risk amount allowed (and even more, especially with the help of securitization and derivative instruments). Indeed, if the deregulation is tied to higher payout and not to a higher banks net worth, then the economy becomes really more fragile (a higher mean unemployment rate and a more volatile business cycle). The Capital Conservation Buffer, introduced with the Basel 3 reform, tries to solve this problem.

Hence, our analyses show that in a complex economic system, the effect of a parameter (regulatory) rule on a target variable (in our case the unemployment rate) could be non-linear, and the interaction of many rules could be even more complex producing unexpected results. Moreover, the implications are strictly related with other behavioural assumptions (for instance the willingness to retain or distribute profits) made in the model. Then, to determine the "right" policy implications is a very difficult task, that should not underevaluate the complexity of the system.

To further develop the analysis we will work on a large research agenda:

- work on other policy experiments (for instance on fiscal and monetary policies);

- test the consequences of alternative assumptions, such as labor market rigidity, heterogeneous consumption/saving behavior, etc.;
- refine the model with a varying number of actors (firms and banks) during the business cycle and a diversity of decisional timings (and frequency) in the different markets;
- extend the model by introducing new markets, for instance the stock and bond markets, the interbank market, and a market for investment goods;
- extend the model with long-run growth factors (heterogeneous workers'skills, R&D investments, etc.);

Obviously, these items are strictly related. When we will extend the model, we will be also able to test for further alternative assumptions and different parameter settings (based on an empirical calibration of the the model), and then we will assess more detailed policy experiments. For instance, the presence of investment goods is strictly related to technological progress underlying economic growth, or the presence of stock, bond and interbank markets will allow us to investigate the impact of agents' portfolio allocation based on a more complicated behavior for financial choices.

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