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## Unemployment benefits and financial factors in an agent-based macroeconomic model

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## **Unemployment Benefits and Financial Factors in an Agent-Based Macroeconomic Model**

*Luca Riccetti, Alberto Russo, and Mauro Gallegati*

**Abstract**

This paper is aimed at investigating the effects of government intervention through unemployment benefits on macroeconomic dynamics in an agent-based decentralized matching framework. The major result is that the presence of such a public intervention in the economy stabilizes the aggregate demand and the financial conditions of the system at the cost of a modest increase of both the inflation rate and the ratio between public deficit and nominal GDP. The successful action of the public sector is sustained by the central bank, which is committed to buy outstanding government securities.

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# 1 Introduction

In this paper we explore the effects of government intervention through unemployment benefits on macroeconomic dynamics. In particular, we slightly modify the agent based decentralized matching macroeconomic model proposed in Riccetti et al. (2012) to allow the government to transfer a certain amount of money to unemployment people. In general, we show that the presence of such a public intervention in the economy stabilizes the aggregate demand and the financial conditions of the system at the cost of a modest increase of both the inflation rate and the ratio between public deficit and nominal GDP. The successful action of the public sector is sustained by the operation of the central bank which is committed to buy outstanding government securities.

There is a huge literature which analyzes the role of unemployment insurance on both individual behavior and aggregate dynamics. From a microeconomic point of view, many papers analyze the nature of incentives and how the introduction of an unemployment insurance scheme modifies individual behavior regarding labor supply, that is the choice between leisure and working time. A typical result is that there is an adverse income effect of “high” unemployment insurance on the incentive to search and accept an employment opportunity. Moreover, “high” unemployment benefits reduce the opportunity costs of unemployment, resulting in a higher wage demand and an incentive to lower labor effort on the workplace. Other researchers noticed that unemployment benefits can have also positive consequences as the improvement of the quality of the matching between employers and employees (Acemoglu and Shimer, 2000) or the welfare-improving effect which emerges when people looking for jobs are liquidity constrained (Bender et al., 2009). Many contributions analyzed the effects of unemployment benefits on employment and unemployment dynamics on the basis of a “search and matching” framework (Mortensen and Pissarides, 1999a,b; Pissarides, 2000). According to this theoretical framework the presence of unemployment insurance produces more unemployment, because of the increase of workers’ bargaining power that decreases the marginal benefit for firms of the search and matching process. Moreover, the unemployment insurance operates as a friction in the labor market, modelled as a search and matching aggregate function, which amplifies business fluctuations.

In mainstream macroeconomics, the presence of unemployment benefits enhances the bargaining power of workers with respect to firms, so leading to an increase of requested wages that, for a given mark-up set by firms, makes the “natural” rate of unemployment (Friedman, 1968; Phelps, 1968), that is the Non-Accelerating Inflation Rate of Unemployment, to rise (Turner, 2001). Hence, *ceteris paribus*, the higher the level of unemployment benefits the larger the rate of unemployment in the macroeconomic equilibrium. Basically, the “natural” rate of unemployment depends on the workers’ reservation wage (that is the bargaining power which is inversely dependent on the unemployment rate and directly related to the degree of unionization, unemployment benefits, etc.), the degree of monopoly in markets (that is

the mark-up set by firms), and labor productivity (which depends on many variables as the accumulation of physical and human capital, and then technological progress and workers' skills). In such a mainstream framework, there is not an impact of the aggregate demand on equilibrium unemployment (but for a limited period of time if agents are characterized by *adaptive* expectations instead of *rational* expectations). Accordingly, the main effect of the unemployment insurance is to act as a *rigidity* that pushes away the economy from Pareto optimality (the same holds for other *frictions*). In principle, indeed, if a demand shock hits the macroeconomy, so leading to higher unemployment, the system is able to spontaneously return to its "natural" equilibrium through a decrease of nominal wages and (with a constant mark-up) a proportional reduction of prices (although policy makers can avoid such a deflationary process of adjustment through an expansionary monetary and/or fiscal policy). Moreover, in such a "natural" equilibrium setting, monetary policy is mainly addressed to assure a low and stable rate of inflation, as the best way to promote macroeconomic stability and a growth-enhancing environment (Allsopp and Vines, 2000). For these reasons, according to the conventional view, the central bank has to be *independent* of the government in setting monetary policy (Walsh, 2010).

However, there are many contributions in the macroeconomic field which investigate the role of unemployment insurance in stabilizing output fluctuation. The transfer of a benefit from the government to unemployed people works as an automatic stabilizer, thus providing a countercyclical action of the public sector which sustains the aggregate demand. Moreover, when the credit market is imperfect, given that the relationship between lenders and borrowers is characterized by asymmetric information (Stiglitz and Weiss, 1981), the additional liquidity provided by the government, that issues bonds to finance unemployment benefits, mitigates the credit constraint to the economy. In such an asymmetric information context, the typical working of credit markets produces financially constrained business cycles (Greenwald and Stiglitz, 1993) and, consequently, the removal or at least the mitigation of the liquidity constraint may improve macroeconomic performances.

Challe et al. (2011) analyze the role of unemployment insurance when capital markets are imperfect, highlighting the macroeconomic nexus between unemployment benefits, public debt and liquidity-constrained firms. Their starting point is the idea that firms can mitigate the liquidity constraint through buying and holding liquid assets to be sold when they need to finance hiring and production (Holmstrom and Tirole, 1998). As a matter of fact, when firms are liquidity constrained, a higher public debt "increases the flexibility of the private sector in responding to variations in both income and spending opportunities, and so can increase economic efficiency" (Woodford, 1990, p. 382). According to Challe et al. (2011), the government raises public debt during recessions to transfer benefits to the unemployed, thus implying an increase of liquidity supply that relaxes the credit constraint faced by firms; in this way, the government (which does not follow a balanced public budget rule) dampens the fall of employment which happens during recessions and stimulates households' consump-

tions because (i) unemployed people now have an income to be spent, and (ii) the sustained aggregate demand improves firms' profits, thus allowing for higher consumption on the part of entrepreneurs too.

As suggested by the cited literature, then, issuing public securities the government improves liquidity conditions on private markets, so mitigating the credit constraint to firms and improving macroeconomic performance. As we will see, indeed, in our model the introduction of unemployment benefits modifies the financial conditions of the macroeconomy, for example influencing firms' leverage and banks' exposure and the impact of these financial variables on the business cycle. The recent financial turmoil has stressed the relevance of financial factors and the fundamental role of leverage cycles in shaping macroeconomic dynamics. Accordingly, many recent contributions have proposed an analysis of the leverage process both for firms and banks: Adrian and Shin (2008, 2009, 2010), Brunnermeier and Pedersen (2009), Flannery (1994), Fostel and Geanakoplos (2008), Greenlaw, Hatzius, Kashyap and Shin (2008), He, Khang and Krishnamurthy (2010), Kalemli-Ozcan et al. (2011). 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).

As for the capital structure of firms, almost all previous papers proposing an agent based approach assumed a "pecking order" theory (Donaldson, 1961; Myers and Majluf, 1984), according to which, when information is asymmetric, investments are financed first with internal funds, then with debt (if internal funds are not enough), and equity is used as a last resort. A different perspective on the firms' financial structure was proposed by the "trade-off" theory, firstly observed in a paper concerning asset substitution (Jensen and Meckling, 1976), and in a work on underinvestment (Myers, 1977). This theory is based on the trade-off between the costs and benefits of debt and implies that firms select a target debt-equity ratio. The empirical literature found at first contrasting evidence to support these theories. Then, a refined version of the trade-off theory was proposed: the "dynamic trade-off theory" (Flannery and Rangan, 2006). In this theory firms actively pursue target debt ratios even though market frictions temper the speed of adjustment. In other words, firms have long-run leverage targets, but they do not immediately reach them, instead they adjust to them during some periods. Dynamic trade-off seems to be able to overcome some puzzles related to the other theories, explaining the stylized facts emerged from the empirical analysis and numerous papers conclude that it dominates alternative hypotheses: Hovakimian et al. (2001), Graham and Harvey (2001), Mehotra et al. (2003), Flannery and Rangan (2006), Frank and Goyal (2008).

In this paper we implement an agent based model in which firms' capital structure is based on the Dynamic Trade-Off theory. According to this theory, we assume that firms have a "target leverage", that is a desired ratio between debt and net worth, and they try to reach it by following an adaptive rule governing credit demand. This capital structure is already

investigated in the agent based model proposed by Riccetti et al. (2011) that builds upon the previous work by Delli Gatti et al. (2010), which is based on a firms' capital structure given by the Pecking Order theory. The Dynamic Trade-Off theory has a relevant role in influencing the leverage cycle, with a strong impact on macroeconomic evolution.

The modeling framework in which we analyze the effects of introducing unemployment benefits on financial and macroeconomic conditions is the one proposed in Riccetti et al. (2012) according to which the macroeconomy is a *complex system* populated by heterogeneous agents (households, firms and banks) which directly interact in different markets (goods, labor, credit, and bank deposits). Then, there are two policy makers: the government and the central bank. 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, that is Walrasian, microfoundation. Indeed, when we consider that the economy is a *complex system* in which aggregate regularities (from meso to macro) emerge from the decentralized interaction of a multitude of autonomous agents, Heterogeneous Interacting Agents (HIA) constitutes an effective alternative to the Representative Agent (RA) hypothesis, which is instead the typical assumption made by mainstream macroeconomics. On these methodological bases, some recent contributions have proposed an analysis of economic policy issues as the role of monetary policy (Delli Gatti et al. 2005; Cincotti et al. 2010, 2012), fiscal policy and its effect on R&D dynamics (Russo et al., 2007), the combination of Keynesian management of aggregate demand and Schumpeterian policies aimed at promoting technological progress (Dosi et al., 2010), the interplay between income distribution and economic policies (Dosi et al., 2012), labor market policies (Neugart, 2008), the effects of introducing a Tobin-like tax (Westerhoff and Dieci, 2006; Mannaro et al. 2008;), and so on. Hence, agent based models represent an alternative formulation of microfoundations suited for a complex macroeconomic system and this different approach may have important implications for policy advice (Dawid and Neugart, 2011). For a comprehensive review, see Fagiolo and Roventini (2009, 2012).

With the present paper we add some results to the analysis of policy issues in an agent based macroeconomic framework. In particular, we show that the countercyclical intervention of the government stabilizes the aggregate demand and the resulting increase of the labor share, due to the introduction of unemployment benefits, does not damage the economic system (in term of firms' profitability) if the benefit paid to unemployed workers is within a certain range. Instead, when unemployment benefits goes beyond a "reasonable" level, the subsequent profit squeeze leads to a marked decrease of the labor demand, resulting in a large unemployment rate and then in a fall of aggregate demand, so amplifying the recessionary

phase.

The paper is organized as follows. Section 2 presents the model setup and the characteristics of the four markets which composes our economy: credit (subsection 2.1), labor (subsection 2.2), goods (subsection 2.3), and bank deposits (subsection 2.4); the evolution of agents' wealth is described in subsection 2.5, while the behavior of policy makers is discussed in subsection 2.6. Model dynamics are studied in section 3 in which we report the results of the simulation of the baseline model; we also provide some Monte Carlo experiments in order to analyze the interplay between financial and real factors, the characteristics of the business cycle and the behaviour of the system when an extended crisis happens. Then we provide a comparison of the baseline model with simulations performed in presence of unemployment benefits, highlighting the potential positive effect of government intervention. In section 5 we provide some concluding remarks.

## 2 The model

We consider a macroeconomy composed of households ( $h = 1, 2, \dots, H$ ), firms ( $f = 1, 2, \dots, F$ ), banks ( $b = 1, 2, \dots, B$ ), a central bank, and the government, which interact over a time span  $t = 1, 2, \dots, T$  in the following four markets: (i) credit market; (ii) labor market; (iii) goods market; (iv) deposit market.

Agents are boundedly rational and follow (relatively) simple rules of behaviour in an incomplete and asymmetric information context: households try to buy consumption goods from the cheapest supplier; firms try to accumulate profits by selling their products to households (they set the price according to their individual excess demand) and hiring cheapest workers; workers update the asked wage according to their occupational status (upward if employed, downward if unemployed); households' saving goes into bank deposits; given Basilea-like regulatory constraints, banks extend credit to finance firms' production; firms choose the banks offering lowest interest rates, while households deposit money in the banks offering the highest interest rates. The government hires public workers, taxes private agents and issues public debt. Finally, the central bank provides money to banks and to the government given their requirements.

To go into details, in each period, at first firms and banks interact in the credit market. Firms ask for credit to banks given the demand deriving from their net worth and leverage target; the leverage level changes according to expected profits and inventories. Banks set their credit supply depending on their net worth, deposits and the quantity of money provided by the central bank. As said above, they must comply with some regulatory constraints. Then, government, firms and households interact in the labor market. The government hires public workers. After, firms hire workers: labor demand depends on available funds, that is net worth and bank credit.

Subsequently, households and firms interact in the goods market. Firms produce consumption

goods on the basis of hired workers. They put in the goods market their current period production and previous period inventories. Households decide their desired consumption on the basis of their disposable income and wealth.

Finally, households determine their savings to be deposited in banks: banks and households interact in the deposit market.

The interaction between the demand and the supply sides of the four markets is set by the following decentralized matching protocol. In general, 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.

At the beginning, a random list of agents in the demand side – firms in the credit market, firms in the labor market, households in the goods market, and banks in the deposit market – is set. Then, the first agent in the list observes a random subset of potential partners; this subset represents a fraction  $0 < \chi \leq 1$  (which proxies the degree of imperfect information) of the whole set of potential partners; thus, the agent chooses the cheapest one. For example, in the labor market, the first firm on the list, say firm  $f_1$  observes the asked wage of a subsample of workers and chooses the agent asking for the lowest one, say worker  $h_1$ .

After that, the second agent on the list performs the same activity on a new random subset of the updated potential partner list. In the case of the labor market, the new list of potential workers to be hired no longer contains the worker  $h_1$ . The process iterates till the end of the demand side list (in our example, all the firms enter the matching process and have the possibility to employ one worker).

Then, 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).

As for the entry-exit process, new entrants replace bankrupted agents according to a one-to-one replacement. New agents enter the system with initial conditions we will define below. Moreover, the money needed to finance entrants is subtract from households' wealth.<sup>1</sup>

Now, we propose a detailed description of the markets.

## 2.1 Credit market

Firms aim at financing production and banks may provide credit to this end. 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:

$$B_{ft}^d = A_{ft} \cdot l_{ft} \tag{1}$$

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<sup>1</sup>In the extreme case in which private wealth is not enough, then government intervenes. However, we can anticipate that it never happens in our simulations.



The evolution of the leverage target depends on the following rule:

$$l_{ft} = \begin{cases} l_{ft-1} \cdot (1 + \alpha \cdot U(0, 1)), & \text{if } \pi_{ft-1}/(A_{ft-1} + B_{ft-1}) > i_{ft-1} \text{ and } \hat{y}_{ft-1} < \psi \cdot y_{ft-1} \\ l_{ft-1}, & \text{if } \pi_{ft-1}/(A_{ft-1} + B_{ft-1}) = i_{ft-1} \text{ and } \hat{y}_{ft-1} < \psi \cdot y_{ft-1} \\ l_{ft-1} \cdot (1 - \alpha \cdot U(0, 1)), & \text{if } \pi_{ft-1}/(A_{ft-1} + B_{ft-1}) < i_{ft-1} \text{ or } \hat{y}_{ft-1} \geq \psi \cdot y_{ft-1} \end{cases} \quad (2)$$

where  $\alpha > 0$  is a parameter representing the maximum percentage change of the relevant variable (in this case the target leverage),  $U(0, 1)$  is a random number picked from a uniform distribution in the interval  $(0, 1)$ ,  $\pi_{ft-1}$  is the gross profit (realized in the previous period),  $B_{ft-1}$  is the previous period effective debt,  $i_{ft-1}$  is the nominal interest rate paid on previous debts<sup>2</sup>,  $\hat{y}_{ft-1}$  represents inventories (that is, unsold goods),  $0 \leq \psi \leq 1$  is a parameter representing a threshold for inventories based on previous period production  $y_{ft-1}$ . Equation 2 means that the leverage target increases (decreases) if the profit rate is higher (lower) than average interest rate and there is a low (high) level of inventories.

On the supply side, bank  $b$  offers a total amount of money  $B_{bt}^d$  depending on net worth  $A_{bt}$ , deposits  $D_{bt}$ , central bank credit  $m_{bt}$ , and some legal constraints (proxied by the parameters  $\gamma_1 > 0$  and  $0 \leq \gamma_2 \leq 1$  that represents respectively the maximum admissible leverage and maximum percentage of capital to be invested in lending activities):

$$B_{bt}^d = \min(\hat{k}_{bt}, \bar{k}_{bt}) \quad (3)$$

where  $\hat{k} = \gamma_1 \cdot A_{bt}$ ,  $\bar{k} = \gamma_2 \cdot A_{bt} + D_{bt-1} + m_{bt}$ . Moreover, in order to reduce risk concentration, banks lend to a single firm up to a maximum fraction  $\beta$  of the total amount of the credit  $B_{bt}^d$ . This behavioural parameter can be also interpreted as a regulatory constraint to avoid excessive concentration.

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

$$i_{bft} = i_{CBt} + \hat{i}_{bt} + \bar{i}_{ft} \quad (4)$$

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 (with  $\rho > 0$ ).

The bank-specific component evolves as follows:

$$\hat{i}_{bt} = \begin{cases} \hat{i}_{bt-1} \cdot (1 - \alpha \cdot U(0, 1)), & \text{if } \hat{B}_{bt-1} > 0 \\ \hat{i}_{bt-1} \cdot (1 + \alpha \cdot U(0, 1)), & \text{if } \hat{B}_{bt-1} = 0 \end{cases} \quad (5)$$

where  $\hat{B}_{bt-1}$  is the amount of money that the bank did not manage to lend to firms in the previous period.

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<sup>2</sup>It is a mean interest rate calculated as the weighted average of interests paid to the lending banks.

As a result of the interaction based on the matching mechanism explained above, each firm ends up with a credit  $B_{ft} \leq B_{ft}^d$  and each bank lends to firms an amount  $B_{bt} \leq B_{bt}^d$ . The difference between desired and effective credit is equal to  $B_{ft}^d - B_{ft} = \hat{B}_{ft}$  and  $B_{bt}^d - B_{bt} = \hat{B}_{bt}$ , for firms and banks respectively. Moreover, we assume that banks ask for an investment in government securities equal to  $\Gamma_{bt}^d = \bar{k}_{bt} - B_{bt}$ . If the sum of desired government bonds exceeds the amount of outstanding public debt then the effective investment  $\Gamma_{bt}$  is rescaled according to a factor  $\Gamma_{bt}^d / \sum \Gamma_{bt}^d$ . Instead, if public debt exceeds the banks' desired demand, then the central bank buys the residual amount.

## 2.2 Labor market

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 the total capital available:  $A_{ft} + B_{ft}$ . Each worker posts a wage  $w_{ht}$  which is updated as follows:

$$w_{ht} = \begin{cases} w_{ht-1} \cdot (1 + \alpha \cdot U(0, 1)), & \text{if } h \text{ employed at time } t - 1 \\ w_{ht-1} \cdot (1 - \alpha \cdot U(0, 1)), & \text{if } h \text{ unemployed at time } t - 1 \end{cases} \quad (6)$$

The required wage has a minimum equal to:  $\theta \hat{p}_{t-1} (1 + \tau)$ , where  $\theta$  is a positive parameter,  $\hat{p}$  is the maximum price of a single good, and  $\tau$  is the tax rate on labor income. This means that a worker asks at least a wage net of taxes able to buy a multiple  $\theta$  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). Obviously, a fraction of households may remain unemployed. In the baseline model, the wage of unemployed people is set equal to zero.

Then, we remove this assumption by introducing an unemployment benefit paid by the government. Accordingly, if the  $h$ -th worker is unemployed at time  $t$  then her income is given by:

$$w_{ht} = \eta \hat{p}_{t-1} \quad (7)$$

where  $\eta$  is a positive parameter. We will explore the role of this parameter on model behavior in the computational experiments proposed below.

## 2.3 Goods market

In the credit market households represent the demand side, while firms are the supply side. Households set the desired consumption as follows:

$$c_{ht}^d = c_1 \cdot w_{ht} + c_2 \cdot A_{ht} \quad (8)$$

where  $0 < c_1 \leq 1$  is the propensity to consume current income,  $0 \leq c_2 \leq 1$  is the propensity to consume the wealth  $A_{ht}$ . If the amount  $c_{ht}^d$  is smaller than the average price of one good  $\bar{p}$  then  $c_{ht}^d = \min(\bar{p}, w_{ht} + A_{ht})$ . By summing up the individual consumption of households we obtain the aggregate demand. It is worth noticing that current income derives from both a cyclical private industrial sector and an acyclical public service sector.

The amount of goods produced by the  $f$ -th firm is given by:

$$y_{ft} = \phi \cdot n_{ft} \quad (9)$$

where  $\phi \geq 1$  is a productivity parameter.

Then, firms want to sell this produced output plus the inventories  $\hat{y}_{ft-1}$ . The selling price is set as follows:

$$p_{ft} = \begin{cases} p_{ft-1} \cdot (1 + \alpha \cdot U(0, 1)), & \text{if } \hat{y}_{ft-1} = 0 \text{ and } y_{ft-1} > 0 \\ p_{ft-1} \cdot (1 - \alpha \cdot U(0, 1)), & \text{if } \hat{y}_{ft-1} > 0 \text{ or } y_{ft-1} = 0 \end{cases} \quad (10)$$

Hence, the firm rises the price if there are no inventories (and it produced some goods in the previous period) and viceversa. The minimum price at which firms want to sell their 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 sell an amount  $0 \leq \bar{y}_{ft} \leq y_{ft}$  and they may remain with unsold goods; as a consequence, in the next period the firm will try to sell the inventories  $\hat{y}_{ft} = y_{ft} - \bar{y}_{ft}$ .

## 2.4 Deposit market

Banks represent the demand side of the deposit market (given that they require capital to extend credit) and households are on the supply side. Banks offer an interest rate on deposits according to their funds requirement:

$$i_{bt}^D = \begin{cases} i_{bt-1}^D \cdot (1 - \alpha \cdot U(0, 1)), & \text{if } \bar{k}_{bt} - B_{bt} - \Gamma_{bt} > 0 \\ \min\{i_{bt-1}^D \cdot (1 + \alpha \cdot U(0, 1)), i_{CBt}\}, & \text{if } \bar{k}_{bt} - B_{bt} - \Gamma_{bt} = 0 \end{cases} \quad (11)$$

where  $\Gamma_{bt}$  is the amount of public debt bought by bank  $b$  at time  $t$ . Hence, the previous equation states that 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.

Then, households set the minimum interest rate they want to obtain on bank deposits as follows:

$$i_{ht}^D = \begin{cases} i_{ht-1}^D \cdot (1 - \alpha \cdot U(0, 1)), & \text{if } D_{ht-1} = 0 \\ i_{ht-1}^D \cdot (1 + \alpha \cdot U(0, 1)), & \text{if } D_{ht-1} > 0 \end{cases} \quad (12)$$

where  $D_{ht-1}$  is the household  $h$ 's deposit in the previous period. This means that a household that 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. A household that decides to not deposit her money in a bank signals a preference for liquidity, because she does not accept to deposit her cash for an interest rate below the desired one.

## 2.5 Wealth dynamics

### 2.5.1 Firms

As a result of the outcomes of the credit, labor and goods markets, the firm  $f$ 's profit is equal to:

$$\pi_{ft} = p_{ft} \cdot \bar{y}_{ft} - W_{ft} - I_{ft} \quad (13)$$

where  $W_{ft}$  is the firm  $f$ 's wage bill, that 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  $\tau$  on positive profits; negative profits will be subtracted from the next positive profits. We indicate net profits with  $\bar{\pi}_{ft}$ .

Finally, firms pay a percentage  $\delta_{ft}$  as dividends on positive net profits. The fraction  $0 \leq \delta_{ft} \leq 1$  evolves according to the following rule:

$$\delta_{ft} = \begin{cases} \delta_{ft-1} \cdot (1 - \alpha \cdot U(0, 1)), & \text{if } \hat{y}_{ft} = 0 \text{ and } y_{ft} > 0 \\ \delta_{ft-1} \cdot (1 + \alpha \cdot U(0, 1)), & \text{if } \hat{y}_{ft} > 0 \text{ or } y_{ft} = 0 \end{cases} \quad (14)$$

This means that firms distribute less dividends when they need self-financing to expand production (that is, they do not have inventories) 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:

$$A_{ft} = (1 - \tau') \cdot [A_{ft-1} + \hat{\pi}_{ft}] \quad (15)$$

where  $\tau'$  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 takes its place. The initial net worth of the new entrant is a multiple of the average goods price, while the leverage is one. Moreover, the initial price is equal to the mean price of survival firms. Banks linked to defaulted firms lose a fraction of their loans (the loss given default rate is calculated as  $(A_{ft} + B_{ft})/B_{ft}$ ).

### 2.5.2 Banks

According to the operations in the credit and the deposit markets, the bank  $b$ 's profit is equal to:

$$\pi_{bt} = int_{bt} + i_t^\Gamma \cdot \Gamma_{bt} - i_{bt-1}^D \cdot D_{bt-1} - i_{CB}^t \cdot m_{bt} - bad_{bt} \quad (16)$$

where  $int_{bt}$  represents the interests gained on lending to non-defaulted firms,  $i_t^\Gamma$  is the interest rate on government securities ( $\Gamma_{bt}$ ), and  $bad_{bt}$  is the amount of “bad debt” due to bankrupted firms, that is non performing loans. Bad debt is the loss given default of the total loan, that is a fraction  $1 - (A_{ft} + B_{ft})/B_{ft}$  of the loan to defaulted firm  $f$  connected with bank  $b$ .

Banks pay a proportional tax  $\tau$  on positive profits; negative profits will be subtracted from the next positive profits. We indicate net profits with  $\bar{\pi}_{bt}$ .

Finally, banks pay a percentage  $\delta_{bt}$  as dividends on positive net profits. The fraction  $0 \leq \delta_{bt} \leq 1$  evolves according to the following rule:

$$\delta_{bt} = \begin{cases} \delta_{bt-1} \cdot (1 - \alpha \cdot U(0, 1)), & \text{if } B_{bt} > 0 \text{ and } \hat{B}_{bt} = 0 \\ \delta_{bt-1} \cdot (1 + \alpha \cdot U(0, 1)), & \text{if } B_{bt} = 0 \text{ or } \hat{B}_{bt} > 0 \end{cases} \quad (17)$$

Hence, 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:

$$A_{bt} = (1 - \tau') \cdot [A_{bt-1} + \hat{\pi}_{bt}] \quad (18)$$

where  $\tau'$  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  $(A_{bt} + D_{bt})/D_{bt}$ ). 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.

### 2.5.3 Households

As a result of interaction in the labor, goods, and deposit markets, the household  $h$ 's wealth evolves as follows:

$$A_{ht} = (1 - \tau') \cdot [A_{ht-1} + (1 - \tau) \cdot w_{ht} + div_{ht} + int_{ht}^D - c_{ht}] \quad (19)$$

where  $\tau'$  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),  $\tau$  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),  $int_{ht}^D$  represents interests on deposits, and  $c_{ht} \leq c_{ht}^d$  is the effective consumption. Households linked to defaulted banks lose a fraction of their deposits as already explained.

## 2.6 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.<sup>3</sup> 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  $\Psi_t$ . Consequently, public debt is  $\Gamma_t = \Gamma_{t-1} + \Psi_t$ .

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 Simulations

We explore the dynamics of the model by means of computer simulations over a time span of  $T = 150$  periods and analyze the results for the last 50 (so the first 100 are used to initialise the model). Table 1 reports the table containing the values of the parameters of the baseline simulation. The initial agents' wealth is set as follows:  $A_{f1} = \max\{0.1, N(3, 1)\}$ ,  $A_{b1} = \max\{0.2, N(5, 1)\}$ ,  $A_{h1} = \max\{0.01, N(0.5, 0.01)\}$ . The central bank sets the policy rate  $i_{CBt}$  at 1% and we leave this value unchanged during simulations.

In 995 out of 1000 Monte Carlo simulations, we observe the emergence of endogenous business cycles with the statistical characteristics reported in column with  $\eta = 0$  of Table 2. Along the typical business cycle, an increase of firms' profits determines an expansion of production and, if banks extend the required credit, this effect could be amplified resulting in

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<sup>3</sup>It could also spend an amount  $\Omega_t$  for extreme cases in which the government has to intervene to finance new entrants when private wealth is not enough. However, in our simulations this never happens.

Figure 1: Baseline model. Simulation results

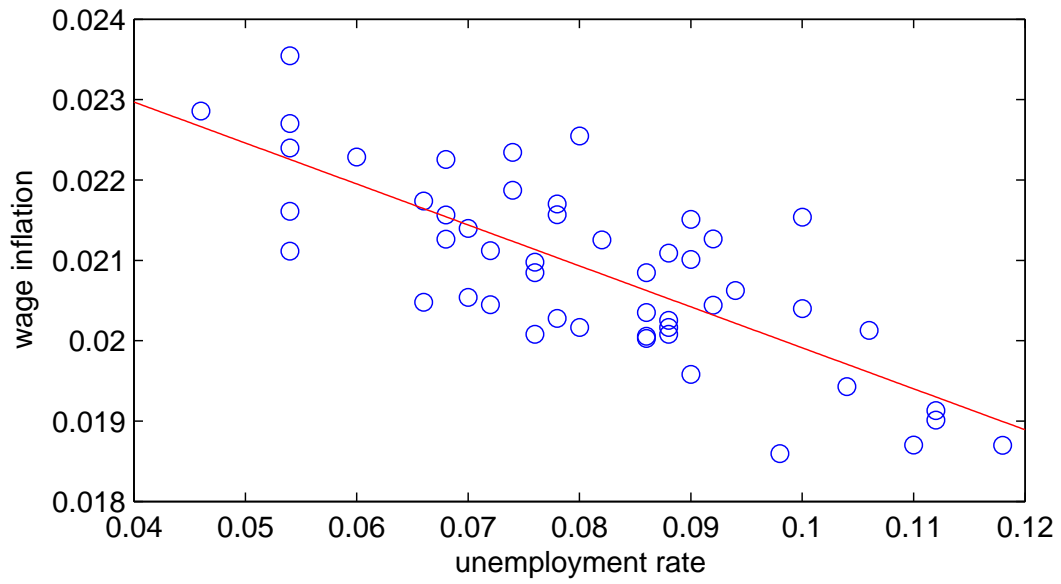
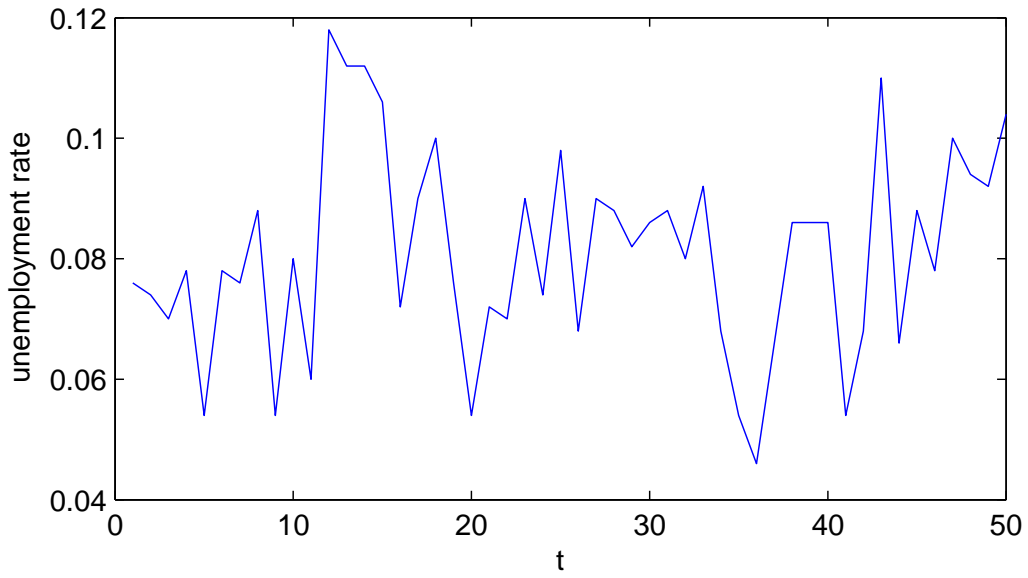


Table 1: Parameter setting

H	number of households	500
F	number of firms	80
B	number of banks	10
$\alpha$	adjustment parameter	0.05
$\chi$	matching imperfect information	0.2
$\psi$	inventory threshold	0.1
$\gamma_1$	max bank's leverage	10
$\gamma_2$	max % of bank's invested capital in lending	0.5
$\beta$	max bank's lending to single firm	0.5
$\rho$	risk premium on firm's loan	2
$c_1$	propensity to consume current income	0.8
$c_2$	propensity to consume wealth	0.3
$\theta$	minimum required wage	1
$\eta$	unemployment benefit	0
$\phi$	firm's productivity	3
$\tau$	tax rate on income	0.3
$\tau'$	tax rate on wealth	0.05
$\bar{\tau}'$	threshold for tax on wealth	3
$g$	% of public workers on population	0.33

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. In particular, Figure 1 displays the evolution of the unemployment rate along the business cycle (upper panel) and the inverse relationship between unemployment and wage inflation, that is the Phillips curve (lower panel). In other words, there is a dynamic relation between the unemployment and the profit rate: the increase of profits boosts the expansion of the economy and then a fall of the unemployment rate follows (negative correlation between the profit rate at time  $t - 1$  and the unemployment rate at time  $t$ ). The reduced unemployment increases wages, so firms want to save on production costs (e.g., wage bill) decreasing labor demand. This results in a rise of unemployment that, in turn, reduces the profit rate at time  $t + 1$  due to a lack of aggregate demand. However, the presence of unemployed people reduces wages and this stimulates firms to hire a larger number of workers, so boosting the beginning of a new expansionary phase of the business cycle.

As for the financial aspects of the cycle, firms' leverage and, in particular, banks' exposure enlarge business fluctuations: when firms are growing they ask for more credit and, if banks extended new loans, then they are able to expand the production; after a while, the rise of em-



ployment fosters wages that, together with the rise of interest payments on an increasing 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. Then, banks' capitalization is the most important determinant of credit conditions, so influencing firms' leverage and the macroeconomic evolution. Moreover, the presence of the government, representing an acyclical sector, plays a central role in mitigating output volatility through stabilizing the aggregate demand.

In the remaining 5 out of 1000 simulations 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 decrease of wages due to growing unemployment does not reverse the cycle, but rather amplifies the recession due to the lack of aggregate demand. Indeed, real wage lowers excessively resulting 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 deteriorates. In these cases, the system may remain trapped in a large crisis unless an exogenous intervention.

## 4 Unemployment benefits

In this section we investigate the effects of introducing unemployment benefits (UB) in the model. As explained above, in this case the government pays a benefit to unemployed workers which is given by equation 7. In particular, we set  $\eta = 0$  in the baseline model, while  $\eta = 0.5$  in the UB scenario.

### 4.1 Baseline model vs. unemployment benefit scenario

As clearly emerges from the Table 2, the average rate of unemployment is markedly lower in the UB scenario (about 6.5%) than in the baseline model (almost 10%). Moreover, we observe a fall of the default rate for both firms and banks, an improvement of credit conditions (from an excess demand to an excess supply of credit in the average), an increase of both firm leverage and bank exposure, while the corresponding volatilities decrease. The negative effects of the government intervention, that is the slight increase of both the average inflation rate (from 1.99% to 2.15%) and the average ratio between the public deficit and the nominal GDP (from 3.26 to 3.37), have a modest impact on the macroeconomy. In particular, the larger public expenditure due to providing benefits to unemployed people is quite well compensated by the increased level of taxes (with an unchanged taxation rate) deriving from a higher level of GDP in an economy with a lower rate of unemployment. Then, the government successfully

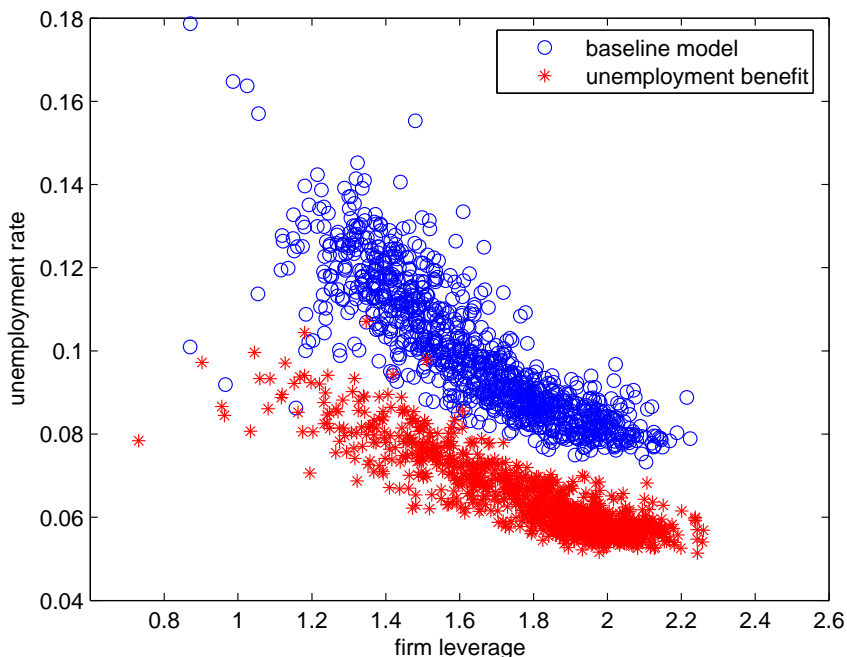
intervenes in the economy through providing unemployment benefits: indeed, in this case unemployed workers can buy more goods (otherwise they can spend only a fraction of their wealth), indeed the wage share is slightly larger in the UB scenario, so increasing the demand for produced goods and then firms' profits; this leads to more employment which further enlarges the aggregate demand. In other words, government intervention through unemployment benefits stabilize the aggregate demand and the system is more stable nevertheless a higher level of both firm leverage and bank exposure. This also means that public intervention looses the credit constraint to the economy; indeed, the larger credit availability results in a lower average rate of interest. In other words, a more leveraged financial sector sustains the expansion of the economy when the government provides more liquidity to the system through the countercyclical mechanism of unemployment benefits, with the fundamental cooperation of the central bank which buys the outstanding public debt.

Table 2: Monte Carlo for  $\eta = 0$  and  $\eta = 0.5$  (time span 101-150) of simulations with average unemployment rate below 20%.

Variable	$\eta = 0$	$\eta = 0.5$
Sim. with ur < 20%	995	1000
Unemployment rate	9.92%	6.46%
Unemployment volatility	2.05%	1.52%
Firm default rate	6.45%	3.36%
Bank default rate	0.57%	0.07%
Wage share	63.4%	65.2%
Public deficit	3.26%	3.37%
Interest rate	9.11%	7.67%
Inflation rate	1.99%	2.15%
Credit constraint	14.83%	-3.78%
Firm mean leverage	1.65	1.80
Bank mean exposure	3.27	3.40
Firm leverage volatility	0.12	0.09
Bank exposure volatility	0.51	0.30

According to what explained above regarding the role of financial factors, the introduction of unemployment benefits leads to an increase of both the mean firm leverage and the mean bank exposure; moreover, for every level of both firm leverage and bank exposure we clearly observe a lower rate of unemployment, as shown in Figures 2 and 3. Another relevant aspect is the non-linear relationship that emerges in the figures. For relatively high levels of firm leverage the unemployment rate tends to be smaller and less volatile; however, for largest values of the firm leverage (above 2) the negative relation with the unemployment rate tends to disappear (Figure 2). As for banks, starting from low levels, an increase of bank exposure

Figure 2: Average unemployment rate and mean firm leverage: Monte Carlo simulations for the baseline model (“circle”) and the unemployment benefit scenario (“star”).



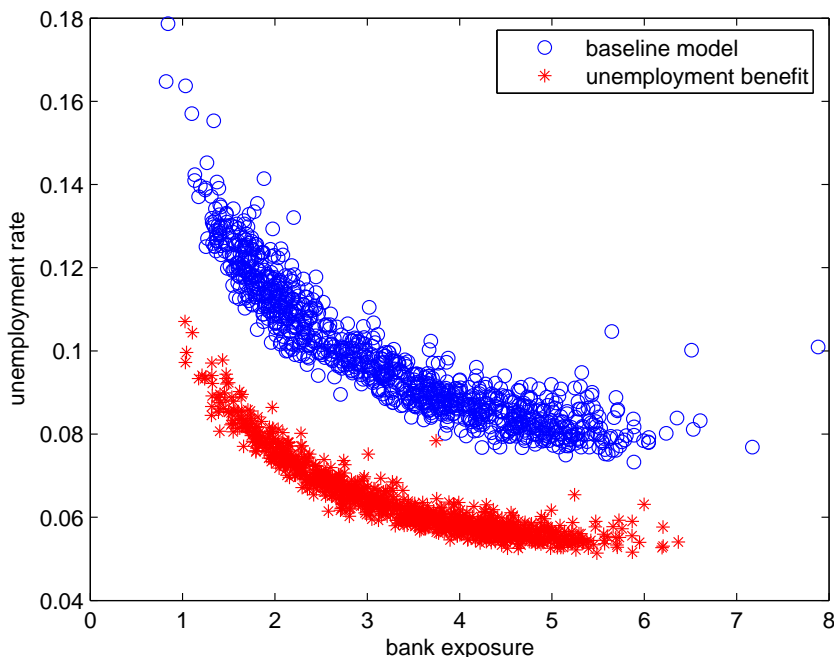
reduces the rate of unemployment; instead, for high levels of bank exposure (above 5) a further increase makes the unemployment higher. In other words, if banks increase their exposure enlarging credit to firms, the latter hire more workers and the unemployment rate decreases. But, when the exposure of banks becomes “excessive” this leads to instability (more defaults) and the rate of unemployment may increase (Figure 3). Moreover, in the UB scenario the relationship between the financial factors and the unemployment rate is flatter and less volatile. This confirms that the government intervention through UB reduces the unemployment rate and stabilizes the macroeconomy.

## 4.2 Sensitivity analysis

In this section we perform a sensitivity analysis on the parameter  $\eta$  that determines the size of unemployment benefits. In particular, we run 1000 simulations for 25 different values of  $\eta$ , from 0 to 2.4 with 0.1 step, then 40 replications for each step. We set  $\theta = \eta$  so that the wage required by households is higher or at least equal to the unemployment benefit.

Figure 4 displays the impact of the parameter  $\eta$  on the following variables: (i) the unemployment rate, (ii) the firm default rate, (iii) the bank default rate, and (iv) the real wage. As it clearly emerges, for low levels of  $\eta$  the real wage is low and the resulting lack of aggregate demand leads to a higher number of both firms and bank defaults, and a consequent high rate of unemployment. As  $\eta$  increases there is a rise of the real wage and a consequent increase and

Figure 3: Average unemployment rate and mean bank exposure: Monte Carlo simulations for the baseline model (”circle”) and the unemployment benefit scenario (”star”).



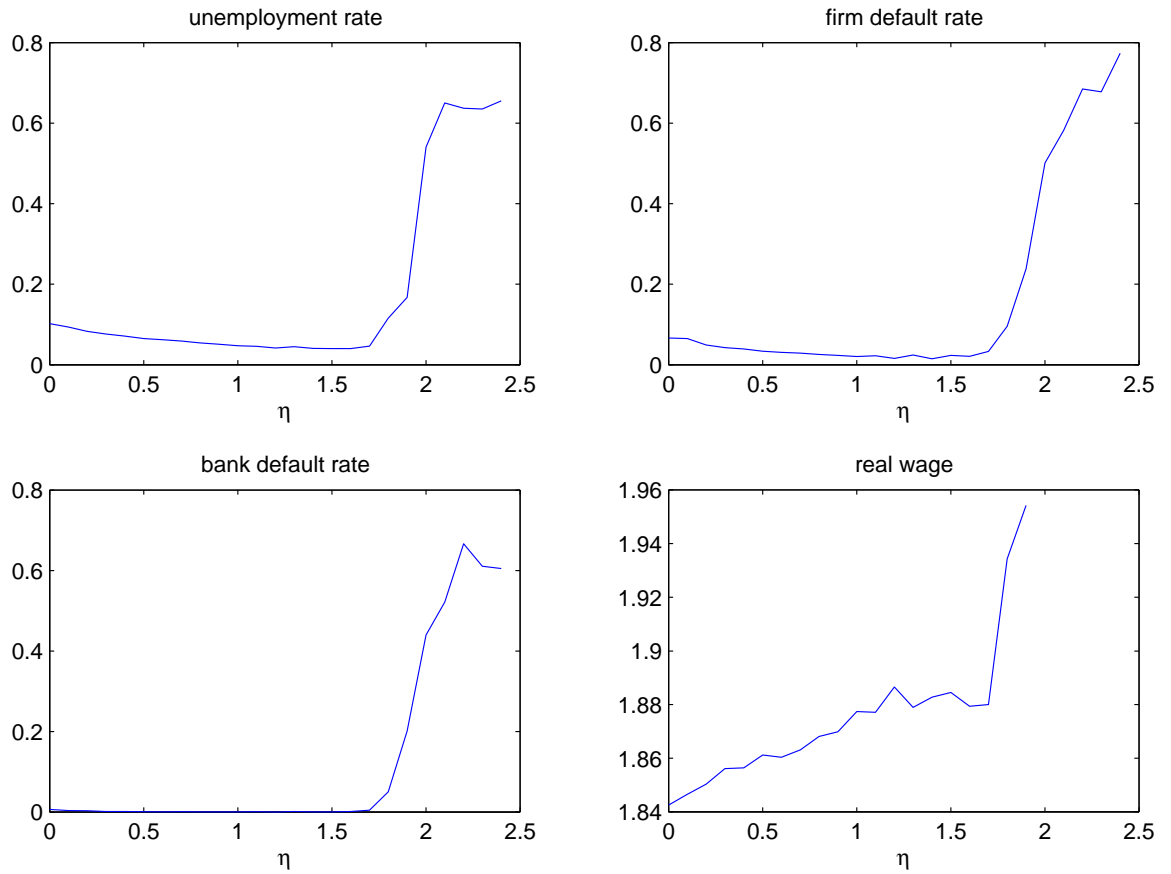
stabilization of the aggregate demand, with a parallel improvement of financial conditions. This evidently confirms the results explained in the previous section.

To better appreciate the positive impact of unemployment benefits on macroeconomic conditions, we present the same sensitivity analysis for a reduced interval of the parameter  $\eta$ , that is from 0 to 1.7, in Figure 5. Looking at that figure, we can clearly see that when  $\eta$  is zero the unemployment rate is about 10%, the firm default rate is almost 7%, the bank default rate is around 0.6%, and the real wage is slightly higher than 1.84. As  $\eta$  grows until about 1.5 the system displays a decreasing rate of unemployment, a rise of the real wage, and a reduction of both the firm and the bank default rate (in the latter case there is a relevant decrease until when  $\eta$  reaches about 0.5; after that, the number of bank defaults remains near zero till  $\eta$  reaches 1.5).

However, for large values of  $\eta$  the real wage strongly increase and the resulting profit squeeze leads to bankruptcy chains (e.g., the default rate for both firms and banks goes above 50% when  $\eta$  is about or more than 2) and to large crises with more than half people in the unemployment status; the consequent fall of aggregate demand reinforces the recession in a vicious circle.

Hence, the growth of  $\eta$  produces beneficial effects on the economy till a threshold of about 1.5. For higher values, the impact of  $\eta$  tends to reverse. Moreover, the behavior of the system radically changes when the value of  $\eta$  tends to approach 2. We can explain this feature of our model in the following way. When  $\eta$  is between 0 and about 1.8, the macroeconomy is char-

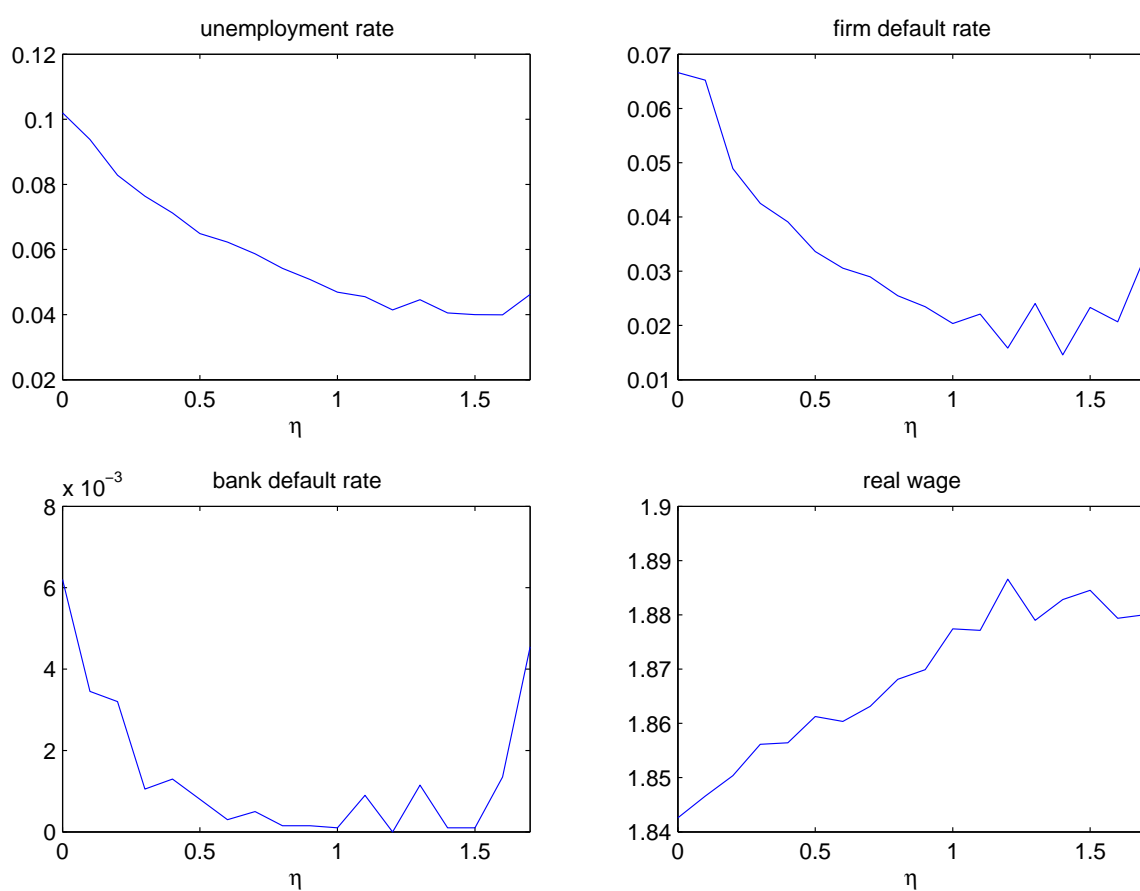
Figure 4: Sensitivity analysis on the impact of the parameter  $\eta$  – from 0 to 2.4 with step 0.1 – on the unemployment rate, firm default rate, bank default rate, and real wage.



acterized by a statistical equilibrium (as a composition of heterogeneous out-of-equilibrium behaviors of single agents) with typical business fluctuations (that is, without large crises), a reasonable rate of unemployment, quite stable financial conditions, and a real wage in the range 1.8-1.9. When the value of  $\eta$  is above 1.8, the intervention of the government through unemployment benefits forces the real wage to be larger than a value compatible with the previously described statistical equilibrium and, therefore, the economy tends to crash.

To sum up, we observe a negative impact of the unemployment benefit on the economy only if its value is “excessive”, that is when the unemployment benefit approaches the mean real wage of employed people. Instead, for a large range below this threshold, increasing unemployment benefits clearly improves the performance of the economic system via the positive effect on the aggregate demand.

Figure 5: Sensitivity analysis on the impact of the parameter  $\eta$  – from 0 to 1.7 with step 0.1 – on the unemployment rate, firm default rate, bank default rate, and real wage.



## 5 Concluding remarks

We propose an agent based decentralized matching macroeconomic model that allowed us to investigate the role of government intervention, based on providing unemployment benefits, in mitigating business cycle fluctuations through both improving the financial conditions of the system and sustaining the aggregate demand. This result depends on a fruitful cooperation between the fiscal policy implemented by the government and monetary policy managed by the central bank.

Our artificial macroeconomy is composed of heterogeneous agents, that is households, firms, banks, which interact in four markets (credit, labor, goods, and deposit markets), and two policy makers: a central bank and the government. Agents are boundedly rational and operate in an incomplete and asymmetric information setting by following quite simple rules of behaviour. Households buy consumption goods from the cheapest supplier, update the asked wage according to their occupational status (upward if employed, downward if unemployed), and deposit money in the bank offering a satisfactory interest rates; given Basilea-like regulatory constraints, banks extend credit to finance firms' production; firms choose the banks offering lowest interest rates, and they are aimed at accumulating profits by selling their products to households and hiring cheapest workers. The government hires public workers, taxes private agents and issues public debt. Finally, the central bank provides money to banks, by managing the supply of money, and the government, by buying outstanding public securities.

In our macroeconomic setting, the consequence of government issuing public securities to finance unemployment benefits is twofold: (i) the public sector transfers a benefit to unemployed people so providing an additional income to be spent, that is the aggregate demand increases due to public resources; (ii) the public sector provides liquidity to the private sector so mitigating the credit constraints to firms and then improving financial conditions. In other words, a more leveraged financial sector sustains the expansion of the economy when the government provides more liquidity to the system through the countercyclical mechanism of unemployment benefits, with the collaboration of the central bank which buys the outstanding public debt.

We think that our model can provide some suggestions to interpret, at least some aspects of, the recent evolution of economic and financial conditions in many countries, after the 2007 financial crisis and the recessive phase that followed the collapse of Lehman Brothers on September 15th, 2008. The current crisis is characterized by financial turmoil on international markets and a slowdown of economic growth in many (advanced) countries, especially in the periphery of the Euro area. The *austerity* strategy is boosting a recessive spiral and the aim of reaching balanced public finances seems to be impossible to obtain, at least in a reasonable time. Indeed, cutting public expenditure and rising taxation is leading to higher unemployment in context of low confidence that results in a lack of private investment, also because

the financial sector, that is banks, is not providing all the credit needed by firms to finance production, and governments are cutting public investments and the welfare state. According to the IMF, in advanced economies, stronger planned fiscal consolidation is associated with lower growth than expected early in the crisis, and this seems to be due to the fact that fiscal multipliers are substantially higher than implicitly assumed by forecasters (Blanchard and Leigh, 2013).

Moreover, financial conditions in the Euro area, as proxied by the behaviour of *spreads* between the interest rate paid on the 10-year German Bund and that paid on other bonds, have been improved only after the announcement of OMT (Outright Monetary Transactions) by the ECB President Mario Draghi with which the central bank can intervene on secondary markets through buying government securities if a country ask for an ESM (European Stability Mechanisms) help and then commits its fiscal policy to be subjects to certain conditions to assure fiscal consolidations. This may suggest that a full operativity of the ECB, that is as a lender of last resort that can also buy outstanding public debt, can be of great help in assuring “orderly market conditions”, while instead just a commitment to objective of a stable and moderate inflation rate may not be enough for financial stability of the Euro area.

Although the interplay between real and financial aspects, in the Euro area as well as in other countries, gives rise to very complex questions, which are hard to solve on the basis of the simulation results of a single model, we show that in our agent based macroeconomic setting the central bank can positively contribute to the financial stability of the system by cooperating with the government, so reinforcing the objectives of fiscal policy. Maybe, then, a high degree of cooperation between the policy makers may be thought as a possible direction to follow (that is an aspect to be reconsidered). Moreover, instead of cutting public expenditure, the government may improve the macroeconomic performance by a countercyclical action like the one based on providing unemployment benefits, taking care of avoiding an excessive intervention that may instead squeeze profits and lead the economy towards recession.

As for future research, our aim is to further improve our macroeconomic setting by introducing new markets, for instance a market for investment goods and then a mechanism of technological progress underlying economic growth, heterogeneous rules of consumption and the possibility of consumption credit, more complicated financial behavior based on managing portfolio choices, and so on, in order to develop a useful tool for interpreting the evolution of economic and financial conditions and to analyze policy issues.



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