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Monetary Policy and Large Crises in a Financial Accelerator Agent-Based Model

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Abstract

An accommodating monetary policy followed by a sudden increase of the short term interest rate often leads to a bubble burst and to an economic slowdown. Two examples are the Great Depression of 1929 and the Great Recession of 2008. Through the implementation of an Agent Based Model with a financial accelerator mechanism we are able to study the relationship between monetary policy and large scale crisis events. The main results can be summarized as follow: a) sudden and sharp increases of the policy rate can generate recessions; b) after a crisis, returning too soon and too quickly to a normal monetary policy regime can generate a "double dip" recession, while c) keeping the short term interest rate anchored to the zero lower bound in the short run can successfully avoid a further slowdown.

Keywords: Monetary Policy, Large Crises, Agent Based Model, Financial Accelerator, Zero Lower Bound .
JEL classification codes: E32, E44, E58, C63.

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1 Introduction

As highlighted by Fratianni and Giri (2015), monetary policy played a non negligible role in both the largest disruptive events of the 20^{th} century, the Great Depression of 1929 and the Great Recession of 2008. The combination of a long-lasting accommodating monetary policy just followed by a sharp and quick monetary contraction results to be a powerful destabilizing mechanism.

To support this view, Taylor (2009, 2007) compared the behavior of the monetary policy conducted by the Federal Reserve and the predicted values implied by a simple Taylor rule.

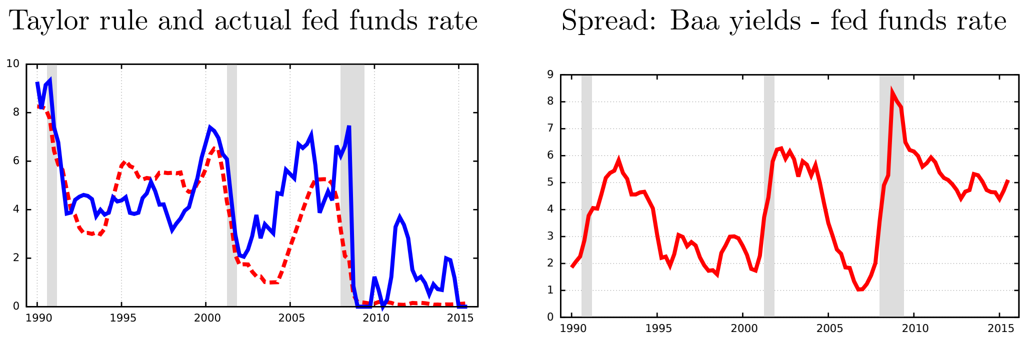
Figure 1 shows that, during the period 2001-2004, the fed funds rate was well below, almost 300 basis points at the end of 2004, the value predicted using a standard Taylor rule (see Taylor, 1993). This part of the decade is usually referred as the "Greenspan put", that is a period of exceptionally low interest rates and expansionary monetary policy under the Fed chairman Alan Greenspan.

The reason of such an aggressive expansionary monetary policy can be traced back to the burst of the "dot com" bubble in 2000-2001. The following recession forced the Federal Reserve to take drastic measures in order to restore the normal functioning of the US economy.

Credit provided by financial intermediaries to buy new houses became cheaper, fueling a bubble on the housing market (see Bordo and Landon-Lane, 2013, and Ferrero, 2015). At the end of 2004, the concerns about a possible resurgence of inflation convinced the governor of the Fed, Ben Bernanke, to abandon the accommodating monetary policy started by his predecessor. He increased the fed funds rate sharply from a value slightly above 1 % to a new one of 5.25 % in less than two years.

Monetary policy actions were also transmitted to the real economy through

Figure 1



Source: FRED database and authors calculations. Left graph: the expression of the Taylor rule is taken from Taylor (1993). $i_{tr} = max\{0, 4\% + 1.5(\pi_t - 2\%) + 0.5\widetilde{y}\}$. The red dashed line represents the effective fed funds rate, the blue line are the values predicted according to the Taylors rule. Grey bars represent recessions according to the NBER classification.

an increase of the interest rates on loans to firms. Following Gilchrist and Zakrajsek (2012), we calculate and report in Figure 1 the spread between the Baa corporate bond yields and the effective Fed funds rate. The cost of external funding rose of more than 8 % during the 2007 financial crisis with respect to the risk free rate.

The main consequence in 2008 of this combination of events was the burst of the sub-prime mortgages crisis (and, consequently, the end of the expansion of the American housing market) and a generalized economic downturn.

Monetary policy after the Great Recession changed radically and it was characterized by extreme monetary policy measures that pushed the interest rates closed to the zero lower bound of interest rates (henceforth ZLB). Moreover, once the ZLB was reached and the effectiveness of monetary policy based on steering the short term interest rates was undermined, central banks began to experiment unexplored way to stimulate the economy.[1]

The aim of this paper is to provide answers to three important questions: a) is there a macroeconomic relationship between monetary policy and large scale crisis events? b) Is the so called "Forward Guidance" of short term interest rates an effective tools of unconventional monetary policy? c) After a crisis, should the conduction of monetary policy return to a normal implementation as soon as possible or is it desirable to keep the interest rates close to the ZLB for an extended period of time?

In order to do that, we built an Agent Based Macroeconomic model (henceforth ABM) with interacting agents including a financial accelerator mechanism as in Bernanke et al. (1999), that is the standard mechanism to introduce financial frictions in the classical DSGE models.

Why do we use an ABM model? Following Quadrini (2011), heterogeneity is an essential element of every DSGE model with financial intermediaries, but taking into account the entire distribution of agents became a daunting task as soon as the model is enriched along several dimensions. The most common shortcut in the mainstream literature is to assume the existence of two representative heterogeneous agents, borrowers and savers, like in

[1]For instance, Fed, Bank of Japan (BoJ), Bank of England (BoE) and European Central Bank (ECB) perform several quantitative easing programs in order to reduce the medium term interest rate and to increase the value of the financial assets. Moreover, the ECB breaks the ZLB for marginal deposit operations since June 2014 (and now this interest rate is set at -0.40%) and it is now programming negative interest rates also for targeted long-term refinancing operations in order to subsidize banks to lend money to the non-financial sector.

Kiyotaki and Moore (1997). Alternatively, one can assume the existence of a continuum of agents (like in Bernanke et al. (1999) and Carlstrom and Fuerst (1997)). The behavior of such agents can be summarized by a single equation thank to the linear aggregation (Quadrini, 2011, p 215). Implementing the financial accelerator framework into an ABM seems to be a natural extension of such models.

Moreover, ABMs have been already used as computational tools to investigate economic policy issues in a macroeconomic framework: for instance, Delli Gatti et al. (2005) explore the role of monetary policy in a complex system with agent's learning; Russo et al. (2007) focus on fiscal policy and its effect on R&D dynamics; Haber (2008) investigates the effect of both fiscal and monetary policies; Cincotti et al. (2010, 2012a) investigate the causes of macroeconomic instability and, in particular, the role of deleveraging; Babutsidze (2012) analyzes the implications for monetary policy of price-setting; Cincotti et al. (2012b) analyze the role of banking regulation finding that both unregulated financial systems and overly restrictive regulations have destabilizing effects; Dosi et al. (2013) consider the interplay between income distribution and economic policies; Salle et al. (2013) focus on inflation targeting; Dosi et al. (2015) evaluate the effect of both fiscal and monetary policy in complex evolving economies; da Silva and Lima (2015) studies the interplay between the monetary policy rate and financial regulation; Krug et al. (2015) evaluate the impact of Basel III on financial instability; Ashraf et al. (2016) analyze the impact of the trend rate of inflation on macroeconomic performance; Riccetti et al. (2016) explore the effects of banking regulation on financial stability and endogenous macroeconomic crises. All in all, ABMs represent an alternative approach for studying a complex macroeconomy that may highlight relevant implications for economic policy design

(Dawid and Neugart, 2011).[2]

Another fundamental issue is the way in which financial factors are included into a macroeconomic model that is strictly related to the problem of replicating, at least qualitatively, the dynamic evolution of the spread between the lending rates and the policy rate.

DSGE models literature focuses its attention on two different approaches to include financial factors into general equilibrium set up, the collateral constraint like in Kiyotaki and Moore (1997) and the already mentioned financial accelerator mechanism like in Bernanke et al. (1999). The first approach focuses its attention on the importance of collateral provided by the borrowers that cannot receive a loans for an amount larger than the expected value of their collaterals, typically physical capital or housing services. Instead, the financial accelerator mechanism boils down from a costly state verification problem. Monitoring a loan is costly for financial intermediaries forcing them to apply a spread over the risk free interest rate, the so called external risk premium.

We decide to include in our ABM a financial accelerator mechanism for two main reasons. The first is a modeling choice since, as we previously stated, the financial accelerator can be naturally extended in a framework with heterogeneous agents. The second motivation is empirical. The financial accelerator seems to perform better with respect to the collateral constraint set up in order to reproduce the same stylized facts like volatilities and hump shape responses of the same variables of interest (Brzoza-Brzezina et al., 2013).

The main findings of our contribution are the followings: a) An increase of short term interest rates can generate a large scale crisis if the increase

[2]See also Fagiolo and Roventini (2012) and Gaffard and Napoletano (2012).

happens too quickly and too sharply; b) after a crisis, if the central bank returns too early to conduct monetary policy steering the short term interest rates, the possibility of falling in a "double dip" recession is significant, while c) keeping short term interest rates close to the zero lower bound helps the central bank to stabilize the economy, at least in the short run.

The paper is organized as follow: Section 2 presents the ABM model in details, while Section 3 shows the general properties of the model, the descriptions of a large scale crisis events produced by the model and a counterfactual unconventional monetary policy experiments. Section 4 summarizes the main findings and the possible future developments of this work.

2 The model

In this section we provide a description of the ABM we propose to analyze macroeconomic dynamics and, in particular, the behavior of the monetary authority during large crisis events. It is worth to notice that model dynamics are not limited to the relationship between monetary policy and recessions. Indeed, the model is able to endogenously reproduce a variety of macroeconomic scenarios and different typology of crises, such as crises due to real factors. Our choice in this paper is, however, to focus on the particular nexus between the central bank's behavior and the evolution of crises.

In what follows, firstly, we present the set up of the model; secondly, we describe the sequence of events occurring in our economy; then, we provide a more detailed explanation of agents' behavior and the working of markets.

2.1 Model setup

The economy evolves over a time span $t = 1, 2, ..., T$ and it is composed of households ($h = 1, 2, ..., H$), capital goods firms ($k = 1, 2, ..., K$), consumption goods firms ($f = 1, 2, ..., F$), a banking system, 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 behavior and use adaptive expectations. For the sake of simplicity, we assume that consumption goods are produced by means of capital goods and that capital goods are produced only by employing labor. This simplifying assumption allows us to border the direct interaction between firms and workers in the labor market to one typology of firms, that is capital goods producers. Although this may lead to a certain loss of realism, for instance resulting in a higher volatility of unemployment, it does not prevent the model to qualitatively explain various characteristics of the business cycles. Moreover, we focus more on financial aspects, as the dynamics of interest rates' spread, than on the level of unemployment.[3]

Agents interact in five markets: credit, labor, investment goods, consumption goods and deposits. The first and the last market in the previous list are not based on a decentralized mechanism, while in other markets the interaction mechanism that matches the demand and the supply sides follows a common decentralized matching protocol (Riccetti et al., 2015). In particular, the interaction process develops as follows: a random list of agents on the demand side is set, then the first agent on the list observes a random subset of potential counterparts on the supply side, the size of which depends on a parameter $0 < \chi \leq 1$ (that proxies the degree of imperfect information), and

[3] In order to reduce unemployment volatility, an alternative choice would be to increase the number of "public workers" to have a larger a-cyclical sector in the economy.

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 until 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 continues 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 available to the richest firm) is lower than the lowest *ask* (for example, the lowest wage asked by unemployed workers).

2.2 Sequence of events

The sequence of events runs as follows.

- At the beginning of each period, new entrants substitute bankrupted agents according to a one-to-one replacement.[4]
- The capital used by consumption goods producers depreciates.
- Firms set their desired production based on past production, expected profitability and the level of inventories.
- Based on desired production and given the expected price of capital, consumption goods producers derive total financing; the demand for credit is then given by total financing less net worth plus the possible outstanding debt.

[4]The initial net worth is related to the average price of consumption goods and capital goods, respectively, for the two types of firms; if the banking sector fails then an initial net worth, tied to the firms' net worth, is given to the new bank; the total amount of resources needed to finance new entrants is subtracted from the flow of dividends to be distributed to households (and only the remaining part is actually distributed); in the case total dividends are not enough to cover the total net worth of entrants, the government intervenes.

- Based on desired production, capital producers set their labor demand; the resulting demand for credit is given by the expected wage bill minus internal resources plus the possible outstanding debt previously received.

- The credit market opens: the demand of credit comes from both capital and consumption goods producers; the supply of credit is set by the banking system as a multiple of its net worth; in particular, credit supply increases (decreases) as the bank's profit increases (decreases); in the case the demand is higher than the supply, firms are credit rationed proportionally. Firms' liquidity is then given by both internal and external resources.

- The bank sets interest rates by charging a risk premium on firm loans which gives rise to the financial accelerator mechanism.

- Insolvent as well as illiquid firms are declared bankrupted; the banking system suffers non-performing loans for the fraction of loans not repaid by firms; moreover, the bank comes into the possession of firms' inventories of capital and consumption goods, respectively, that it tries to sell at a discounted price in the respective markets.

- The labor market opens: employed workers get their wage on which they pay a proportional tax; the unemployment rate can be computed; some vacancies may remain unfulfilled due to both mismatch between the supply and the demand of labor and a lack of aggregate demand.

- Workers update their desired wage: upwards if employed, downwards otherwise; however, the desired wage has a lower bound tied to the price of consumption goods.

- Capital goods are produced by employing the hired workers; current production plus inventories is available on the market to be sold to consumption goods producers.
- The capital goods market opens and a decentralized matching between firms takes place; due to both a lack of demand and supply/demand mismatch, some capital goods may remain unsold and then considered as inventories.
- Consumption goods are produced by employing capital goods; current production plus inventories is available on the market to be sold to households.
- The consumption goods market opens and a decentralized matching between firms and households takes place: due to both a lack of demand and supply/demand mismatch, some consumption goods may remain unsold and then considered as inventories.
- Firms update their selling prices.
- Households' saving is deposited in the banking system and gives rise to the payment of an interest on which depositors pay a proportional tax; households also pay a wealth tax according to a proportional tax rate.
- The public deficit and the public debt is computed.
- Government securities are bought by the banking sector; in the case the private demand for these bonds is below the supply, the central bank buys the difference.

- Depending on the balance sheet of the banking sector, the central bank either provides money injection or receives reserves.
- Firms compute their profits on which they pay a proportional tax (negative profits are subtracted from the tax that the firm should pay on next positive profits); a fraction of net profits is distributed as dividends to households (proportionally to their relative wealth); then, firms' net worth is updated.
- In the case firms' liquidity is negative, they decide to ask a bank loan to cover it (if in the next period they do not receive such a loan, they go bankrupt).
- The banking sector computes its profit on which it pays a proportional tax (negative profits are subtracted from the tax that the bank should pay on next positive profits); a fraction of the net profit is distributed as dividends to households (proportionally to their relative wealth); then, the net worth of the banking sector is updated.
- Aggregate variables are computed.
- The central bank sets the policy rate for the next period according to the Taylor rule.

In next subsections, we describe in more detail the behavior of agents and the specific structure of different markets.

2.3 Consumption goods producers

Firms that produce consumption goods use capital goods as the only factor of production. Capital goods owned by consumption goods producers depreciates at the rate δ. Consequently, the number of capital goods of the firm f at the beginning of period t is:[5]

$$x'_{ft} = \left\|(1-\delta)x''_{ft-1}\right\| \tag{1}$$

where x''_{ft-1} represents the capital goods already owned by the firm.[6]

The desired level of sales for consumption goods producers depends on past sales, profits and inventories as follows:

$$\bar{y}^d_{ft} = \begin{cases} \bar{y}_{ft-1} \cdot (1 + \alpha \cdot U(0,1)), & \text{if } \ \pi_{ft-1} > 0 \text{ and } \hat{y}_{ft-1} < \psi \cdot y_{ft-1} \\ \bar{y}_{ft-1}, & \text{if } \ \pi_{ft-1} = 0 \text{ and } \hat{y}_{ft-1} < \psi \cdot y_{ft-1} \\ \bar{y}_{ft-1} \cdot (1 - \alpha \cdot U(0,1)), & \text{if } \ \pi_{ft-1} < 0 \text{ or } \hat{y}_{ft-1} \geq \psi \cdot y_{ft-1} \end{cases} \tag{2}$$

where $\bar{y}_{ft-1}$ represents the quantity of consumption goods sold in the previous period, $\alpha > 0$ is the maximum percentage change of the target sales, $U(0,1)$ is a uniformly distributed random number, π_{ft-1} is the previous period gross profit, $\hat{y}_{ft-1}$ are inventories of consumption goods, and $0 \leq \psi \leq 1$ is a threshold for inventories compared to past production y_{ft-1}.

Taking into account the level of inventories, firms decide their desired

[5] We assume that the number of capital goods has to be an integer. For this reason we use the *round* operator in Equation 1.

[6] Obviously we take into account the actual value of capital goods, e.g. without rounding to the nearest integer, that we use to calculate the depreciation of capital goods. In other words, while x' is an integer number representing the number of capital goods from the previous period to be used in production at time t, x'' is the actual value of capital goods that we use in the next period to compute the depreciation. Let's make a numerical example: suppose, for instance, that firm A has 2 capital goods at time 1, and that the depreciation rate is 20%. At the end of period 1 its capital goods are depreciated to 1.6. Therefore at period 2, assuming no other capital goods purchase, it uses again 2 capital goods. At the end of period 2, we depreciate the capital goods starting from 1.6 (and not from 2 again!) to 1.28, therefore firm A in period 3 has only 1 capital good available for production.

production as the consumption goods to be added to inventories, considering that the lower bound for production depends on available capital goods:

$$y^d_{ft} = max(\bar{y}^d_{ft} - \hat{y}_{ft-1},\ \phi_K x'_{ft}) \tag{3}$$

where ϕ_K is an integer number which represents the productivity of capital goods. Afterwards, firms determine the demand for new capital goods to be used in the production of final goods:

$$x^d_{ft} = max\left(0,\ \frac{y^d_{ft}}{\phi_K} - x'_{kt}\right) \tag{4}$$

The total financing of desired production x^d_{ft} depends on the expected price of capital as follows:

$$\gamma^d_{ft} = x^d_{ft}\ p^K_{t-1}\left(1 + \dot{p}^K_{t-1}\right) \tag{5}$$

where p^K_{t-1} is the average price of capital in the previous period and $\dot{p}^K_{t-1}$ is the last period inflation rate of capital price.

Given the amount of internal resources and the outstanding debt, the credit demand of consumption goods producers is:

$$b^d_{ft} = max\left(0,\ \gamma^d_{ft} - \gamma_{ft-1} + \bar{b}_{ft-1}\right) \tag{6}$$

where γ_{ft-1} is the liquidity already available, and $\bar{b}_{ft-1}$ is the debt needed by the firm to cover negative liquidity resulted in the previous period.[7]

[7] As we will see, if the firm does not obtain at least $\bar{b}_{ft-1}$ it goes bankrupt.

2.4 Capital goods producers

The desired level of sales for capital goods producers depends on past sales, profits and inventories as follows:

$$\bar{x}^d_{kt} = \begin{cases} \bar{x}_{kt-1} \cdot (1 + \alpha \cdot U(0,1)), & \text{if } \pi_{kt-1} > 0 \text{ and } \hat{x}_{kt-1} < \psi \cdot x_{kt-1} \\ \bar{x}_{kt-1}, & \text{if } \pi_{kt-1} = 0 \text{ and } \hat{x}_{kt-1} < \psi \cdot x_{kt-1} \\ \bar{x}_{kt-1} \cdot (1 - \alpha \cdot U(0,1)), & \text{if } \pi_{kt-1} < 0 \text{ or } \hat{x}_{kt-1} \geq \psi \cdot x_{kt-1} \end{cases} \tag{7}$$

where $\bar{x}_{kt-1}$ represents the quantity of capital goods sold in the previous period, π_{kt-1} is the previous period gross profit, $\hat{x}_{kt-1}$ are inventories of capital goods, and x_{kt-1} stays for past production.

The labor demand of consumption goods producers is given by:

$$l^d_{kt} = max\left(1, \left\|\frac{\bar{x}^d_{kt}}{\phi_L}\right\|\right) \tag{8}$$

where ϕ_L is an integer number representing the productivity of labor. Accordingly, all firms demand at least one worker in each time period.

Total financing required to hire workers depends on the expected wage bill as follows:

$$\gamma^d_{kt} = l^d_{ft}\ w_{t-1}\,(1 + \dot{w}_{t-1}) \tag{9}$$

where w_{t-1} is the average wage of the previous period and $\dot{w}_{t-1}$ is the last period wage inflation rate.

Given the amount of internal resources and the outstanding debt, the credit demand of capital goods producers is:

$$b_{kt}^d = max\left(0,\ \gamma_{kt}^d - \gamma_{kt-1} + \bar{b}_{kt-1}\right) \tag{10}$$

where γ_{kt-1} is the liquidity already available, and $\bar{b}_{kt-1}$ is the debt needed by the firm to cover negative liquidity resulted in the previous period.[8]

2.5 Credit market

Consumption goods producers, capital goods producers and the banking system interact in the credit market. Summing up the credit demand of both capital goods producers and consumption goods producers we obtain the total demand of credit B_t^d. The banking system sets the credit supply B_t^s depending on its net worth A_t^b and the propensity to lend ρ_t:

$$B_t^s = \rho_t A_t^b \tag{11}$$

The propensity to lend evolves as follows:

$$\rho_t = \begin{cases} \rho_{t-1} \cdot \alpha_B \cdot (1 + U(0,1)) & \text{if } \left(int_{t-1} - bad_{t-1} + rep_{t-1}\right)/A_{t-1}^b > i_{t-1}^{CB} \\ \rho_{t-1} \cdot \alpha_B \cdot (1 - U(0,1)) & \text{if } \left(int_{t-1} - bad_{t-1} + rep_{t-1}\right)/A_{t-1}^b < i_{t-1}^{CB} \\ \rho_{t-1} & \text{otherwise} \end{cases} \tag{12}$$

where $\alpha_B > 0$ is an adjustment parameter, int_{t-1} represents the interest gained on loans to firms, bad_{t-1} stays for non-performing loans, rep_{t-1} is the repossession of inventories (both capital and consumption goods) in case of

[8] As for consumption goods producers, if the firm does not obtain at least $\bar{b}_{kt-1}$ it goes bankrupt.

firm defaults,[9] and i^{CB}_{t-1} is the policy rate.[10]

Given B^d_t and B^s_t, two cases can emerge: (i) if $B^d_t \leq B^s_t$ then all firms obtain the requested credit; in this case the bank employs the difference $B^s_t - B^d_t$ to buy government securities; (ii) if $B^d_t > B^s_t$ then firms are rationed proportionally to the ratio B^s_t/B^d_t. Either in one case or in the other, the loans received by firms are represented by b_{ft} and b_{kt} for consumption goods producers and capital goods producers, respectively.

As in Bernanke et al. (1999), the bank charges a risk premium on firm loans as follows:

$$rp_{zt} = i^{CB}_{t-1} \cdot \left(\frac{a_{zt-1}}{b_{zt}} \right)^{\nu} \tag{13}$$

where $z = f, k$ indexes a firm, a_{zt-1} is the firm's net worth, and $\nu < 0$ is the parameter that governs the financial accelerator mechanism. Therefore, a firm with a higher leverage (computed as the ratio between debt and net worth), that is a riskier firm, pays a higher interest rate.

Then, the interest rate charged on firm loans is:[11]

$$i_{zt} = i^{CB}_{t-1} + rp_{zt} \tag{14}$$

Finally, the liquidity available for a generic firm z is given by the sum of initial liquidity, γ_{zt-1}, and the loan provided by the bank, b_{zt}. If such a loan does not cover at least the negative liquidity inherited from the previous period, the firm goes bankrupt, even if its net worth is positive. Thus, this

[9] The value of the variable rep is given by the inventories repossessed by the bank in the last period and sold in the market at a discounted price (see below for the setting of that price).

[10] The bank compares the remuneration of firm loans to the policy rate as an alternative investment, that is buying government bonds.

[11] In the case the policy rate reaches the Zero Lower Bound, the interest rate on the firm z is: $i_{zt} = \sigma \cdot \left(\frac{a_{zt-1}}{b_{zt}} \right)^{\nu}$, where $\sigma > 0$ is a parameter.

is a default due to a liquidity shortage. The other condition for bankruptcy is that the net worth of the firm is negative. In this case, the default is due to insolvency. Defaulted firms are inactive during the next phases of the current period and their inventories (both consumption and capital goods) are repossessed by the bank, so that it can covers, at least partially, the loss due to non-performing loans generated by firm bankruptcies.

2.6 Labor market

Capital goods producers and the government on the demand side and households on the supply side interact in the labor market according to the decentralized matching process described above. First of all, the government hires a fraction g of households picked at random from the whole population. The remaining part is available for working in private firms. The number of workers hired by the k-th firm is $l_{kt} \leq l^d_{kt}$.

On the supply side, each worker posts a wage w_{ht} that increases if she was employed in the previous period, and vice versa:

$$w_{ht} = \begin{cases} w_{ht-1} \cdot (1 + \alpha \cdot U(0,1)) & \text{if } \ h \text{ employed at time } t-1 \\ w_{ht-1} \cdot (1 - \alpha \cdot U(0,1)) & \text{otherwise} \end{cases} \tag{15}$$

Moreover, the requested wage has a minimum value which is tied to the price of consumption goods. Due to mismatch firms may remain with unfulfilled vacancies as well as workers may remain unemployed, also due to the lack of demand. Unemployed people gain no labor income nor receive unemployment benefits. Households pay a proportional tax on gross wage w'_{ht} so that the net labor income is equal to $w_{ht} = (1 - \tau^W_{t-1})w'_{ht}$, where τ^W_{t-1}

is set by the government in a way we will explain below.

2.7 Capital goods market

The supply side of this market is composed of both capital goods producers and the bank (that sells capital goods repossessed after firm defaults). The production of capital goods involves only labor as input in the following way:

$$x_{kt} = \phi_L l_{kt} \tag{16}$$

Capital goods producers try to sell on the market the new capital goods and the inventories (if present) at the price they set at the end of the last period, according to a mechanism we will explain in a while. As for the bank, it sets a discounted price $\bar{p}^K_t$ by applying a markdown β on the previous period lowest price p^{Kmin}_{t-1}, that is $\bar{p}^K_t = (1-\beta) \cdot p^{Kmin}_{t-1}$, in order to sell the capital goods repossessed.

The demand side of the capital goods market is represented by consumption goods firms. Even in this market agents interact according to a decentralized matching. The number of capital goods bought by the *f-th* firm at time t is x_{ft}, while the number of capital goods sold by the *k-th* firm at time t is $\bar{x}_{kt}$. Unsold capital goods are kept by capital goods producers as inventories to be sold in the next period.[12]

The gross profit of capital goods producers can be computed as follows:

$$\pi''_{kt} = p^K_{kt-1} \cdot \bar{x}_{kt} - wb_{kt} - int_{kt} \tag{17}$$

where wb_{kt} is the wage bill and int_{kt} represents the interest paid on the

[12]It is very unlikely that the bank does not sell all capital goods repossessed due to the discounted price. However, if the bank remains with unsold goods these are eliminated at no costs.

bank loan. The net profit is $\pi'_{kt} = (1-\tau^K_{t-1})\pi''_{kt}$, where τ^K_{t-1} is the proportional tax rate set by the government according to a rule we will explain below. Negative profit is used to reduce the taxes on next positive profit. If the profit is positive, a fraction of it is distributed to households, proportionally to their wealth, as dividends. Subtracting the dividends div_{kt} to the profit net of tax, we obtain π_{kt}. In particular, the dividend distributed is equal to $div_{kt} = \eta_{kt-1}\pi'_{kt}$, where η_{kt-1} depends on the weight of indebtedness on firm's total liquidity, that is the fraction of profit to be distributed increases if the liquidity is larger than the bank loan, and vice versa:

$$\eta_{kt} = \begin{cases} min\,(1,\ \eta_{kt-1} \cdot (1 + \alpha \cdot U(0,1))) & \text{if } \gamma_{kt} > b_{kt} \\ min\,(1,\ \eta_{kt-1} \cdot (1 - \alpha \cdot U(0,1))) & \text{otherwise} \end{cases} \tag{18}$$

Based on production and the selling performance, firms update the price of capital that will be applied in the next period:

$$p^{K'}_t = \begin{cases} p^K_{kt-1} \cdot (1 + \alpha \cdot U(0,1)) & \text{if } x_{kt} > 0 \text{ and } \hat{x}_{kt} = 0 \\ p^K_{kt-1} \cdot (1 - \alpha \cdot U(0,1)) & \text{otherwise} \end{cases} \tag{19}$$

Therefore, the price increases if the firm sold all produced capital goods plus inventories, and vice versa. The price of capital for each capital goods producer will be in any case equal or higher than the average cost of production (plus the interest on the bank loan):

$$p^K_{kt} = max\left(p^{K'}_{kt},\ \frac{wb_{kt} + int_{kt}}{x_{kt}}\right) \tag{20}$$

Finally, firms check the available liquidity: $\gamma_{kt} = \gamma_{kt-1} + p^K_{t-1} \cdot \bar{x}_{kt} - wb_{kt} - int_{kt} - div_{kt} - b_{kt}$; in case of a negative value, they ask for a bank loan aimed at covering this imbalance. Therefore, the additional demand of credit, to be asked in the next period, is equal to:

$$\bar{b}_{kt} = \begin{cases} 0 & \text{if } \gamma_{kt} \geq 0 \\ -\gamma_{kt} & \text{otherwise} \end{cases} \tag{21}$$

Finally, firms update their net worth:

$$a_{kt} = p^K_{kt-1} \cdot \hat{x}_{kt} + \gamma_{kt} - \bar{b}_{kt} \tag{22}$$

where $p^K_{kt-1} \cdot \hat{x}_{kt}$ is the value of inventories. Therefore, if the firm has not a debt to cover past negative liquidity, that is $\bar{b}_{kt} = 0$, the net worth is equal to the sum of the value of inventories and the cash flow. Otherwise, this has to be reduced for an amount given by outstanding debt.

2.8 Consumption goods market

The final goods market involves the households on the demand side, while the supply side is composed of both consumption goods producers and the bank (that sells consumption goods repossessed after firm defaults). Households set the desired consumption on the basis of their disposable income and wealth:

$$c^{d'}_{ht} = max\,(\bar{p}_t, c_w \cdot w_{ht} + c_a \cdot a_{ht-1}) \tag{23}$$

where $0 < c_w < 1$ and $0 < c_a < 1$ are the propensity to consume out of income and wealth, respectively, a_{ht-1} is the net wealth accumulated till the previous period, and $\bar{p}_t$ is the average price of consumption goods. Accordingly, we assume that households desire to consume at least one good, therefore the level of the desired consumption is not smaller than the average price of one consumption good. Moreover, a budget constrain has to be considered as a household, given that consumer credit is not allowed, cannot spend more than available resources, so that the (financially constrained) desired consumption is: $c^d_{ht} = min\left(c^{d'}_{ht}\ ,\ w_{ht} + a_{ht-1}\right)$.

Firms produce consumption goods by means of capital goods:

$$y_{ft} = \phi_K \cdot x_{ft} \tag{24}$$

Firms try to sell the current production y_{ft} and the previous period inventories $\hat{y}_{ft-1}$. The number of consumption goods sold by the firm f at time t is $\bar{y}_{ft}$. The gross profit of consumption goods producers can be computed as follows:

$$\pi''_{ft} = p_{ft-1} \cdot \bar{y}_{ft} - xb_{ft} - int_{ft} \tag{25}$$

where xb_{ft} is the total cost of capital goods and int_{ft} represents the interest paid on the bank loan. The net profit is $\pi'_{ft} = (1 - \tau^F_{t-1})\pi''_{ft}$, where τ^F_{t-1} is the proportional tax rate set by the government according to a rule we will explain below. Negative profit is used to reduce the taxes on the next positive profit. If the profit is positive, a fraction of it is distributed to households, proportionally to their wealth, as dividends. Subtracting the dividends div_{ft} to the profit net of tax, we obtain π_{ft}. In particular, the dividend distributed is equal to $div_{ft} = \eta_{ft-1}\pi'_{ft}$, where η_{ft-1} depends on the weight of indebtedness on firm's total liquidity, that is the fraction of profit to be distributed increases if the liquidity is larger than the bank loan, and vice versa:

$$\eta_{ft} = \begin{cases} min\left(1,\ \eta_{ft-1} \cdot (1 + \alpha \cdot U(0,1))\right) & \text{if } \gamma_{ft} > b_{ft} \\ min\left(1,\ \eta_{ft-1} \cdot (1 - \alpha \cdot U(0,1))\right) & \text{otherwise} \end{cases} \tag{26}$$

At the end of the decentralized interaction process between the supply and the demand sides in the consumption goods market, firms may remain with unsold goods (inventories) that they will try to sell in the next period. At the same time, each household ends up with a residual cash which does not cover the purchase of additional goods. This amount is considered as involuntary saving. The fraction of households' income which is not spent to consume goods, the interest (net of taxes) received on the previous deposit and distributed dividends form the voluntary saving, on which households pay a wealth tax at the fixed rate τ^A. The household deposits the whole saving (net of the tax wealth) at the bank.[13]

Based on production and selling performance, firms update the price of consumption goods to be applied in the next period:

$$p'_{ft} = \begin{cases} p_{ft-1} \cdot (1 + \alpha \cdot U(0,1)) & \text{if } y_{ft} > 0 \text{ and } \hat{y}_{ft-1} = 0 \\ p_{ft-1} \cdot (1 - \alpha \cdot U(0,1)) & \text{otherwise} \end{cases} \tag{27}$$

Moreover, the minimum price at which the firm wants to sell its output is set such that it is at least equal to the average cost of production (plus interest on the bank loan int_{ft}):

$$p_{ft} = max\left(p'_{ft},\ \frac{wb_{ft} + int_{ft}}{y_{ft}}\right) \tag{28}$$

The liquidity available to consumption goods producers after the closing of the consumption goods market is:

$$\gamma_{ft} = \gamma_{ft-1} + p_{t-1} \cdot \bar{y}_{kt} - xb_{ft} - int_{ft} - div_{ft} - b_{ft} \tag{29}$$

In case of a negative value, they ask for a bank loan aimed at covering

[13]The setting of the interest rate on deposits i_t^D will be described below.

this imbalance. Therefore, the additional demand of credit is equal to:

$$\bar{b}_{ft} = \begin{cases} 0 & \text{if } \gamma_{ft} \geq 0 \\ -\gamma_{ft} & \text{otherwise} \end{cases} \tag{30}$$

Finally, firms update their net worth:

$$a_{ft} = \hat{p}^K_{ft} \cdot x''_{ft} + p_{ft} \cdot \hat{y}_{ft} + \gamma_{ft} - \bar{b}_{ft} \tag{31}$$

where $\hat{p}^K_{ft}$ is the weighted average price of capital paid during the decentralized matching by the *f-th* firm.

2.9 The banking sector

The profit of the bank is given by:

$$\pi^{b''}_t = int_t + int^G_t + int^{RE}_t + rep_t - i^D_t D_t - int^{CB}_t - bad_t \tag{32}$$

where int_t represents the interest on loans to both consumption and capital goods producers, int^G_t is the interest on government bonds, int^{RE}_t is the interest on reserves deposited at the central bank, rep_t stays for the repossession of both capital and consumption goods after firm's default, i^D_t is the interest rate on deposits, D_t represents households' deposits, int^{CB} is the interest rate on central bank's money injection, and bad_t refers to non-performing loans due to firms' default. The bank pays a proportional tax on positive profit at the rate τ^B_t (see below for its setting), so that the net profit is $\pi^{b'}_t = (1 - \tau^B_t)\pi^{b''}_t$. Negative profit is used to reduce the taxes on the next positive profit. If the profit is positive, a fraction of it, that is $div^b_t = \eta^b_{t-1}\pi^{b'}_t$, is distributed as dividends to households, proportionally to their wealth. The factor η^b_t evolves according to the evolution of the bank's profit rate and the balance sheet as follows:

$$\eta_t^b = \begin{cases} min\left(1,\ \eta_{t-1}^b \cdot \left(1 + \alpha^B \cdot U(0,1)\right)\right) & \text{if } \frac{\pi_{t-1}^{b''}}{a_{t-1}^b} > \frac{\pi_{t-2}^{b''}}{a_{t-2}^b} \text{ and } re_{t-1} > 0 \\ min\left(1,\ \eta_{t-1}^b \cdot \left(1 - \alpha^B \cdot U(0,1)\right)\right) & \text{otherwise} \end{cases} \tag{33}$$

where re_{t-1} represents the banks' free reserves at the central bank. Therefore, the bank distributes more dividends if the growth of the profit rate is positive and it has reserves at the central bank, and vice versa. The bank's profit net of both tax and dividend is then $\pi_t^b = \pi_t^{b'} - div_t^b$. Based on that, the banks' net worth is equal to $a_t^b = a_{t-1}^b + \pi_t^b$.

Before interacting with the central bank, the bank's balance sheet presents firm loans and government securities on the assets side, households' deposits and the net worth on the liabilities' side. Depending on the combination of these variables, the bank either receives money injections (on which it pays an interest at the policy rate i_t^{CB}) or holds deposits in an account with the central bank (on which it receives an interest at the rate $i_t^{CB}(1-\omega)$, where $\omega > 0$ is a markdown).

2.10 Government

Government's expenditure is given by the wage bill to pay public workers and the interest paid on government bonds (bought by the bank and/or by the central bank); in case of bank and/or firm defaults, if the aggregate dividend is not enough to cover the negative net worth, the government intervenes and another source of expenditure has to be considered. As for government's revenues, we consider tax revenues and the transfer from the central bank.[14]

[14] All in all, the interest paid by the government to the central bank is then repaid by the central bank to the government.

The evolution of public debt, $PDebt_t$ depends on the accumulation of deficits $PDef_t$ (or surpluses, in these cases $PDef_t$ is negative): $PDebt_t = PDebt_{t-1} + PDef_t$.[15] Government securities are bought by the banking sector. If the private demand is not enough to cover the whole debt, then the central bank buys the difference.

The tax rates on agents' income evolves according to the following fiscal rule:

$$\tau_t^q = \begin{cases} \tau_{t-1}^q \cdot [1 + \alpha^\tau \cdot U(0,1)] & \text{if } \frac{PDebt_t}{GDP_t} > \frac{PDebt_{t-1}}{GDP_{t-1}} \\ \tau_{t-1}^q & \text{if } \frac{PDebt_t}{GDP_t} = \frac{PDebt_{t-1}}{GDP_{t-1}} \\ \tau_{t-1}^q \cdot [1 - \alpha^\tau \cdot U(0,1)] & \text{otherwise} \end{cases} \tag{34}$$

where the q indexes the various agents composing the economy, that is capital goods firms, consumption goods firms, households and the banking sector. For each typology of agents a different tax rate is computed according to the above fiscal rule, that is the same rule is applied but for different random numbers. This means that if the ratio between the public debt and the GDP is increasing, then all agents will be taxed more but the tax rate can be different for each typology of agents, due to the sequence of random numbers.

2.11 Central bank

The central bank sets the policy rate i_t^{CB} according to the following Taylor rule:

[15] If $PDebt_t$ becomes negative, this is considered as cash to be used in the next period to cover government expenditures.

$$i_t^{CB} = max\left(0,\ \bar{r}\ (1-\phi_R) + \phi_R\ i_{t-1}^{CB} + (1-\phi_R)\ (\phi_{\dot{p}}\ (\dot{p}_t - \dot{p}^T) - \phi_U\ (u_t - u^T))\right) \tag{35}$$

where $\bar{r}, \phi_R, \phi_{\dot{p}}, \phi_U$ are positive parameters, u_t is the unemployment rate at time t, $\dot{p}^T$ and u^T are the central bank's targets for inflation and unemployment, respectively. Similarly to Gerali et al. (2010), the parameter $\bar{r}$ represents the long run level of the short-term interest rate.

Based on the banking sector's balance sheet, the central bank either provides money injections or receives reserves. Finally, the central bank is committed to buy outstanding government securities for the fraction of public debt not covered by the the bank's demand.

3 Simulation results

We run 100 Monte-Carlo replications of the model. The length of each replication is 1000 periods with the first 300 draws used as transient and not taken into account in the simulation analysis. Firstly, we assess some of the generic features of the model focusing on the first and second moment of several variables of interest checking the accuracy of the results with respect to different values of the parameter ν related to the financial accelerator mechanism. Secondly, we present two alternative policy scenarios that can be implemented by the central bank once a large scale crisis event occurred. The baseline scenario is consistent with the idea that the central bank has to switch back immediately to a conduction of monetary policy implemented following a standard Taylor rule. The alternative scenario is consistent with the possibility that the central bank can keep the short term interest rate close to the ZLB for several periods in the simulation. Table 1 reports the values of parameters used in the simulations.

Table 1: Calibrated parameters

Parameter	Definition	Value
H	Number of households	400
F	Number of consumption good producers	50
CP	Number of capital good producers	150
ϕ_L	Labor productivity	1
ϕ_K	Capital productivity	10
ν	Financial accelerator parameter	-0.05
σ	Risk free rate under ZLB	0.005
δ	Depreciation rate of capital	0.01
ψ	Inventory parameter	0.1
ϕ_R	Interest rate degree of stickiness	0.8
ϕ_p	Coeff. Inflation target	1.5
ϕ_U	Coeff. Unempl. target	0.1
$\bar{r}$	Long run interest rate	0.02
$\dot{p}^T$	Central Bank inflation target	0.04
u^T	Central Bank unemployment target	0.08
g	Public workers	0.4
c_a	Propensity to consume out of income	0.8
c_w	Propensity to consume out of wealth	0.3
β	Discounted price mark down	0.3
ω	Deposits mark down	0.2
χ	Share of partners matching problems	0.5
α	Behavioral adjustment parameter	0.1
α^T	Fiscal rule adjustment parameter	0.05
α_B	Bank's adjustment parameter	0.05
τ^A	Wealth tax	0.03

3.1 Simulations of the baseline model

Table 2 reports theoretical moments of our Monte Carlo simulations and the relative empirical counterparts taken from US data from 1990:Q1 to 2015:Q4. In general, the model presents a higher volatility with respect to the data due to the decision of linking employment to the sector of capital goods that is more volatile than consumption goods sector. Nevertheless, the model is able to replicate satisfactorily several stylized facts especially the ones related to interest rates and spreads

Table 2: Theoretical and empirical moments of Monte Carlo simulations

	Theoretical moments		Empirical moments	
Variables	Mean	Standard deviation	Mean	Standard deviation
Growth rate	0.040	0.077	0.044	0.020
Inflation	0.040	0.067	0.024	0.011
Policy rate	0.023	0.024	0.032	0.024
Unemployment rate	0.116	0.143	0.061	0.016
i^k	0.050	0.045	0.072	0.014
i^f	0.080	0.063		
Spread: $i^k - i$	0.027	0.022	0.041	0.016
Spread: $i^f - i$	0.057	0.046		

Note: empirical moments are calculated on US data, 1990:Q1-2015:Q4. Source: FRED database, see data appendix for a description of the data.

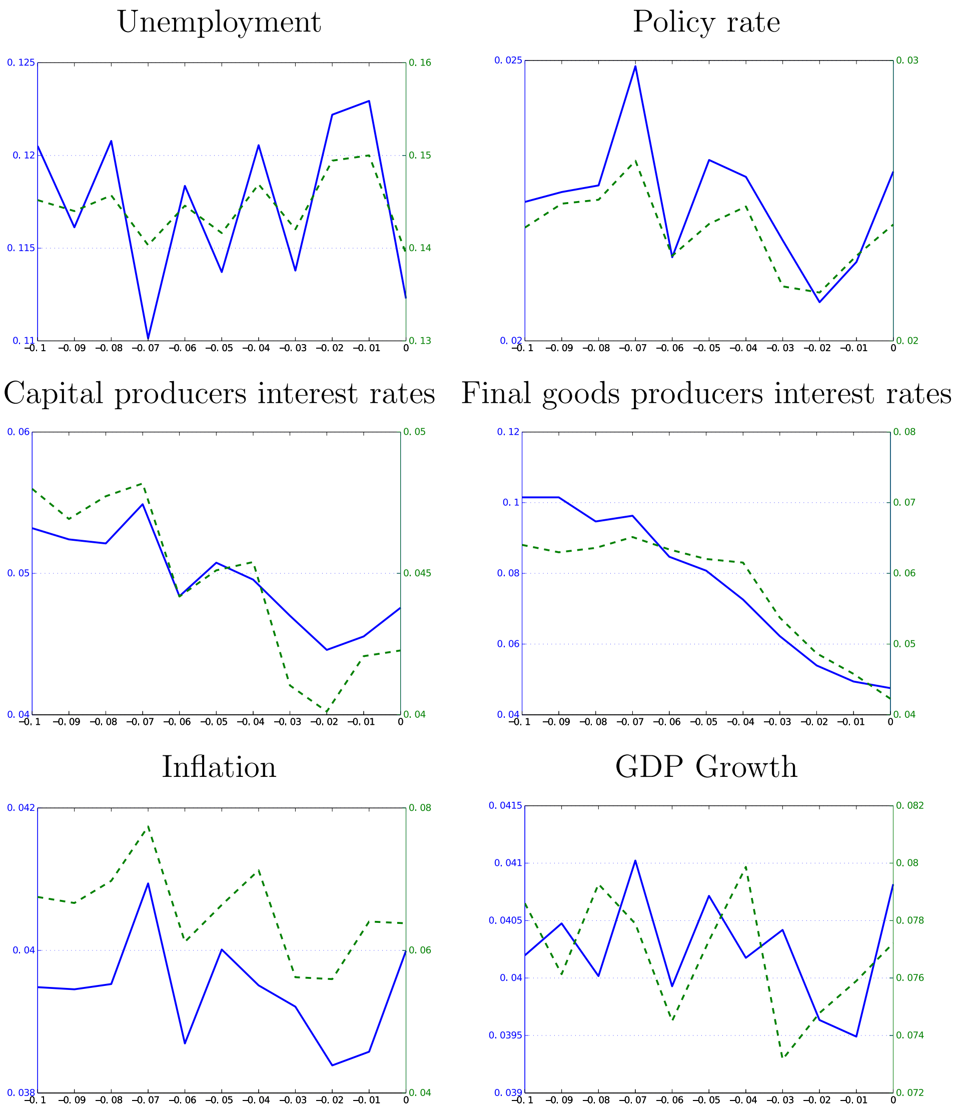
In the data the average level of the *Baa bonds yield* is about to the 7 % on annual base very close to the value of 6.5% found in the model. The average level of the policy rate in the model (2.3%) is slightly lower than the value obtained by the data (3.2%) implying an average spread between corporate loans and the policy rate (4.2%) very close to the empirical counterpart.

3.2 Sensitivity analysis

In order to check the robustness of our results, we perform a sensitivity exercise. Our parameter of interest is the coefficient related to the financial accelerator mechanism ν. The reasons are twofolds: a) the parameter ν is strictly related to the transmission of the monetary policy to the real economy; b) since our model is an extension of Riccetti et al. (2015) many other features have been tested in the original contribution. Figure 2 reports the sensitivity analysis of six variables of interest over a grid of eleven combinations of the parameters ν.[16] The blue line reports the mean while the green dashed line represents the standard deviation.

[16] The grid is $\nu = -[0.11, 0.10, 0.09, 0.08, 0.07, 0.06, 0.05, 0.04, 0.03, 0.02, 0.01, 0]$.

Figure 2: Sensitivity analysis



The solid blue line represents the mean across the Monte Carlo simulation with respect to the parameters of the financial accelerator ν. The green dotted line represents the relative standard deviation

Simulations are relatively stable across all the possible combinations of the parameter ν, proving the robustness of our set up. The only notable exception reagrds the interest rates on loans that are significantly affected by variations of the financial accelerator parameter. Their mean and standard deviation decrease when the parameter ν rises meaning a weaker effect of the financial accelerator mechanism.[17]

3.3 Policy experiments

3.3.1 Monetary policy restriction

According to Taylor's view, our simulation results show how a sudden monetary policy tightness after a periods of prolonged low interest rates can have destabilizing effects on the whole economy.

Figure 3 reports the simulated time series of twelve variables in a selected period of time: the policy rate and the corporate loans interest rates (both for capital producers and consumption goods producers), the unemployment rate, the GDP growth rate, the inflation rate, the quantity of capital recovered by the bank after firms' defaults, firms' real liquidity, the total loans and the amount of external funds that is needed to refinance firm's past debt, firms' net worth, the ratio between public debt and GDP, the production of capital and the relative stock of inventories, the ratio between bank's bad debt and the total amount of loans, the wage inflation.

Central bank keeps the nominal interest rate quite low for about 20 periods in response to a previous slow down of the economy that determined an increase of the unemployment rate. The low level of the policy rate, very close to the ZLB, successfully restore full employment and high GDP growth. The stabilization of the economy is followed by an increase of loans provided by banks to the real economy and a reduction of the bad debt over the total amount of loans. Capital good producers restore the maximum production

[17]The extreme case is when $\nu = 0$. In this scenario the model is equivalent to a set up without the financial accelerator.

capability. Firm's net worth and the related available liquidity increase.

For several periods, unemployment rate is below the long run target of 8% specified by the monetary authority. At period $t = 18$, the central bank starts to raise the short term interest rates in order to prevent an upturn of inflation. The increase of the short term interest rate is quite sharp, from a value very close to the ZLB to almost 4% in a short period of time, closely resembling the behavior of the Federal Reserve at the end of the so called "Greenspan put" at the end of 2006 in the US. The financial accelerator mechanism amplifies the external funding cost for both capital and consumption goods producers. Loans demand is negatively affected by the higher corporate interest rates and immediately begins to shrink.

Real variables reacts accordingly to the negative financial conditions of the economy. The production of new capital decreases, negatively affecting GDP growth and wages. Public debt over GDP increase due to the contraction of the GDP.

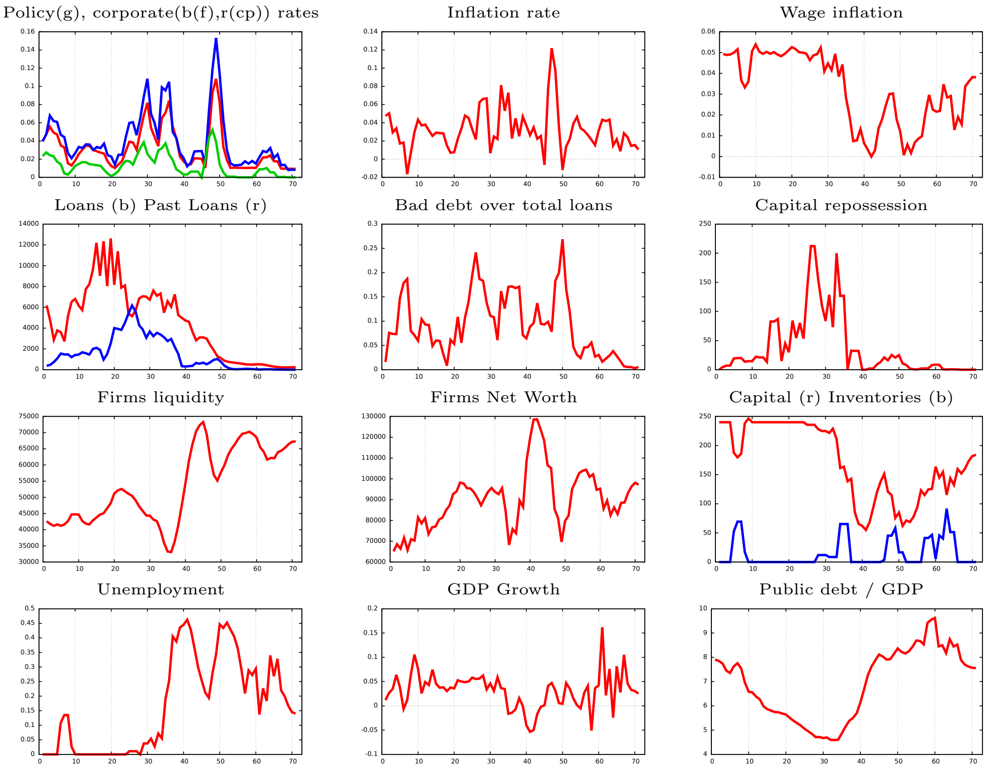
3.3.2 The aftermath of a large crisis event

After the great recession of 2008, the Federal Reserve brought the short term interest rate very close to the ZLB and it kept fix to zero until December 2015, the beginning of the so called "Yellen call". [18]

Figure 4 shows a counterfactual experiment in which the central bank reacts accordingly to two different scenario. In the baseline one, monetary authority returns to conduct monetary policy steering short term interest rates following a classical Taylor rule. This allows the interest rates to be stacked for a short period close to the ZLB and than they start to rise again

[18] http://www.wsj.com/articles/how-the-yellen-call-will-keep-stocks-in-check-1457554210

Figure 3: Monetary policy restriction



Simulation data are filtered using a simple moving average of order 3.

as soon as the economy begins to recover.

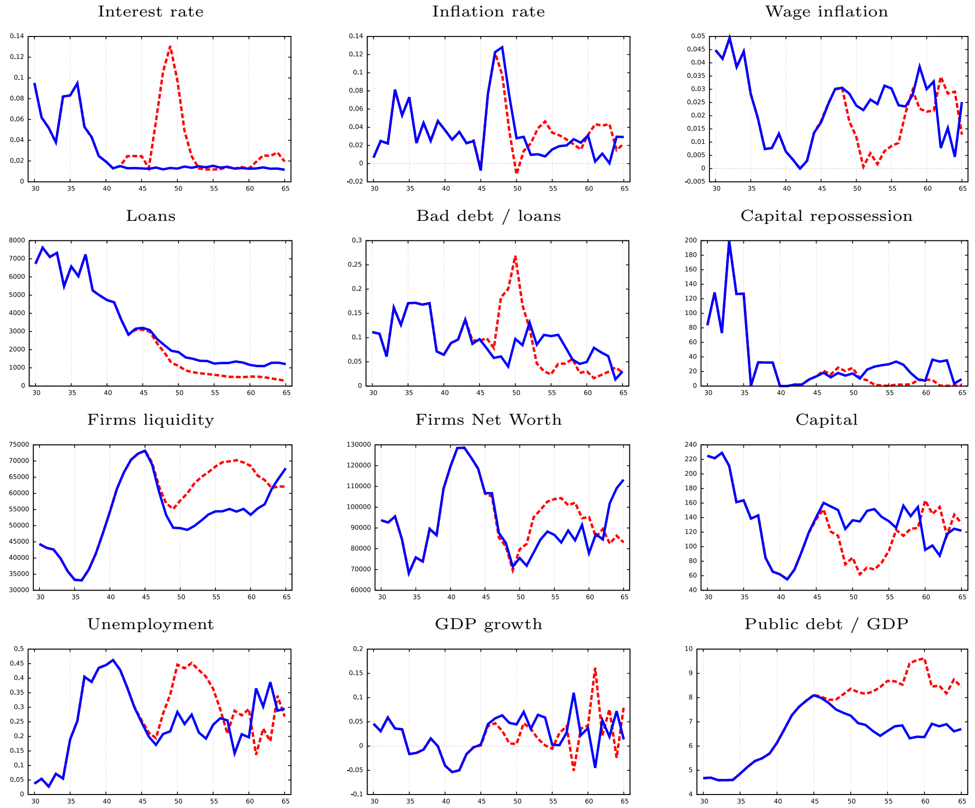
In the alternative scenario the central bank starts to implement the "forward guidance" (see Campbell et al., 2012) of the short term interest rates committing itself to the promise that they will be kept close to the ZLB for the necessary period of time.

The baseline scenario shows that a "double dip" recession is a major threat when the central bank starts to rise the short term interest rate too much and too early. Under the unlimited forward guidance scenario, the central bank is able to stem the magnitude of the recession, at least in the short run.

Keeping the growth rate above the level of the baseline scenario, the central bank is able to stabilize the unemployment rate avoiding the second recession. The accommodating monetary policy is also capable of mitigating the credit crunch on the corporate loans market; a stabilization of the ratio of the bad debt over total loans, due to a lower level of bad debt and a higher level of extended loans, follows. Another significant effect is the reduction of public debt over GDP in the ZLB scenario with respect to the baseline. The reduction of public debt is mainly due to both higher GDP growth and the lower interest rates paid on government bonds.[19]

[19] The relatively low level of public debt over GDP could allow the government to further sustain the economy, unless its target is fiscal austerity.

Figure 4: ZLB vs no intervention by the central bank



The red dashed line represents the scenario in which the central bank return to the standard Taylor rule immediately after the crisis while the blue line represents the zero lower bound scenario. Simulation data are filtered using a simple moving average of order 3.

4 Concluding remarks

This paper contributes to the growing literature on the post crisis behavior of monetary authority. In order to do that we built an ABM model with a financial accelerator mechanism like in Bernanke et al. (1999). The simulations show that a scenario where the central bank is able to keep the short term interest rates very close to the zero lower bound for an extended period of time can help the economy to better react to large crisis events, at least in the short run. Such intervention can potentially avoid a "double dip" recession where a fragile recovery is hampered by a premature increase of the policy rate by the central bank.

The ABM framework potentially can have several advantages over the traditional DSGE model in several aspects. Firstly, the ABM model allows us to fully manage heterogeneity, an essential ingredients of models with financial intermediaries. Secondly, it allows us to simulate endogenously large scale crises and the relative monetary policy responses.

As stated by Howitt (2012), ABM can be used by the policy makers alongside with the traditional DSGE models allowing them evaluate the possible policy implications from a different perspective and an alternative economic theory.

In this context our contribution can be viewed as one of the first attempts to evaluate unconventional monetary policies in a framework different from the standard DSGE model.

Many potential issues are not covered in this contribution and they are left for further research. A first class priority will be to conduct a deep comparison between the standard financial accelerator mechanism and the new agent based version in order to understand similarities and differences in a systematic way. Moreover, the model can be used to explored large crises that do not burst in the financial sector but that occurred in the real side of the economy.

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6 Data appendix

Policy rate: Effective Federal Funds Rate (FEDFUNDS), percentage, non seasonal adjusted.

Corporate loans rates: Baa corporate bond yields (BAA) , percentage, non seasonal adjusted.

Consumer price index: Consumer Price Index for All Urban Consumers: All Items (CPIAUCSL), 1982-84=100, non seasonal adjusted.

Unemployment rate: Civilian Unemployment Rate (UNRATE), percentage, seasonal adjusted.

Gross domestic product: Gross Domestic Product (GDP), Billions of US Dollars, SAAR.