

Giri, Federico

**Research Report**

## Credit networks, leverage and macro dynamics

FinMaP-Policy Letter, No. 7

**Provided in Cooperation with:**

Collaborative EU Project FinMaP - Financial Distortions and Macroeconomic Performance, Kiel University et al.

*Suggested Citation:* Giri, Federico (2016) : Credit networks, leverage and macro dynamics, FinMaP-Policy Letter, No. 7, Kiel University, FinMaP - Financial Distortions and Macroeconomic Performance, Kiel

This Version is available at:

<https://hdl.handle.net/10419/150545>

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# FinMaP-Policy Letter No. 7



This project has received funding from the European Union's Seventh Framework Programme for research, technological development and demonstration under grant agreement no. 612955

**FINMAP -**

**FINANCIAL DISTORTIONS AND MACROECONOMIC PERFORMANCE: EXPECTATIONS, CONSTRAINTS AND INTERACTION OF AGENTS**

**DATE: 10/04/2016**

**TITLE**

**CREDIT NETWORKS, LEVERAGE AND MACRO DYNAMICS**

by: Federico Giri, Università Politecnica delle Marche

The global crisis of 2007-2008 showed the limits of the mainstream economic models in dealing with complex contingent events as financial crises. Thus, following different methodologies, we developed models that describe the economy as a complex system that evolves according to the interactions of heterogeneous agents. Our models underline the importance the role played by credit network configurations and leverage cycles in determining macroeconomic dynamics.

In order to develop macro-prudential policies aimed at increasing the resilience of the economic system, these models try to shed some light into the conditions that may foster the occurrence of crises. In particular, the models underline the importance of monitoring the evolution of credit networks in order to avoid the excessive concentration of the credit market in the hands of few central actors as large banks or firms which become 'too interconnected to fail'. Moreover, the models underline the importance of non-standard monetary policies during and after crises to avoid triggering a new recession ("double dip" recession).

Mainstream macroeconomic models, the so called Dynamic General Equilibrium Model (henceforth DSGE) used by central bankers to produce policy analyses were unfitted to properly capture a recession generated by a sudden collapse of the credit market. After 2007, an army of scholars tried to extend the current framework in order to include financial markets and banks into an otherwise standard DSGE. Despite the huge amount of recent contributions in the field of DSGE models with financial frictions, a modelling approach based on optimizing rational representative agents is not still able to fully capture the entity and the proper dynamic of a strong recession.

What are we still missing? Work package number 5 (henceforth WP5) of the FinMaP project contributes to the research agenda that suggests that HETEROGENEITY, NON-LINEARITY AND INTERACTION are key elements when we want to properly describe the economy as a complex evolving system. Indeed, in complex system aggregate phenomena emerge as the result of the decentralized interaction of heterogeneous agents that lead to non-linear aggregate behaviour. For instance economic dynamics and, in particular, crises may be conceived as the emergent result of the interactions of firms and banks in the credit network which may amplify the effects of individual agents vulnerability, thus, generating dramatic events as huge recessions.

In order to explore the role played by heterogeneity and interactions in determining macroeconomic dynamics, WP5 develops several AGENT-BASED MODELS (henceforth ABM) trying to draw innovative policy suggestions in the specific context of macro-prudential and unconventional monetary policies.

In the last few years, ABM models have become a popular alternative tool with respect to the standard DSGE models (see for further details Caiani et al., 2016). The reasons of the success have to be found in the possibility of flexible modelling strategy of heterogeneity, interaction and non-linearity, all elements that are difficult to design in the context of DSGE framework.

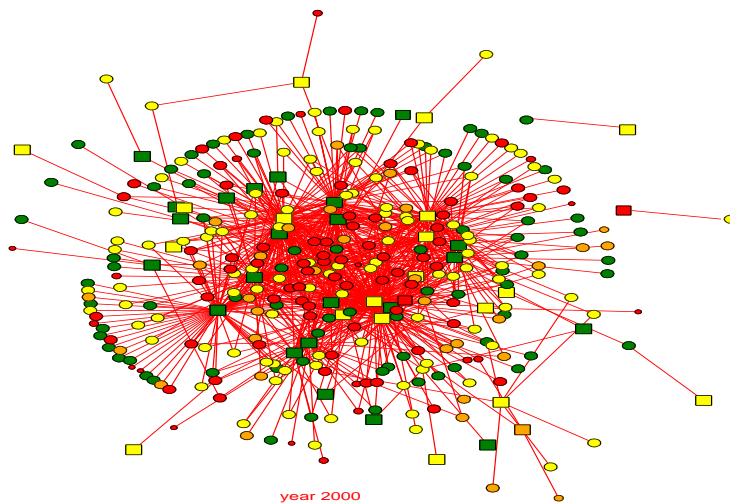
In the next section, we will briefly describe two contributions taken from WP5 of the FinMaP project discussing the relative policy implication of an ABM approach.

## EVIDENCE AND ANALYSIS

We select two papers from WP5 of the FinMaP project to illustrate the potentiality of ABM as a valid alternative policy tool. a) SYSTEMIC RISK AND MACRO-PRUDENTIAL POLICIES: A CREDIT NETWORK-BASED APPROACH by Ermanno Catullo, Mauro Gallegati and Antonio Palestrini (FinMaP Deliverable D5.2). b) MONETARY POLICY AND LARGE CRISES IN A FINANCIAL ACCELERATOR AGENT-BASED MODEL by Federico Giri, Alberto Russo, Luca Riccetti and Mauro Gallegati (FinMaP Deliverable D5.4).

The first paper focuses on systemic vulnerability. It tries to define macro-prudential policies based on the analysis of the relations between firms and banks. Indeed, credit networks play a crucial role in diffusing and amplifying local shocks, following the network-based financial accelerator approach (Riccetti et al., 2013, Battiston et al., 2012). We constructed an ABM model reproducing an artificial credit network populated by heterogeneous firms and banks. The network evolves endogenously according to individual leverage choices of banks and firms. Calibrating the model on a sample of firms and banks quoted in the Japanese stock-exchange from 1980 to 2012, (see Figure 1) we try to define both early warning indicators of crises and precautionary policy measures based on the analysis of the endogenous dynamics of credit network connectivity.

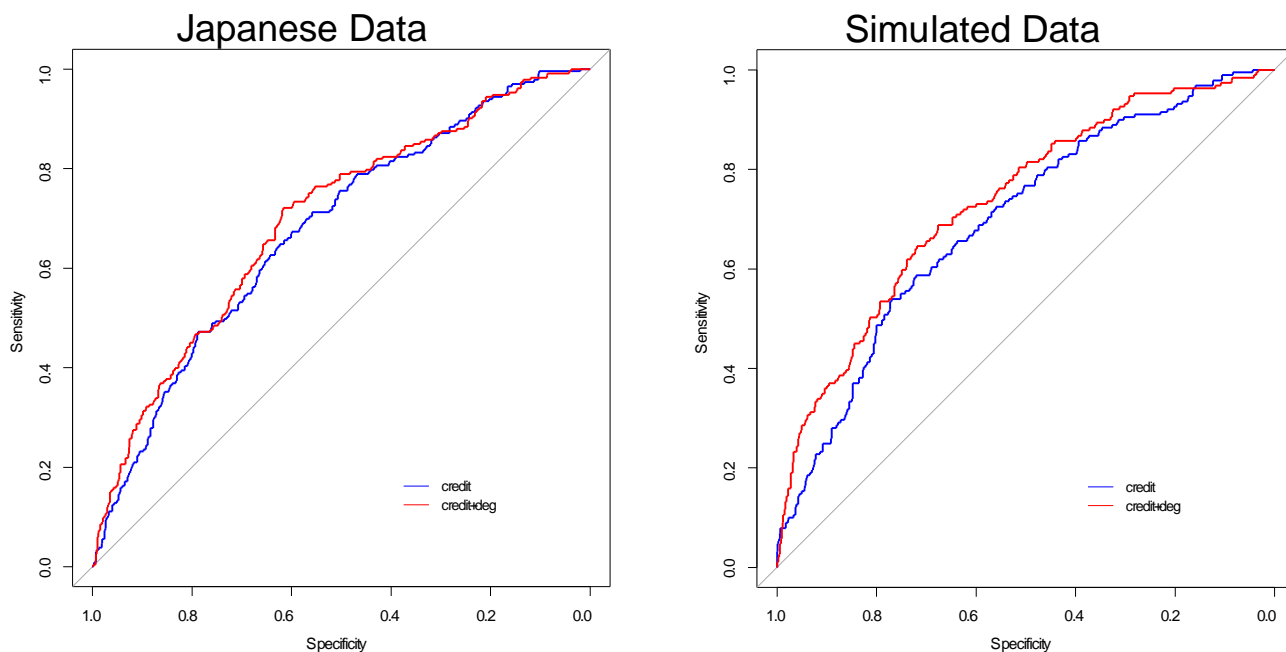
Figure 1: japanes Credit Network (square are banks, circle firms, colors represent the leverage level, red agents are riskier)



Both simulated and empirical data show that growth of credit and connectivity increases the probability of having a crisis. Indeed, when credit increases usually also the level of leverage for both firms and banks augments, thus their individual riskiness grows. Moreover, credit growth is often associated with the raise of credit network connectivity. When agents are riskier and more connected among them even a small local shock as the failure of a relatively small firm may be easily amplified and diffused affecting the whole economic system. Indeed, the variation of network connectivity may be used to increase the effectiveness of credit variation as early warning indicators of crises. Early warning measure effectiveness derives from their capacity of reducing the trade-off between false alarms and hits. A good early warning measure is the one that is able to anticipate crises occurrence (hits) but at the same time does not generate too many false alarms. The ROC curve represents the trade-off between false alarm and hits (see Figure 2) and the larger is that area below the curve (the so-called AUROC) the higher the effectiveness of the indicator.

In both empirical and simulated data, credit growth is an effective early warning measure of crises occurrence. Moreover, considering also connectivity variations increases the effectiveness of credit as an early warning indicator (see Figure 2).

Figure 2:

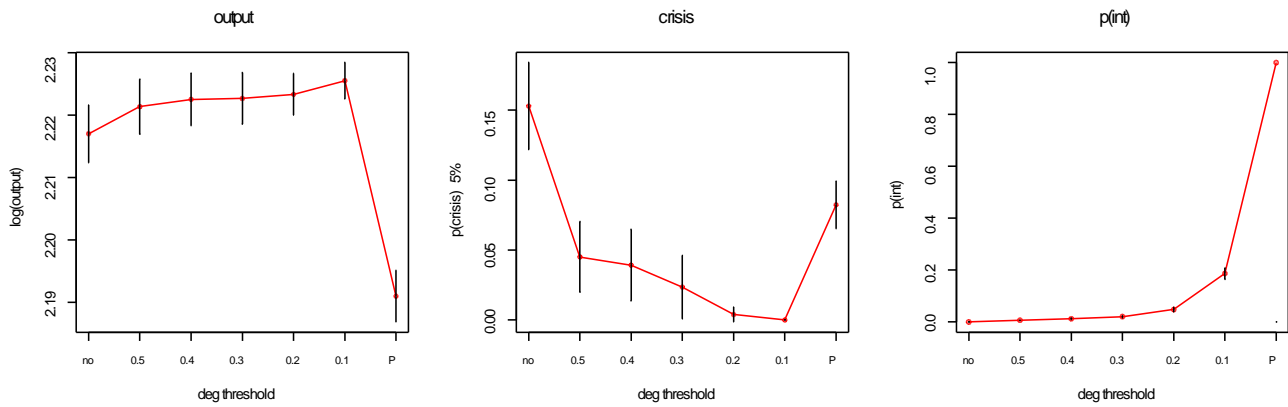


Roc Curves in empirical Japanese data and simulated data. Blue line represents credit variations and red dashed line connectivity variations.

Moreover, exploiting the agent based structure of the simulated credit network, we can experiment the effect of policies that focus on agents' interactions and heterogeneity. Indeed, we tested the effect of non conventional macro-prudential policies that influence the structure of the credit networks according to agents' size or connectivity. In particular, we applied a basic loan-to-value policy: we force banks to avoid providing credit to riskier firms and we applied these targeting banks according to their centrality in the network.

Figure 3 shows as targeting only more connected banks can be an effective strategy to reduce crisis probability with respect to a baseline scenario without policy. For instance, targeting just more connected banks (the ones connected with at least more than the 50% of the firms in the network, 0.5 in the figure 3) does not affect output (output), but at the same time consistently reduces crisis probability (crisis), while the number of banks affected by the policy is extremely low,  $p(\text{int})$ . On the opposite, applying this policy the all the banks (P) reduces crisis probability but at the cost of a relevant output contraction because the credit supplied to the economy suffers a significant reduction.

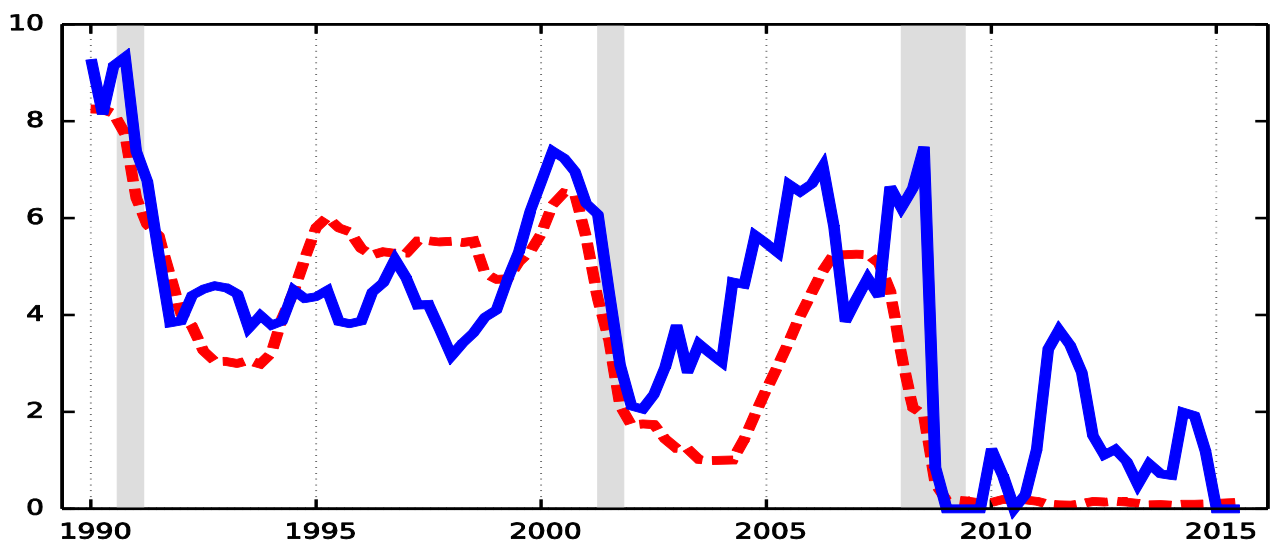
Figure 3



Targeting more connected banks. On the left, the aggregate output level in logarithms. In the center, crisis probability. On the right, intervention probability.

The second contribution focuses its attention on the role of monetary policy as a potential trigger of large crisis events and the related post-crisis behavior of the monetary authorities. The first questions is also investigated in another paper produced by WP5 (“The Tale of two Great Crisis”, FinMaP wp n. 51). The main idea is that an accommodating monetary policy followed by a sudden increase of the short-term interest rates (see Figure 4) can be one of the potential trigger of a large recession. FinMap wp n.51 finds evidence that this destabilizing channel of monetary policy was prominent both in the recent financial crisis of 2007 and in the 1929 Great Depression.

Figure 4: Effective Fed funds rate vs Taylor Rule implied values



The red dashed line represents the effective fed funds rate, the blue line are the values predicted according to the Taylor's rule. Grey bars represent recessions according to the NBER classification.

In order to explore these two issues, we expand the ABM model proposed by Riccetti et al. (2013) including a capital producer sector and a financial accelerator mechanism like in Bernanke et al. (1999) borrowing from the standard DSGE literature of financial frictions. Such elements allow us to analyze the role of monetary policy before a crisis and the relative post-crisis response.

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

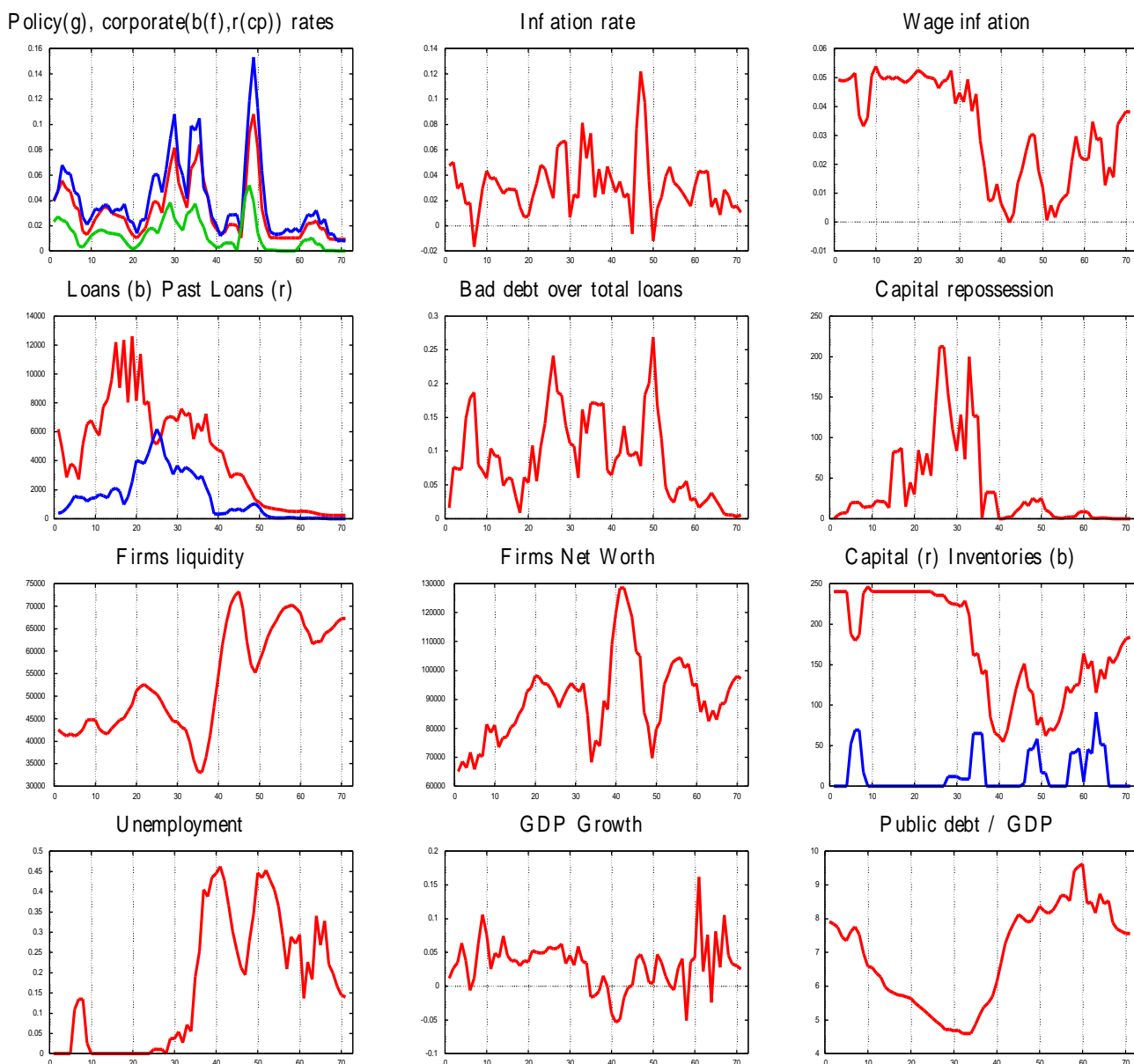
According to the proposed model, monetary policy can act as trigger of a recession. Moreover, a zero lower bound (henceforth ZLB) policy of short-term interest rate can be a powerful tool to smooth the effects of a strong recession, at least in the short run, and at the same time, it can prevent a “double dip” recession scenario where a short recovery after a crisis is followed by another recession.

Figure 4 reports the simulations relative to the pre-crisis scenario. Central bank keeps the nominal interest rate quite low for about 20 periods in response to a previous slowdown of the economy that determined an increase of the unemployment rate. The low level of the policy rate, very close to the ZLB, successfully restores 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 goods producers restore the maximum production capability. Firms’ 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 behaviour of the Federal Reserve in 2006 at the end of the so called "Greenspan put". 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 react 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 increases due to the contraction of the GDP.

Figure 4: Simulation results of a monetary policy restriction



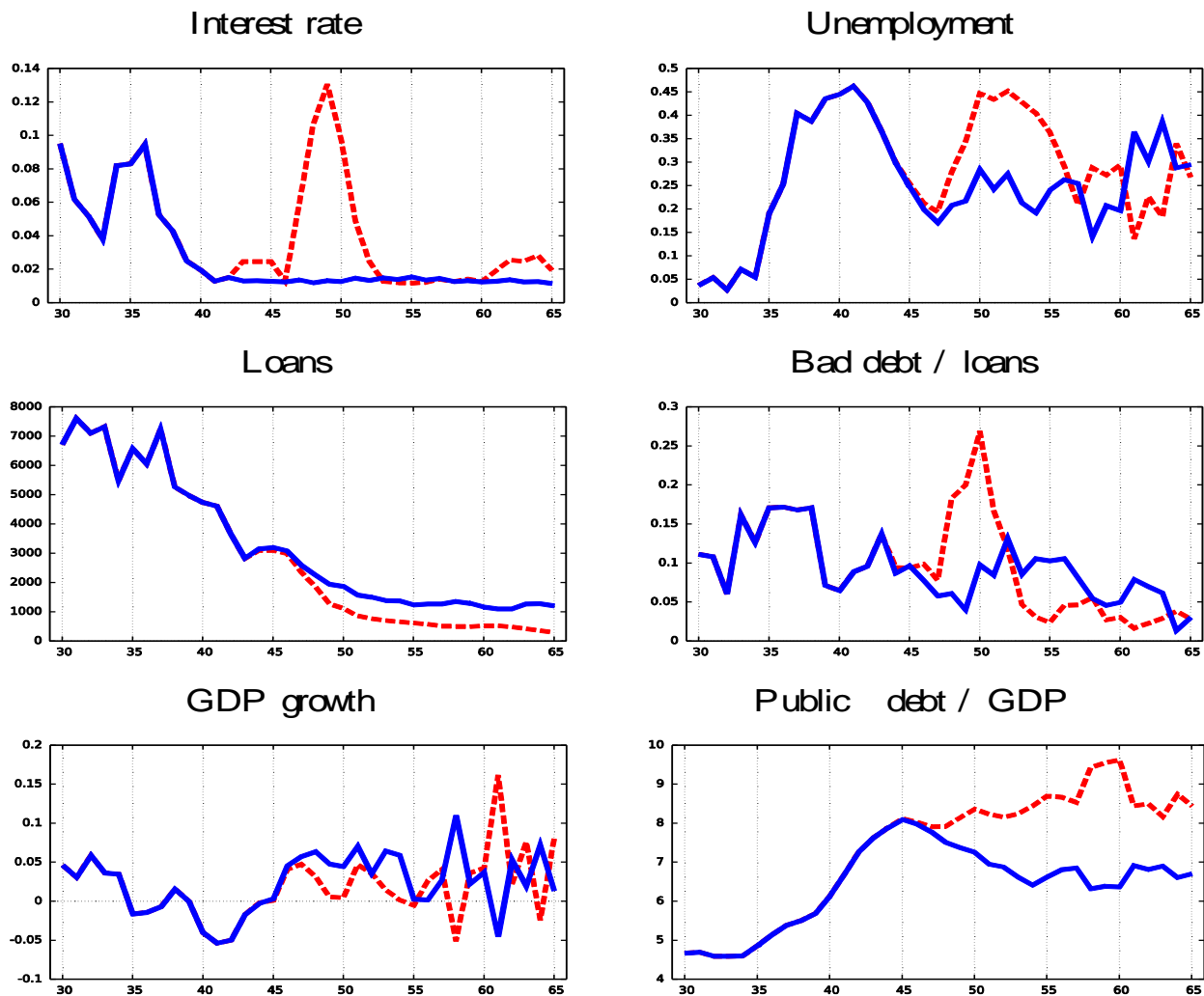
After the great recession of 2008, the Federal Reserve brought the policy rate very close to the ZLB keeping it fix to zero until December 2015.

Figure 5 shows a counterfactual experiment in which the central bank reacts accordingly to two different scenarios. In the baseline one, monetary authority returns to conduct monetary policy steering short term interest rate following a classical Taylor rule. The policy rate is stacked for a short period close to the ZLB and then it starts to rise again as soon as the economy begins to recover.

In the alternative scenario the central bank starts to implement the “forward guidance” 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.

Figure 5: Simulations results of ZLB vs no intervention by the central bank



Zero Lower Bound policy (blue line) vs no intervention by the central bank (red dashed)

In particular, keeping the short-term interest rate anchored to the ZLB, the central bank is able to stabilize the unemployment rate avoiding the second recession. An accommodating monetary policy is also capable of mitigating the credit crunch on 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.

## POLICY IMPLICATIONS AND RECOMMENDATIONS

In terms of policy recommendations, both contributions suggest non-conventional responses to two relevant questions related to the implementation of macro-prudential policy and the exit strategy from the unconventional monetary policy measures put in place by several central banks around the world after 2008.

According to our research, the actual macroprudential policy paradigm should also consider “Too-interconnected too fail” approaches. In fact, the analysis of credit network configurations may offer some insight into the dynamics of business cycles and, in particular, may be helpful to assess systemic risk. Both our empirical and simulated data seem to show that credit and connectivity variations are effective early warning measures. Indeed, expansions lead to an increase of credit and connectivity that may create the conditions for the following slow-downs or even for crises.

Therefore, credit network connectivity may be used to define timing and targeting of macro-prudential policies. According to our simulated experiments loan-to-value restricting policies may be effective in reducing crisis probability: when banks are forced to avoid lending credit to riskier firms the probability of crises' occurrence decreases. However, excessive loan-to-value interventions may excessively reduce credit and consequently economic growth. At the same time, selective loan-to-value measures that are activated only when credit or connectivity growth overcome certain threshold, or alternatively focusing only on larger or more connected banks, may reduce systemic risk without affecting negatively credit access and output level.

The second contribution feeds the literature of central banks' post-crisis behaviour suggesting that the return of monetary policy to the traditional pre-crisis rules should be postpone, at least in the short run, in order to avoid to trigger a “double dip” recession. Another policy implication is that large swings of short-term interest rate can be a potential destabilizing factor. Monetary policy authorities should avoid large and sudden increase of the policy rate. In this sense, the actions of the FED after 2001 (see Figure 3), according to our model, can be seen potentially dangerous for the stability of the economic system.

## RESEARCH PARAMETERS

In terms of methodology, our research agenda exploits the ABM framework and in general the complex system approach to deliver innovative policy suggestions. With respect to the existing literature, we extend the previous models adding new crucial elements (credit network and monetary policy) to draw our policy recommendations. A general policy conclusion is that Heterogeneity, interaction and non-linearity should not be neglected when we want to build macroeconomic models that are able to capture salient features of a large crisis event.