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TAMING MACROECONOMIC INSTABILITY: MONETARY AND MACRO PRUDENTIAL POLICY INTERACTIONS IN AN AGENT-BASED MODEL

Lilit POPOYAN
Institute of Economics (LEM)

Mauro NAPOLETANO
OFCE-Sciences Po and SKEMA Business School

Andrea ROVENTINI
Institute of Economics (LEM)

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Taming Macroeconomic Instability: Monetary and Macro Prudential Policy Interactions in an Agent-Based Model

Lilit Popoyan* Mauro Napoletano† Andrea Roventini‡

Abstract

We develop an agent-based model to study the macroeconomic impact of alternative macro prudential regulations and their possible interactions with different monetary policy rules. The aim is to shed light on the most appropriate policy mix to achieve the resilience of the banking sector and foster macroeconomic stability. Simulation results show that a triple-mandate Taylor rule, focused on output gap, inflation and credit growth, and a Basel III prudential regulation is the best policy mix to improve the stability of the banking sector and smooth output fluctuations. Moreover, we consider the different levers of Basel III and their combinations. We find that minimum capital requirements and counter-cyclical capital buffers allow to achieve results close to the Basel III first-best with a much more simplified regulatory framework. Finally, the components of Basel III are non-additive: the inclusion of an additional lever does not always improve the performance of the macro prudential regulation.

Keywords: macro prudential policy; Basel III regulation; financial stability; monetary policy; agent-based computational economics.

JEL classification numbers: C63, E52, E6, G01, G21, G28.

*Institute of Economics (LEM), Scuola Superiore Sant'Anna, Pisa (Italy); Piazza Martiri della Libertá 33 - I-56127 Pisa (Italy) E-mail address: l.popoyan@sssup.it.

†OFCE and Skema Business School, 60 rue Dostoievski - 06902 Sophia Antipolis (France); and Institute of Economics (LEM), Scuola Superiore Sant'Anna; Piazza Martiri della Libertá 33 - I-56127 Pisa (Italy); E-mail address: mauro.napoletano@sciencespo.fr

‡Corresponding author: Institute of Economics (LEM), Scuola Superiore Sant'Anna; Piazza Martiri della Libertá 33 - I-56127 Pisa (Italy), and OFCE and Skema Business School, 60 rue Dostoievski - 06902 Sophia Antipolis (France); E-mail address: a.roventini@sssup.it

1 Introduction

In this work we develop an agent-based model (ABM) to study the impact on macroeconomic dynamics of alternative macro prudential regulations and their possible interactions with different monetary policy rules. The aim is to shed light on the most appropriate policy mix to make the banking sector more resilient and foster macroeconomic stability.

The recent crisis has revealed the fundamental role of credit and more generally of financial markets in triggering deep and long downturns. Ng & Wright (2013) find that in the last thirty years all recessions hitting the U.S. originated in financial markets. More generally, financial crises are not rare events (apart from the calm of the 1930-1970 period), they occur both in developed and emerging economies, and their cost is much more severe than "normal recessions" (Taylor 2015). Finally, credit booms can fuel asset price bubbles, leading to deeper recessions and slower recoveries (Jordà et al. 2015; see also Stiglitz 2015 on the links between credit and deep downturns).

In such a framework, monetary policy is an inadequate tool to achieve both price and financial stability. Given the numerous faults in the global regulatory framework and in banks' risk management practices, a growing consensus has grown to improve macro prudential regulatory tools in order to better supervise the banking sector and tame financial market instability (Borio 2011, Blanchard et al. 2013, Zhang & Zoli 2014, Blundell-Wignall & Roulet 2014, Gualandri & Noera 2014). The policy debate is focusing in particular on the adoption, implementation and effectiveness of different macro prudential tools (Balasubramanyan & VanHoose 2013, Claessens et al. 2013, Miles et al. 2013, Aiyar et al. 2014, Cerutti et al. 2015), as well as on their impact on macroeconomic outcomes and their relationship with monetary policy (Beau et al. 2012, Kannan et al. 2012, Agénor et al. 2013, Angeloni & Faia 2013, Lambertini et al. 2013, Spencer 2014, Suh 2014).

However, many questions are still open. To name a few, how can one solve the potential conflict between Central Bank's (CB) objectives of price and financial stability (Howitt 2011)? Should CBs use the policy interest rate to prevent the formation of credit bubbles (Blanchard et al. 2013)? What is the effectiveness of different combinations of macro prudential tools? In particular, given the increasing complexity of financial markets, do we need complex or simple macro prudential rules (Haldane 2012)? Are monetary and macro prudential policies complementary in increasing the stability of the banking sector and more generally of the whole economy?[1]

These are the questions we are going to address extending the agent-based model (Tesfatsion & Judd 2006, LeBaron & Tesfatsion 2008) developed in Ashraf et al. (2011). The model is populated by heterogenous, interacting firms, workers and banks, a Government and a Central Bank. Firms and workers exchange goods and services in decentralized markets. Firms need credit to finance production which is provided by banks according to the macro prudential

[1]Empirical findings about the effectiveness of macro prudential instruments are few due to the scarcity of data, and they mainly focus on the static capital adequacy requirement and the loan-to-value ratio (see in particular Shim et al. 2013, Aiyar et al. 2014, Cussen et al. 2015, McDonald 2015). A growing literature also uses DSGE models to study the interactions between macro prudential regulation and monetary policy (see e.g. Angelini et al. 2011, Agénor et al. 2013, Angeloni & Faia 2013, Zilberman & Tayler 2014, Kannan et al. 2012, Quint & Rabanal 2014, Ozkan & Unsal 2014).

regulation. If firms are not able to sell their goods, they can go bankrupt and default on their loans, possibly triggering a banking crisis. The Government bails out banks and levies a sales tax. Finally, the Central Bank sets monetary policies according to different types of Taylor rules and fixes the macro prudential regulation in the spirit of Basel II or III frameworks.

Our approach consider the economy as a complex, evolving system (Kirman 1992, Colander et al. 2008), where macroeconomic outcomes do not coincide with the behavior of a representative agent, but rather emerge out of the interactions taking place among heterogenous agents (more on that in Farmer & Foley 2009, Kirman 2010, Dosi 2012). Such a research methodology is fruitful to analyze not only how complex market economies manage to coordinate activities in normal times (Howitt 2011), but especially to study how major crises emerge, pushing the economy outside the stability "corridor" (Leijonhufvud 1973), in "dark corners" (Blanchard 2014). As endogenous banking crises are very often at the root of deep downturns, our agent-based approach is well suited to be employed as a laboratory to design and test how different monetary and macro prudential policies combinations may impact on the resilience of the banking sector and on the overall macroeconomic performance[2]

First, we test the explanatory power of our model. We find that the model endogenously generates business cycles and banking crises. Moreover the model accounts for the major co-movements of macroeconomic variables (e.g. output, unemployment, credit, inflation, etc.) at business cycle frequencies. Finally, the Okun and Phillips curves are emergent properties of the model.

We then compare the impact of Basel II and III regulations on financial stability and macroeconomic performance, by carefully studying the role (both, jointly and in isolation) of the different components of the Basel III framework. The effects of alternative macro prudential regulations are analyzed for different Taylor rules focused on e.g. output and price stability, unemployment, credit growth.

Simulation results show that the adoption of the Basel III regulation improves the stability of the banking sector and the performance of the economy vis-à-vis the Basel II framework. Considering the different levers of Basel III and their possible combinations, we find that the minimum capital requirement cum counter-cyclical capital buffer produce results quite close to the Basel III first-best in a much more simplified regulatory framework, thus supporting the plea of Haldane (2012) for simple policy rules in complex financial systems. In particular, the contribution of counter-cyclical capital buffer is fundamental in reducing the pro-cyclicality of credit, thus allowing firms to get more credit during recessions, i.e. when they need it most (Bernanke et al. 1999, Gertler et al. 2007, Christensen & Dib 2008).

We also find that the relation among the different components of the macro prudential regulation is not trivial. Indeed, the effects of the adoption of the complete Basel III regulation are much stronger than the summation of the impact of its single components. In addition, the levers of Basel III are non-additive: the inclusion of additional components does not always

[2]For germane macroeconomic agent-based models with credit and financial markets, see Delli Gatti et al. (2005, 2010), Ashraf et al. (2011), Gai et al. (2011), Battiston et al. (2012), Geanakoplos et al. (2012), Raberto et al. (2012, 2014), Dosi et al. (2010, 2013, 2015), Riccetti et al. (2013), Dawid et al. (2014), Krug et al. (2015), Napoletano et al. (2015), Seppecher & Salle (2015), van der Hoog & Dawid (2015), van der Hoog (2015), and the papers in Gaffard & Napoletano (2012). See Fagiolo & Roventini (2012) for a critical comparison of macroeconomic policies in standard DSGE and agent-based models.

improve the performance of the macro prudential regulation.

Finally, we find that a "leaning against the wind" monetary policy, which fixes the interest rate in order to stabilize output and inflation, but also takes into account credit growth, reduces the inflation rate and achieves the best results in terms of output stabilization. Our results thus suggest that the joint adoption of a triple-mandate Taylor rule and a Basel III prudential regulation allows the Central Bank to reduce the conflict between price and financial stability (see e.g. Howitt 2011, Blanchard et al. 2013).

The rest of the paper is organized as follows. In Section 2 we describe the model. We than present simulation results in Section 3. Finally, Section 4 concludes.

2 The model

The model studies the possible complementarities between different macro-prudential measures,[3] and alternative monetary policies, in an economy populated by heterogenous, interacting agents. Its closest antecedent is the model developed in Ashraf et al. (2011),[4] which we expand by providing a more detailed account of bank's decisions and balance-sheets, and by exploring different types of macro prudential regulation in the vein of Basel II and III frameworks.

In the model, there are N agents and M banks. The production possibilities contemplate n varieties of non-perishable goods, which are manufactured employing n different types of labor. Each agent z is characterized by the coefficients (i, j), where i denotes the goods she is able to produce, and j and $j+1$ capture respectively her primary and secondary consumption goods. In line with Ashraf et al. (2011), we assume that agents cannot consume the goods they produce, i.e. $i \neq j$ and $i \neq j+1$. This forces them to trade in the labor and goods markets. As there is one agent for each type of good, the population of our artificial economy is equal to $N = n(n-2)$.

The real sector is composed of specialized traders — the "shops" — which produce and sell different types of consumption goods, forming trading relationship with agents. The varieties of shops correspond to the ones of goods produced in the economy (n). A shop i employs labor of type i to produce a good of the same varieties which will be sold in the market. Each agent can be employed only in one shop and she has only one supplier for its primary and secondary consumption goods. Trading and employment relationships evolve endogenously over time. Each shop is owned by an agent. In order to open a shop, an agent has to invest (part of) her wealth. Shops produce using labor only and they fix their price ($p_{i,t}$) applying an after-tax mark-up on the wage rate ($w_{i,t}$).

In the economy, there is a fixed number M of banks, indexed by m, with the same number of customers. The banking sector provides credit to open new shops or to finance production if the wealth of the shop owner is not sufficient for that purpose. Loans are made with full recourse and are collateralized by inventories. Prudential regulation constrains the endogenous

[3]Micro-prudential instruments typically focus on the health of individual financial institutions. In contrast, macro-prudential policy tools are directed to address risks concerning the financial system as a whole. The literature (see e.g. Osinski et al. 2013) traditionally considers the measures in the Basel II and Basel III accords - taken as a whole - as macro-prudential regulation. We shall follow the same rule in this paper, although single tools in each package (e.g. the leverage ratio or the liquidity coverage ratio in Basel III) have instead a micro-prudential character.

[4]See also Howitt & Clower (2000), Howitt (2008), and Howitt (2006), Ashraf et al. (2016).

supply of credit in the economy. Beyond loans and seized collateral, banks can hold money and government bonds. Banks are heterogenous in terms of their balance sheets and may go bankrupt if shops do not pay back their loans, thus triggering a banking crisis.

The Central Bank (CB) is responsible for monetary policy and it sets the nominal interest rate following different types of Taylor rules (cf. Section 2.9.2). Moreover, the CB supervises the banking system and fixes the macro prudential regulation (Basel II vs. III, more on that in Section 2.9.3).

The Government levies a sales tax and it employs the gathered resources to recapitalize banks whenever they do not satisfy the minimum capital requirements fixed by the macro prudential regulation. In case of deficits, the Government issues bonds which are bought by banks and, as a residual, by the Central Bank.

In the next sections, we first provide a description of the timeline of events in any given time step (cf. Section 2.1). We then present a description of how agents (firms, workers, banks) take their decisions and interact in the goods, labor, and credit markets (see Sections 2.2-2.8). Finally, in Section 2.9, we describe how fiscal, monetary and macro prudential policies are fixed.

2.1 The timeline of events

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In the model, time steps correspond to months. In every time period t, the sequence of events runs as follow:

1. policy variables (e.g. baseline interest rate, sales tax rate, etc.) are fixed;
2. new shops enter the market;
3. search and matching occur in the goods and labor markets;
4. trading in financial markets occur;
5. labor and good market trading takes place;
6. bankrupted shops and banks exit;
7. wages and prices are set

At the end of each time step, aggregate variables (e.g. output, inflation, unemployment, etc.) are computed, summing over the corresponding microeconomic variables.

2.2 Shop entry

At the beginning of each period, each person who is not already a shop owner or a bank owner can become a potential entrepreneur with probability θ/N ($1 \leqslant \theta \leqslant N$). A potential entrepreneur can open a shop only if she can afford to pay the setup cost S (expressed in units of her consumption good) with her stock of available liquid resources. The liquidity of agents is composed of money and deposits plus the credit line provided by banks, which is equal to 0 if the agent did not receive a line of credit in the previous period, and to $P_{h,t}(S + I_{i,t})$ otherwise, where I is the potential entrepreneur's stock of inventories and P_h is the haircut price discussed later in Equation 9.

Once the setup cost requirement is satisfied the potential entrepreneur checks whether entry in the market is profitable. The expected profits from entry, $\Pi_{i,t}$, read as:

$$\Pi_{i,t} = w_{i,t}(\mu_{i,t} y_{i,t}^{trg} - (F-1)) - w_{i,t} i_t^D (y_{i,t}^{trg} + F - 1) > 0, \tag{1}$$

where $w_{i,t}$ is the wage rate and F is the fixed cost (also expressed in terms of units of type i labor). In the above equation, the first term represents the operative margin of the shop owner, the second one captures the opportunity cost of investing in the shop instead of in a deposit account yielding an interest rate i_t^D. The potential entrepreneur decides to enter if the business plan is viable, i.e. if $\Pi_{i,t} > 0$.

If the profitability test is successful, the potential shop owner checks whether she can actually produce and sell its product at the current market conditions. More specifically, she sends to an unemployed worker a job offer specifying the wage, and to a potential consumer (i.e. a randomly chosen agent whose primary consumption good is the same as the entrepreneur's production good) the selling price of the product. The wage rate is equal to:

$$w_{i,t} = W_t(1+\pi^*)^{\frac{\Delta+1}{2}}, \tag{2}$$

where W_t is the publicly know, (employment-weighted) average wage rate computed by the Government across all shops, Δ is the fixed contract period and π^* is the Central Bank's target inflation rate.[5] The unemployed worker will agree to be hired by the new shop if her effective wage (determined according to Equation 13 below) is less than the one offered by the potential entrepreneur, i.e. if $w_t^{eff} < w_{i,t}/(1+\pi^*)$. Similarly, the potential consumer will become a customer of the new shop if her effective price, p_t^{eff} is greater than the one offered by the firm, $p_{i,t}^{nor}$, i.e. if $p_t^{eff} > p_{i,t}^{nor}/(1+\pi^*)$. The price $p_{i,t}^{nor}$ is equal to

$$p_{i,t}^{nor} = \frac{(1+\mu_{i,t})}{(1-\tau)} w_{i,t}, \tag{3}$$

where τ is the sales tax rate and $\mu_{i,t}$ is the mark-up.

2.3 Search and matching in goods and labor markets

Agents try to form new trading relationships both in the goods and labor markets. In the latter, workers engage in job search with probability σ (with $0 \leq \sigma \leq 1$). Once they search, they ask for a job to another randomly chosen agent who produces the same type of goods. The contacted agent can either be a shop owner or a worker, who then pass the job application to her employer. In both cases, the labor contract is signed and the searcher is hired if: a) the labor employed in the last period by the shop owner who received the application is not sufficient to meet her current input target; b) the wage offered to the searcher is higher than her effective one.

Likewise, every agent searches for a potential new shop. In their search consumers first ask the effective retail price to a randomly chosen agent with the same consumption good. If that

[5] Inflation target is equal to 3%, which is the average in the U.S. over the 1984-2006 period.

	Consumer	*Shop*	*Bank*	*Gov*	*CB*	Σ
Deposit	$+D^c$	$+D^s$	$-(D^c+D^s), +D(R)$		-D(R)	0
Loan		$-L^s$	$+L^s, -L^{cb}$		$+L^{cb}$	0
Bond			$+B^b$	-B	$+B^{cb}$	0
Inventory		$+I, -SC^b$	$+SC^b$			$+I$
HPM	$+H^c$	$+H^s$	$+H^b$		$-H^{cb}$	0
Balance	$-E^c$	$-E^s$	$-E^b$	$+GD$		$-I$
Σ	**0**	**0**	**0**	**0**	**0**	**0**

[a] ***Note:*** *The matrix describes the accounting structure of the model. All rows related to financial assets or liabilities sum to zero except the inventories which are connected to tangible capital.*

Table 1: The balance-sheet matrix of the model

attempt is unsuccessful (i.e. the price is higher than the currently paid price), the consumer asks the price to a randomly selected shop, which may trade or not her consumption good. The consumer will become a customer of the new shop if the price is lower than the one of her current supplier. Once search and matching activities are concluded, agents adjust their balance sheets and set their expenditures plan. Before discussing the latter, let us first consider the functioning of banks and of the credit market.

2.4 Banks and credit

The balance sheet of the banking sector is represented in the fourth column of Table 1. The assets of bank m are constituted by loans to shops L^s_m, cash H^b_m, Government bonds B^b_m, collaterals SC^b_m seized from defaulted shops and valued at firesale prices (cf. Equation 10 below), and reserves $D(R)_m$ at the Central Bank. Banks are indeed obliged to hold minimum reserves against deposits of shops (D^s_m) and consumers (D^c_m). More precisely, bank's reserves are equal to $D(R)_{m,t} = \xi(D^s_{m,t} + D^c_{m,t})$, with $0 < \xi < 1$.

The liabilities of bank m are constituted by deposits, D^s_m and D^c_m, and by loans provided by the Central Bank, L^{cb}_m. Banks demand for CB loans originates from prudential regulation. More specifically, if the Liquidity Coverage Ratio (LCR, defined later in Section 2.9.3) falls below a minimum value γ_b, the bank cannot supply new loans and thus asks for liquidity advances from the Central Bank in order to restore the minimum ratio. Bank's m liquidity demand to the CB is thus equal to:

$$L^{cb}_{m,t} = zz\{\gamma_b(D^s_{m,t} + D^c_{m,t}) - B^b_{m,t} - D(R)_{m,t} - H^b_{m,t}\}, \tag{4}$$

where $zz = 1$ if $LCR < \gamma_b$ and $zz = 0$ otherwise.

Furthermore, the equity of bank m (E^b_m) is obtained by subtracting bank's liabilities from her assets. Banks with negative equity fail. In this case the Government first injects money to fully recapitalize the new bank to fulfill the minimum capital requirement (discussed in Section 2.9.3 below). Next, a new bank owner is chosen. Notice that such procedure guarantees that deposits are never destroyed after bank failures.

Credit supply depends on bank's equity. First, the Central Bank checks if a bank satisfies the prudential regulation requirements akin to Basel II or III framework (and described in details in Section 2.9.3 below). If a bank does not satisfy one of the conditions of the prudential regulation, it is considered "troubled" and it is not allowed to provide new loans. The total supply of credit of a non-troubled bank m is equal to:

$$L_{m,t}^{sup} = \frac{1}{\chi_b} E_{m,t}^{b} - (L_{m,t}^{s} + SC_{m,t}^{b}), \tag{5}$$

where the χ_b stands for the minimum capital requirement of Basel II and III (respectively $b = 2$ and $b = 3$), E_m^b is the equity of the bank, $L_{m,t}^s$ is her current stock of loans and $SC_{m,t}^b$ is the stock of collaterals. Note that $(L_{m,t}^s + SC_{m,t}^b)$ measures the bank's total exposure to credit risk.

Banks grant loans to shops according to a "6C" approach to creditworthiness. Such a method is commonly employed by banks to determine the financial and economic situation of the loan applicant and its potential future revenues (see e.g. Jiang 2007). More specifically, the aim of the "6C" analysis is to provide a positive answer to the following questions about a shop demanding a loan: (i) Can the shop pay its loan? (capacity check); (ii) Does the shop have enough liquidity to pay its loan if a period of adversity arises? (capital check); (iii) Will the bank be protected if the shop fails to repay the loan? (collateral check); (iv) Did the shop pay back its loans in the past? (credit reputation check); (v) Are there some known factors that could adversely affect the shop's ability to pay back its loan? (credit conditions check); (vi) Does the shop owner demonstrates the ability to make wise decisions? (common sense check).

In real economies, banks following the "6C" approach use both objective credit ratios and more subjective evaluations based on privileged information resulting from the historical experience with their borrowers. In the current model, we focus our attention only on objective ratios, which are caught by the first three "C's" of credit rating, namely capital, capacity and collateral. The "capacity" of the lender will be measured employing the "quick ratio" (QR) and the "return on asset" (ROA) indicators:

$$QR_{i,t} = \frac{\text{Current Assets-Inventories}}{\text{Current Liabilities}} = \frac{D_{i,t}^s + H_{i,t}^s - I_{i,t}}{L_{i,t}^s} \geq \kappa, \tag{6}$$

$$ROA_{i,t} = \frac{\text{Net income(after tax)}}{\text{Total assets}} = \frac{\Pi_{i,t}^s}{D_{i,t}^s + H_{i,t}^s + I_{i,t}} \geq \psi, \tag{7}$$

where D_i^s and H_i^s are respectively shop $i's$ deposits and cash (i.e. their internal liquid resources), I_i, is the value of inventories, and $\Pi_{i,}^s$ are the profits. Finally, κ and ψ are bounded between zero and one.

The capital check is captured by the "debt to equity" ratio (DER):

$$DER_{i,t} = \frac{\text{Total liabilities}}{\text{Equity}} = \frac{L_{i,t}^s}{E_{i,t}^s} \geq \varrho \tag{8}$$

with $0 < \varrho < 1$.[6] Finally, in accordance with the third component of the "6C" (the collateral check) loans are provided to shops in exchange of a collateral represented by firms' inventories. Banks apply a haircut to collateral, which enters in banks' balance sheet with a price P_h equal

[6] The values of the parameters are in line with commercial banks' internal regulatory practices, see Table 12 in Appendix.

to:

$$P_{h,t} = hW_t(1 + \pi^*), \tag{9}$$

where $0 \leqslant h \leqslant 1$ stands for the haircut imposed by bank regulation on the unit value of the inventories. The latter is given by the unit cost value of their replacement in production and is therefore equal to the average wage rate W_t updated for the Central Bank's inflation target π^*. A bank will lend to a shop i up to the value of the inventories accepted as collaterals, and given by

$$P_{h,t}(I_{i,t} + S)$$

Notice that in the above $S > 0$ whenever the shop owner is an entrant and $S = 0$ otherwise.[7]

Shops that pass the bank's creditworthiness test are eligible for loans. They receives credit whenever the bank's total credit risk exposure remains below the limit imposed by regulation. If the residual credit supply of the bank (see Equation 5 above) is not enough to satisfy a shop's credit demand, the shop is credit rationed (Stiglitz & Weiss 1981).

If the shop owner is unable to repay its loan, the bank seizes all her collateralized inventories and the deposits up to the amount of the shop's exposure. Seized assets (SC^b) are present in bank's balance sheet until sold in firesale markets (see Section 2.6 below) with a firesale price P_f equal to:

$$P_{f,t} = \frac{W_t(1 + \pi^*)}{2}. \tag{10}$$

Banks set the interest rate on new commercial loans (i^L) as well as on deposits (i^D) held at the end of the previous stage. The interest rate on loans is common across all banks and it is fixed applying an annual spread ($s > 0$) on the baseline interest rate set by the Central Bank (i):[8]

$$i_t^L = i_t + s/12 \tag{11}$$

The deposits interest rate is equal to the baseline interest rate, i.e. $i_t^D = i_t$.

2.5 Budget planning

Agents decide their planned consumption expenditures and relatedly their stock of assets. First, they adjusts their permanent income according to the following adaptive rule:

$$\Delta Y_{z,t}^p = \lambda_p(Y_{z,t} - Y_{z,t-1}^p),$$

where Y_z is actual income, Y_z^p is her permanent income, and λ_p is the adjustment speed parameter.

Agents plan consumption expenditures (CE_z) as a fixed fraction υ of their total wealth A_z, and permanent income:

$$CE_{z,t} = \upsilon(A_{z,t} + Y_{z,t}^p) \tag{12}$$

The financial wealth (A) of a worker corresponds to the sum of money holdings (H^c), bank

[7] The setup cost is specified in terms of units of the consumption good of the shop owner and is therefore part of the unencumbered capital of the shop.

[8] In our simulations we assume that the value of the annual loan spread s is equal to the average spread between lending and deposit rates for all commercial and industrial loans during the period 1986-2008.

deposits (D^c), plus the resale value of the stock of inventories (if any) in firesale markets ($P_f * I$). For shop owners, financial wealth is equal to the sum of money (H^s) and deposit holdings (D^s) minus outstanding loans (L^s). Finally, the financial wealth of a bank owner is constituted by money H^b, and if the bank is not troubled, by the bank's equity after subtracting required capital, i.e. $B^b_{m,t} + (CE^b_{m,t} - \chi_b(L^s_{m,t} + SC_{m,t})$. The balance-sheets of all the types of agents are reported in Table 1. Notice that the model is stock-flow consistent (see e.g. the seminal contribution of Godley & Lavoie 2007).

Once planned consumption expenditure are set, agents decide how to reallocate their wealth portfolio across different financial assets. We assume that all agents are subject to a cash-in-advance constraint. Accordingly, they need a stock of money when they visit shops to pay for the goods they want to buy.

Let us consider workers first. They owns $\overline{H^c_z}$ in cash and $\overline{D^c_z}$ in deposits and must choose the level of deposits D^c_z and money balances H^c_z to finance their consumption plans respecting the constraint:

$$D^c_{z,t} = (1 + i^D_t)(\overline{H}^c_{z,t} + \overline{D}^c_{z,t} - H^c_{z,t}).$$

Given the cash-in-advance constraint, the worker/consumer needs to have money when she visits shops. However, she does not know whether she will receive her wage before or after shopping. As a consequence, she must employ her current wealth to finance her planned expenditures CE_j. This implies that if $CE_{j,t} \leq \overline{H}_{z,t} + \overline{D}_{z,t}$, the worker sets $CE_{z,t} = H_{z,t}$ and leaves the rest in her bank account. Otherwise, $CE_{z,t} = H_{z,t} = \overline{H}_{z,t} + \overline{D}_{z,t}$.

Next consider the portfolio allocation of a bank owner. If she owns a troubled bank, her consumption expenditures CE_z are bounded by current money holdings $\overline{H_z}$. If the latter exceeds CE_z, the bank owner deposits the difference $\overline{H}_{z,t} - CE_{z,t}$ in her bank account. Otherwise, she sets $CE_{z,t} = \overline{H}_{z,t} = H_{z,t}$. If the bank is not troubled and $CE_{z,t} \leq A_{z,t}$, the owner fixes $H_{z,t} = CE_{z,t}$ and leaves the surplus $A_{z,t} - CE_{z,t}$ in bank equity. Otherwise, she sets $H_{z,t} = CE_{z,t} = A_{z,t}$.

Finally, consider the portfolio reallocation of a shop owner. Beyond money H_z and deposits D_z, a shop owner can also take a loan L_z up to her credit limit. If the shop has already a credit line and the bank is not troubled, the credit limit equal to the haircut value of her eligible collateral (determined in Eq. 9). Accordingly, the shop owner's financial constraints will be:

$$\begin{aligned} &H_{z,t} - \overline{H}_{z,t} = \overline{D}_{z,t} - \tfrac{D_{z,t}}{1+i^D_t} + \tfrac{L_{z,t}}{1+it^L} - \overline{L}_{z,t}, \\ &L_{z,t} \leq P_{h,t}(I_t + S)(1 + i^L_t). \end{aligned}$$

where $H_{z,t} \geq 0$, $D_{z,t} \geq 0$, $L_{z,t} \geq 0$ and where $\overline{H}_z$, $\overline{D}_z$ and $\overline{L}_z$ are the current levels of, respectively, cash, deposits, and bank loans. The shop owner can satisfy the above constraints and repay back his loan only if $\overline{H}_{z,t} + \overline{D}_{z,t} + P_{h,t}(I_t + S) \geq \overline{L}_{z,t}$.

2.6 Labor and goods market trading

Let us now consider how agents interact in the firesale, labor and goods markets.

Firesale markets. The supply side of firesale markets is constituted by banks selling foreclosed capital, and former shop owners liquidating their inventories. The buyers in firesale markets are shops, whose actual level of inventories are lower than their inventory target (which in turn is equal to their sale target). A buyer is matched to the first seller (if any) in the *i-th* queue. If the first seller in the queue cannot fullfil the whole order, the shop buys from the next one, and so on, until either the order is satisfied or the queue runs out of sellers. Buyers pay their orders with deposits and then, if necessary, with credit. Once firesale markets close, workers engage in labor and goods market trading.

Labor markets. Shops fix their posted wage w according to Equation 15 below. Employees offer to trade their endowment in exchange for an effective wage equal to

$$w_t^{eff} = min(w_{i,t}, H_{i,t}), \tag{13}$$

where H is the employer's money holdings (if $H = 0$, the worker will not supply labor). The shop accepts the offer of the worker unless its labor input exceeds its target and the ratio of inventory-to-sales target (IS) exceeds the critical threshold value $IS > 1$. Shop owners are self-employed and they use their endowment as an input.

Goods markets. Consumers learn the selling price p_s of the primary and secondary good they want to consume ($s = 1, 2$) and they send orders for some amount c_s given the cash-in-advance constraint $pc \leqslant H$. Given their level of inventories (I), shops then sell an amount $c^{eff} = min(c_s, I)$. The effective price paid by consumers is thus equal to $p_s^{eff} = p_s c_s / c_s^{eff}$. Consumers choose their desired consumption bundle $(c_1; c_2)$ in order to maximize the utility function:

$$u(c_1, c_2) = c_1^{\varepsilon/(\varepsilon+1)} + c_2^{\varepsilon/(\varepsilon+1)}, \tag{14}$$

with the demand parameter $\varepsilon > 0$, and subject to the budget constraint $p_1 c_1 + p_2 c_2 = E$.

2.7 Exit

At the end of each period bankrupted shops exit. A shop fails if the value of her financial wealth is lower than the value of her outstanding loans:

$$A^s_{i,t} = H^s_{i,t} + D^s_{i,t} + P_{h,t} * I_{i,t} - L^s_{i,t} < 0$$

If the bankrupted shops had loans, the bank seizes the collateralized inventories, and, if necessary, put shop's deposit to zero. Bankrupted shops will fire their workers, who will then become unemployed, and they will break their trading relationships in the goods market. Besides bankruptcy, a shop can exit also for some exogenous reasons with probability δ. In addition, it can voluntarily choose to exit if it is not able to pay for the fixed cost of the next period.[9]

Bank faces losses whenever one of their clients goes bankrupt. As a consequence, banks can fail if their equity becomes negative:

$$E^b_{m,t} = L^s_{m,t} + H^b_{m,t} + B^b_{m,t} - (D^s_{m,t} + D^c_{m,t}) - L^{cb}_{m,t} < 0.$$

In such a case, a new bank owner is chosen by selecting the richest customer (i.e., the one with the highest sum of cash and deposit holdings) of the bank who is not already an entrepreneur.

[9]Notice that this occurs in the model whenever the liquid wealth of the shop owner (and thus the sum of her cash holding, deposits and loan of the bank) is below the value of the fixed cost.

If the new bank owner has some legacy capital, the value of the latter is placed in the bank's balance sheet. Equity is then updated to take into account the variations occurred in the balance sheet of the bank.

2.8 Wage and price setting

At the end of every period, shops update their prices and wages. First, shops compute their sales target $y_{i,t}^{trg}$, by setting it equal to past sales. Next, they update their wages. Shops change their posted wage every Δ periods, according to:

$$w = \overline{w}\left[\left(1 + \beta\left(\overline{x^{trg}}/\overline{x^{pot}} - 1\right)\right)(1 + \pi^*)\right]^{\Delta/12}, \tag{15}$$

where $\overline{w}$ is the current wage, $\overline{x^{trg}}$ and $\overline{x^{pot}}$ are respectively the average input target and potential input[10] over the past Δ periods, and the parameter β captures the degree of wage (and price) flexibility in the economy.

Once wages are set, shops proceed to change prices. Recall from Equation 3 that the "normal" price is equal to $p_{i,t}^{nor} = (1 + \mu)w_{i,t}/(1 - \tau)$. Shops will stick to their normal price unless there is a big mismatch between inventories and sales target. More specifically, shops have an inventory-to-sale ratio (IS). If the demand LC is stronger than expected and inventories fall too much, the shop will increase its price by the factor δ_p, whereas it will cut the price by δ_p^{-1} if inventories accumulate too fast:

$$p_{i,t} = \begin{cases} p_{i,t}^{nor} * \delta_p, & \text{if } LC > y_{i,t}^{trg} * IS \\ p_{i,t}^{nor} * \delta_p^{-1} & \text{if } LC < y_{i,t}^{trg} * IS^{-1} \\ p_{i,t}^{nor}, & \text{otherwise} \end{cases}$$

Notice that in such framework, the frequency of price changes is endogenous.

2.9 Fiscal, monetary and macro prudential policies

To complete the exposition of the model, let us present how fiscal, monetary and prudential policies are implemented in our artificial economy.

2.9.1 Fiscal policy

The Government levies a sales tax τ on transactions occurring in the goods markets. It employs the collected revenues to recapitalize banks, thus providing public bail out of the financial sector. As a consequence, public deficit can arise. In such a case, the Government issues bonds that are bought by banks and, if necessary, by the Central Bank.

To keep public finances under control, the Government updates the sales tax rate according to the evolution of the ratio between sovereign debt and GDP. More specifically, first the Government computes the level of government debt relative to annual estimated potential output (y^*, see Section 2.9.2 below). Then, it adds to τ^* —the tax rate that stabilize the debt-to-GDP ratio

[10] Potential input corresponds to the number of agent having an employment relationship with the shop, even if they were laid off or if they refused to work because they were not paid.

in absence of entry and breakup shocks— an adjustment factor proportional to the difference between the actual and target debt-to-GDP ratio b^*:

$$\tau_t = \tau^* + \lambda_\tau \left(\frac{B_t}{P_t(1+i_{m,t})(12e^{y^*})} - b^* \right), \tag{16}$$

where B is the total stock of government bonds, P is the current price level, λ_τ is the adjustment parameter, and $1+i_m$ is the monthly interest rate, i.e. $1+i_{m,t} = (1+i_t)^{1/12}$.

The Government also computes the average wage rate W of the economy as the employment-weighted average wage across all shops.

2.9.2 Monetary policy

The Central Bank performs monetary policy by setting the nominal interest rate i via different types of Taylor rule (Howitt 1992, Taylor 1993).

In the benchmark scenario, the CB follows a dual-mandate Taylor rule ($TR_{\pi,y}$), where the interest rate is fixed according to the difference between current and target inflation and output gap:

$$ln(1+i_t) = max\{ln(1+i^*_t) + \varphi_\pi(ln(1+\pi_t) - ln(1+\pi^*)) + \varphi_y((y_t - y^*_t), 0\} \tag{17}$$

where φ_π and φ_y are fixed coefficients ($\varphi_\pi > 1$ and $0 < \varphi_y < 1$), $(1+\pi_t)$ is the inflation over the past 12 months, π^* is the fixed inflation target, y_t is the log GDP, y^*_t is the CB's estimate of log potential output and $i^*_t = r^*_t + \pi^*$.[11] As the Central Bank does not know the natural interest rate and the potential output of the economy, it must estimate them adaptively. It adjusts r^* according to the difference between current and target inflation with an adjustment speed η_r. It then estimates y^*_t employing an AR(1) model whose parameters are re-estimated right after r^* is adjusted.

We also consider a "conservative" Taylor rule (TR_π), where the Central Bank only cares about inflation stabilization:

$$ln(1+i_t) = max\{ln(1+i^*_t) + \varphi_\pi(ln(1+\pi_t) - ln(1+\pi^*)), 0\}, \tag{18}$$

with $\varphi_\pi > 1$. Next, we study a monetary rule in which the Central Bank responds to inflation and unemployment dynamics ($TR_{\pi,u}$, see also Dosi et al. 2015, Yellen 2014, Walsh 2009):

$$ln(1+i_t) = max\{ln(1+i^*_t) + \varphi_\pi(ln(1+\pi_t) - ln(1+\pi^*) + \varphi_U(ln(U_t) - ln(U^*_t)), 0\} \tag{19}$$

with $\varphi_\pi > 1$, $\varphi_U \geq 1$ and U^* is the target unemployment rate (Dosi et al. 2015). Finally, we explore the impact of a "three-mandate" Taylor rule, where the Central Bank takes into account credit dynamics beyond price and output stabilization ($TR_{\pi,y,c}$):

$$ln(1+i_t) = max\{ln(1+i^*_t) + \varphi_\pi(ln(1+\pi_t) - ln(1+\pi^*)) + \varphi_y(y_t - y^*_t) + ln(\frac{C_t}{C_{t-1}})^{\varphi_c}, 0\} \tag{20}$$

with $\varphi_\pi > 1$, $0 < \varphi_y < 1$ and $0 \leq \varphi_c \leq 1$. The inclusion of credit growth —a measures of

[11] Adjustment parameters on inflation and output gap are set in line with Woodford (2001) and are Taylor's original specification (Taylor (1993))

financial vulnerability— in the Taylor rule provides a connection between monetary and macro prudential policies (more on that in Lambertini et al. 2013, Ozkan & Unsal 2014, Verona et al. 2014).

2.9.3 Macro prudential policy

The primary objective of macro prudential policy is to limit systemic financial risk in order to minimize the incidence of disruptions in the provision of key financial services that could have serious consequences for financial markets as well as for the real economy. Macro prudential policies aim to achieve these results by (i) dampening the building up of financial imbalances; (ii) building defenses that contain the speed and sharpness of financial downswings and of their effects on the real economy; (iii) identifying and addressing common exposures, risk concentrations, and interdependencies in the financial system which could be sources of contagion, thus jeopardizing the functioning of the system as a whole.

This is the policy milieu in which the Basel Committee on Banking Supervision (BCBS) issued the so called *Basel III* reform of global regulatory standards (see BCBS 2011). To study the impact of different prudential policies in the model, as well as their interactions with alternative monetary policy rules, we start from the old Basel II framework and we then study the different levers of Basel III.

Basel II framework. This is the benchmark prudential policy scenario in the model. Under the Basel II regulatory framework, the minimum capital requirement ($CAR2$), defined as the ratio between bank's capital (TC) and its weighted assets (RWA) must not to be lower than $\chi_2 = 8\%$:[12]

$$CAR2_{m,t} = \frac{TC_{m,t}}{RWA_{m,t}} = \frac{E(T1)^b_{m,t} + E(T2)^b_{m,t}}{L^s_{m,t} + SC^b_{m,t}} \geq \chi_2. \tag{21}$$

In the model, RWA corresponds to the sum of loans to shops and seized collaterals.[13] The bank's total capital (TC) is the sum of Tier 1 ($E(T1)$) and Tier 2 ($E(T2)$) equities. $E(T1)$ is the core equity capital and $E(T2)$ is the supplementary capital computed as earnings form firesale market liquidations and revaluations.

Basel III framework. Given the unsatisfactory performance of the Basel II prudential regulation, the Basel Committee has tried to increase the resilience of the banking sector by designing the Basel III framework, which is grounded on two frameworks, namely the *global capital framework* and the *global liquidity requirements.* The global capital framework focuses on strengthening capital adequacy requirements, as well as on the introduction of a new leverage requirement and of counter-cyclical macro prudential measures. The global liquidity requirements are based on the liquidity coverage ratio in order to protect the financial system from potential liquidity disruptions.

[12] Minimum capital requirement in Basel II is taken form Basel II regulatory (BCBS (2004)))

[13] Risk-weighted assets (RWA) are computed by adjusting each asset class for risk in order to determine bank's exposure to potential losses. Following Basel II and Basel III requirements, loans to shops and seized collateral are weighted with 100% whereas cash, government bonds and reserves are considered riskless and have a weight equal to zero.

Global capital framework. The regulatory capital framework is grounded on three indicators that banks have to simultaneously satisfy: the minimum static capital requirement, the counter-cyclical capital buffer, and the leverage requirement.

1. *Minimum static capital requirement ($CAR3$)* is akin to the one computed in Basel II. However, the new index focuses on common equity, which is the highest quality component of banks' capital:
$$CAR3_{m,t} = \frac{Tier1_{m,t}}{RWA_{m,t}} = \frac{E(T1)^b_{m,t}}{L^s_{m,t} + SC^b_{m,t}} \geq \chi_3,$$
where χ_3 must be at least 4.5% according to the Basel III regulation.

2. *Counter-cyclical capital buffer (CCB)* supplements the $CAR3$ and it is supposed to dampen the destabilizing credit pro-cyclicality resulting from the Basel II framework. More specifically, the measure consists in the determination of the level of add-on of the bank capital determined by $CAR3$ in order constitute a safe buffer against risk (Drehmann & Gambacorta 2012, Behn et al. 2013, Drehmann & Tsatsaronis 2014). The aim is to achieve the broader macro prudential goal of protecting the banking sector from periods of excess aggregate credit growth, which are often associated with the building up of system-wide risk. In the model, the CCB is determined as follows: (i) compute the aggregate private sector (shops) credit-to-GDP ratio; (ii) compute the credit-to-GDP gap as the difference between the credit-to-GDP ratio and its long-run trend.[14] The size of the buffer add-on (as a percent of risk-weighted assets) is zero when the credit-to-GDP gap (G_t) is below the threshold J. It then increases with G_t until the buffer reaches its maximum level H. After that it stays at the upper bound of 2.5% of risk-weighted assets. More formally:
$$\kappa = CCB_{m,t} = \begin{cases} 0, & \text{if } G_t < J \\ \frac{(G_t - J)}{(H-J)} * 0.025, & \text{if } J \leq G_t \leq H \\ 0.025, & \text{if } G_t > H. \end{cases}$$
where $0 \leq \kappa \leq 0.025$. The analysis performed by the Basel committee has found that an adjustment factor based on $J = 2$ and $H = 10$ provides a reasonable and robust specification based on historical data about banking crises.

3. The *leverage requirement (LR)* is designed to constrain excess leverage in the banking system, also providing an extra layer of protection against model risk and measurement errors. In that, the non-risk based LR serves as a backstop to the risk-based capital measures (Jarrow 2013, Kiema & Jokivuolle 2010):
$$LR_{m,t} = \frac{Tier1_{m,t}}{TotalAssets_{m,t}} = \frac{E(T1)^b_{m,t}}{L^s_{m,t} + SC^b_{m,t} + B^b_{m,t} + D(R)_{m,t} + H^b_{m,t}} \geq \alpha,$$
with $\alpha = 3\%$.

[14]We assume that the credit-to-gdp indicator follows a linear trend based on OLS estimation of 5 years (first 5 years are transient). The coefficients of regression are recursively updated using data from the start of the observation period (5 periods) up to end 60 years. The trend forecast is performed on yearly bases.

Global Liquidity Requirement. The recent financial crisis has highlighted the importance of liquidity for the proper functioning of financial markets and of the banking sector. Hence, the Basel Committee introduced the *liquidity coverage ratio (LCR)* (Cooke et al. 2015, Calomiris et al. 2014, De Nicolò et al. 2012, Bindseil & Lamoot 2011). The LCR builds on traditional liquidity coverage methodologies already internally used by banks to assess exposures to stress events. More specifically, the LCR requires a bank's stock of unencumbered high-quality liquid assets ($HQLA$) to be larger than the expected net cash outflows ($NCOF$)[15] over a 1 month-long stress scenario:

$$LCR_{m,t} = \frac{HQLA_{m,t}}{NCOF_{m,t}} \geq \gamma,$$

with $\gamma = 1$. In the model, we employ the Level 2 definition of $HQLA$ provided by the Basel III regulatory framework:[16]

$$HQLA_{m,t} = D(R)_{m,t} + H^b_{m,t} + \min[0.85B^b_{m,t};\;\; 0.75(D(R)_{m,t} + H^b_{m,t})].$$

Total expected net cash outflows ($NCOF$) are calculated by multiplying the size of liabilities and assets by the rates at which they are expected to, respectively, run off or default in a situation of liquidity stress.[17] The LCR rules specify the run-off and default rates for the different types of liabilities and assets in the stress scenario. Let $\overline{O}^{b(-)}_t$ and $\overline{O}^{b(+)}_t$ denote the current contractual cash outflows and inflows of the bank. Expected cash outflows, $Ex[O^{b(-)}_t]$, and expected cash inflows, $Ex[O^{b(+)}_t]$, are then calculated as follows:

$$Ex[O^{b(-)}_{m,t}] = \overline{O}^{b(-)}_{m,t} + \sum_{e=1}^{n} \vartheta_e Liab^e_{m,t} = O^-_{m,t} + \vartheta_D(D^s_{m,t} + D^c_{m,t}) + \vartheta_{cb} L^{cb}_{m,t}$$

$$Ex[O^{b(+)}_{m,t}] = \overline{O}^{b(+)}_{m,t} - \sum_{a=1}^{n} \vartheta_a Asset^a_{m,t} = O^+_{m,t} - \vartheta^s_L + \vartheta_H H^b_{m,t} + \vartheta_b B^b_{m,t} + \vartheta_{D(R)} D(R)_{m,t},$$

where $\vartheta_D = 0.1$, $\vartheta_{cb} = 0.25$, are the run-off rates of liabilities, and $\vartheta^s_L = 0.5$, $\vartheta_H = 0$, $\vartheta_b = 0.2$ and $\vartheta_{D(R)} = 0$ are the default rates of assets as specified in the Basel III accord. Accordingly, $NCOF_{m,t} = Ex[O^{b(-)}_{m,t}] - Ex[O^{b(+)}_{m,t}]$.

3 Simulation results

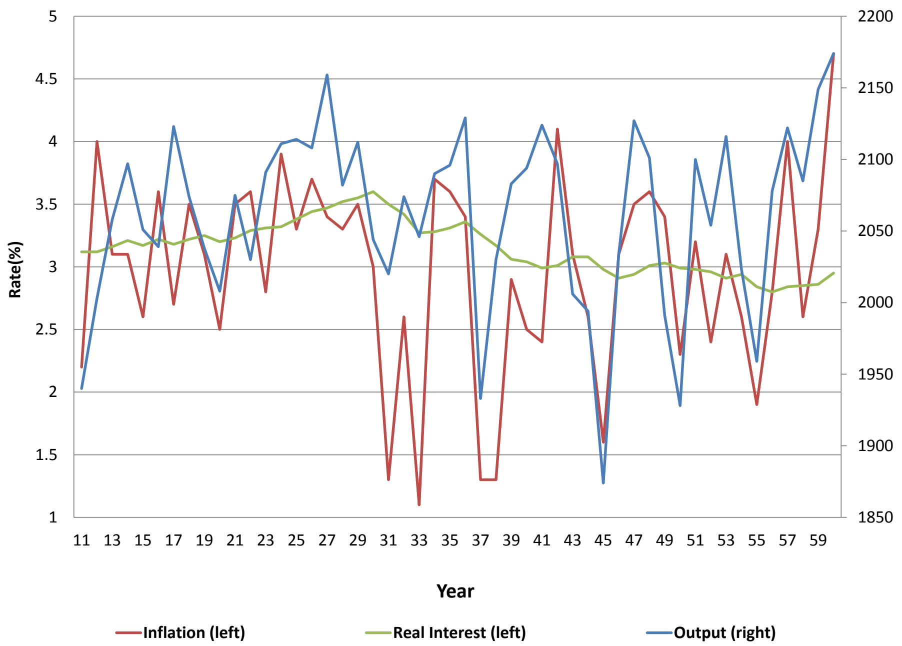
We analyze the model via computer simulations running a Monte Carlo exercise composed of 150 independent runs, whose time span covers sixty years.[18] Before employing the model to address

[15] The "expected" net cash outflow refers to a special terminology of Basel III rule's definition. It means the possible cash outflows of bank balance-sheet components computed on a base of run-off rates of assets and liabilities.

[16] More precisely, two types of assets can be considered to compute the $HQLA$. Level 1 assets include cash H^b_t and Central Bank reserves $D_t(R)$. Level 2 assets cannot be higher than 40% of bank's total $HQLA$, i.e. they can be at most two thirds of the quantity of Level 1 assets. Moreover, Level 2 assets enter in the $HQLA$ with a 15% haircut. All assets included in the calculation must be unencumbered (e.g. not pledged as collateral) and operational (e.g. not used as a hedge on trading positions).

[17] The run-off rates of liabilities as well as the default rates of assets are fixed by the Basel committee of bank supervision and are general for all banks. For more details see BCBS (2013) and Keister & Bech (2012)

[18] Extensive tests show that the results are robust to changes in the initial conditions for the microeconomic variables of the model. In addition, they show that, for the statistics under study, Monte Carlo distributions



Note: The time series are depicted from the 11-th year since the first 10 years are accounted as transient because of the learning process

Figure 1: The time series of Output, inflation and real interest rate (50 Years)

policy issues (see Section 3.2), we study its explanatory capability, i.e. the set of stylized facts it is able to replicate (cf. Section 3.1). The values of the parameters of the model are spelled out in Table 12 in Appendix A.

3.1 Empirical validation

The time series of output gap, inflation and the real interest rate generated by the model are presented in Figure 1. The model exhibits endogenous business cycles (see the output time series), as well as fluctuations in the inflation rate between 1% and 4%. The real interest rate is rather stable over time.

We than report in Table 2 the averages of some relevant U.S. macroeconomic variables for the period 1986-2008 and we compare them with the ones produced by our model. We find that the average values of inflation, unemployment, output-gap volatility and bank failure rate generated by the model are not that far from real ones.

In order to study the behavior of macroeconomic variables at business-cycle frequencies, we filter them with a HP-filter and we compute standard deviations and cross-correlations. The results are reported in Table 3. In line with the empirical evidence (see e.g. Stock & Watson 1999, Napoletano et al. 2006), we find that inventories are more volatile than GDP, while the fluctuations of consumption are milder. The co-movements between output and the other macroeconomic variables suggest, again well in tune with empirical works, that consumption, inventories, inflation and credit are pro-cyclical, whereas unemployment is counter-cyclical.

Finally, for each simulation scenario we estimated the Okun's law and the Phillips curve

are sufficiently symmetric and unimodal. This justifies the use of across-run averages as meaningful synthetic indicators. All our results do not significantly change if the Monte Carlo sample size is increased.

Variable	*U.S.data*	*Model*
Inflation	3.0	2.9396
Inflation volatility	1.3	0.6711
Unemployment	6.1	5.8804
Real interest rate	1.8	3.2097
Bank failure rate	0.51	0.5000
GDP gap volatility	2.0-3.2	2.7796

Table 2: U.S. data vs. median model-generated outcomes

Variable	St. Dev	t-4	t-3	t-2	t-1	t	t+1	t+2	t+3	t+4
GDP	1.5611	0.1556	0.4762	0.7814	0.9487	1.0000	0.9487	0.7814	0.4762	0.1556
Unemployment	0.7192	-0.7705	-0.8147	-0.8554	-0.8868	-0.8877	-0.8096	-0.6544	-0.3936	-0.1511
Inventories	1.6821	0.3727	0.3729	0.3681	0.3587	0.3328	0.2720	0.1810	0.0786	-0.0024
Credit	2.4530	0.4822	0.4599	0.4446	0.4367	0.4242	0.4068	0.3683	0.3268	0.2775
Consumption	1.1408	-0.0516	0.0816	0.3270	0.5752	0.7108	0.6724	0.4933	0.3673	0.0462
Inflation	0.3631	-0.0851	0.0311	-0.2117	0.2646	0.4222	0.1043	0.1174	-0.1435	-0.1894

Table 3: Cross-correlation structure of output and other macro variables. Simulated series have been detrended with HP filter ($\lambda = 100$)

(see Tables 4 and 5). We find that both curves are robust emergent properties of the model. Indeed, Table 4 and 5 reveal for any scenario the presence of, respectively, a negative relationship between output and unemployment (Okun's law) as well as the presence of a negative relationship between inflation and unemployment (Phillips' curve).

3.2 Monetary and macro prudential policies

We now explore the possible interactions between different macro prudential policies and alternative monetary rules on a range of target variables. These include output gap, output gap volatility, inflation, unemployment, likelihood of economic crises (defined as a drop of GDP higher than 3%) and bank failure rate. The results of the policies experiments are reported in Tables 6-11. Each entry in a table returns the ratio between the Monte Carlo average of the macroeconomic variable generated under a given prudential and monetary policy combination and the one in the benchmark scenario (i.e. Basel II and dual-mandate Taylor rule).

Macro prudential policies. Let us start by comparing for the baseline monetary policy scenario ($TR_{\pi,y}$), the impact of the different levers of the Basel III regulation ($CAR3$, CCB, LR, LCR) with respect to Basel II one. First, the introduction of the Basel III agreement appears to stabilize the banking sector and to improve the performance of the economy. Indeed, with respect to the Basel II scenario, the output gap and its volatility, the average unemployment, the likelihood of economic crises and the bank failure rates are significantly lower. Furthermore, the type of macro prudential regulation has limited effect on inflation (see also Suh 2012, Spencer 2014), which seems instead to be more dependent on the monetary policy rule implemented[19] (see also discussion below).

[19] The average inflation rate is 2.94% under the Basel II regime and 3.15% in the Basel III regulatory framework.

	$TR_{\pi,y}$		$TR_{\pi,y,c}$	
	Basel 2	Basel 3	Basel 2	Basel 3
MC Average of β_1	-1.6803^{***}	-2.0816^{**}	-1.5935^{*}	-1.8117^{**}
	(0.031 4)	(0.052 2)	(0.027 3)	(0.048 2)
R^2	0.2446	0.3254	0.2710	0.3626
	(0.044 2)	(0.062 7)	(0.051 6)	(0.069 5)

Note: $TR_{\pi,y}$ = dual-mandate Taylor rule; $TR_{\pi,y,c}$ = three-mandate Taylor rule, Estimation of $\Delta log(Y_t) = \beta_0 + \beta_1 \Delta log(U_t) + \epsilon_t$. MonteCarlo standard errors in parentheses, Monte Carlo sample size M = 150. (***) significant at 1% level; (**) significant at 5% level; (*) significant at 10% level.

Table 4: Emergence of the Okun's curve in alternative setups

	$TR_{\pi,y}$		$TR_{\pi,y,c}$	
	Basel 2	Basel 3	Basel 2	Basel 3
MC Average of β_1	-0.3306^{**}	-0.2658^{*}	-0.3866^{*}	-0.3060^{**}
	(0.045 1)	(0.025 8)	(0.030 5)	(0.041 6)
R^2	0.1204	0.1765	0.2141	0.2378
	(0.051 8)	(0.059 1)	(0.047 6)	(0.063 7)

Note: $TR_{\pi,y}$ = dual-mandate Taylor rule; $TR_{\pi,y,c}$ = three-mandate Taylor rule, Estimation of $\pi_t = \beta_0 + \beta_1 U_t + \epsilon_t$. Monte Carlo standard errors in parentheses, MonteCarlo sample size M = 150. (***) significant at 1% level; (**) significant at 5% level; (*) significant at 10% level.

Table 5: Emergence of the Phillips curve in alternative setups

We now consider which levers of the Basel III regulation allow a performance improvement over the benchmark prudential scenario. More specifically, we compare the impact of each Basel III lever alone and in combinations. We find that the joint adoption of minimum static capital requirement ($CAR3$) and counter-cyclical capital buffer (CCB) is the major driver of the improved performance of the economy under the Basel III framework. Indeed, the results in the $CAR3 + CCB$ scenario are almost as good as the ones attained in the Basel III one, but with a much more simplified regulatory framework (in the case of output gap volatility, they are even better). This supports the conjecture of Haldane (2012) and Aikman et al. (2014), about the trade off between complex and simple policy rules. In that, the contribution of the counter-cyclical capital buffer is fundamental. The CCB dampens the pro-cyclicality of credit, thus correcting the destabilizing impact of capital requirements. In a financial accelerator framework (see Bernanke et al. 1999, 1994, Gertler et al. 2007), the introduction of counter-cyclical capital buffer reduces credit booms during expansions, allowing banks to have more solid balance sheets in recessions, thus providing more credit to firms when they need it most (in line with the results in Ashraf et al. 2011).

The performance of the economy worsens in the LR, LCR, and $LCR + LR$ scenarios. The negative impact of such instruments is due to the fact that, by cutting down financial leverage (without the underpinning of the $CAR3$ and CCB components), they trigger credit crunches and reduce shops' production and overall economic activity.

Finally, our results suggest that complexity is a pervasive feature of the macro prudential regulatory framework. Indeed, the effects of the joint adoption of all levers of Basel III are much

	$TR_{\pi,y}$	TR_{π}	$TR_{\pi,u}$	$TR_{\pi,y,c}$
Basel II	1.0000	1.6702*	1.3264	0.9671**
		(0.1025)	(0.0854)	(0.0622)
Basel III	0.6214**	1.4402	1.0231*	0.5838**
	(0.0533)	(0.1851)	(0.1532)	(0.0652)
$LCR + LR$	1.1610*	1.8261	1.4820**	1.0792
	(0.2013)	(0.2490)	(0.4632)	(0.3025)
$CAR3 + CCB + LCR$	0.8114*	1.6017	1.2207**	0.7816*
	(0.0892)	(0.1283)	(0.1455)	(0.1095)
$CAR3 + CCB + LR$	0.8816**	1.6501	1.2671*	0.8200**
	(0.1186)	(0.5329)	(0.4239)	(0.0958)
$CAR3 + CCB$	0.7185**	1.5114*	1.1351*	0.6741*
	(0.0685)	(0.1752)	(0.1459)	(0.0867)
$CAR3$	1.0314*	1.7284 *	1.3614	0.9822*
	(0.3695)	(0.3967)	(0.3055)	(0.2011)
LR	1.2185**	1.8700*	1.5128	1.1370*
	(0.2511)	(0.3058)	(0.2395)	(0.1733)
LCR	1.0605	1.7802*	1.4103**	1.0384**
	(0.3675)	(0.4962)	(0.3421)	(0.3251)

[a] *Note:* Absolute value of the simulation t-statistic of H0: "no difference between baseline and the experiment" in parentheses; (***) significant at 1% level; (**) significant at 5% level; (*) significant at 10% level.

Table 6: Normalized values of average output gap across experiments.
Basel III prudential tools: LCR, liquidity coverage ratio; LR, leverage ratio; $CAR3$, capital adequacy ratio; CCB, counter-cyclical capital buffer. *Monetary policies:* $TR_{\pi,y}$, dual-mandate Taylor rule; TR_{π}, "conservative Taylor rule; $TR_{\pi,u}$, unemployment and inflation Taylor rule; $TR_{\pi,y,c}$, three-mandate Taylor rule (output gap, inflation and credit growth).

	$TR_{\pi,y}$	TR_{π}	$TR_{\pi,u}$	$TR_{\pi,y,c}$
Basel II	1.0000	2.2412**	1.9641*	0.9250**
		(0.5294)	(0.3259)	(0.0942)
Basel III	0.9468 *	2.0655 **	1.8917	0.8901 **
	(0.1102)	(0.6288)	(0.4410)	(0.0925)
$LCR + LR$	1.3122*	2.5201 *	2.3014 **	1.1655 *
	(0.3860)	(0.8264)	(0.7641)	(0.5012)
$CAR3 + CCB + LCR$	0.9195**	1.9855**	1.8700 *	0.8731 **
	(0.1382)	(0.6680)	(0.5213)	(0.2384)
$CAR3 + CCB + LR$	0.9764 **	2.1602	1.9318 *	0.9109**
	(0.1866)	(0.6778)	(0.5840)	(0.1600)
$CAR3 + CCB$	0.8964*	1.8582*	1.6721**	0.8433 **
	(0.1497)	(0.4673)	(0.4025)	(0.1102)
$CAR3$	1.2465**	2.3188*	2.0264*	0.9866**
	(0.3300)	(0.7025)	(0.6754)	(0.1758)
LR	1.3864*	2.8402	2.6358 *	1.2208 *
	(0.4013)	(0.8547)	(0.7821)	(0.3451)
LCR	1.2700*	2.4561*	2.2318**	1.0852 **
	(0.2750)	(0.6475)	(0.5821)	(0.2245)

[a] *Note:* Absolute value of the simulation t-statistic of H0: "no difference between baseline and the experiment" in parentheses; (***) significant at 1% level; (**) significant at 5% level; (*) significant at 10% level.

Table 7: Normalized values of average output gap volatility across experiments.

	$TR_{\pi,y}$	TR_{π}	$TR_{\pi,u}$	$TR_{\pi,y,c}$
Basel II	1.0000	3.5013 *	0.7811**	0.8241*
		(2.1258)	(0.1358)	(0.1584)
Basel III	0.8517*	1.8955 *	0.6514 **	0.7016 *
	(0.1685)	(0.8654)	(0.1254)	(0.1469)
$LCR + LR$	1.5344 *	5.1182	1.0645*	1.3899
	(0.4658)	(1.2325)	(0.4258)	(0.5218)
$CAR3 + CCB + LCR$	0.9611 *	2.3184*	0.7600	0.7955**
	(0.0962)	(0.8545)	(0.2358)	(0.2690)
$CAR3 + CCB + LR$	1.2460**	4.0281*	0.8294*	1.1482**
	(0.5002)	(1.5248)	(0.3325)	(0.4114)
$CAR3 + CCB$	0.9123*	2.0277*	0.7014**	0.74213**
	(0.0896)	(0.7562)	(0.0921)	(0.0654)
$CAR3$	1.2864*	4.4823	0.8654*	1.2088**
	(0.6950)	(1.9024)	(0.1254)	(0.2650)
LR	1.6895**	5.4921	1.1682 *	1.5360*
	(0.8521)	(2.0232)	(0.7024)	(0.8921)
LCR	1.4950**	4.8902*	0.9267*	1.3688*
	(0.6201)	(1.6408)	(0.2368)	(0.5503)

[a] *Note:* Absolute value of the simulation t-statistic of H0: "no difference between baseline and the experiment" in parentheses; (***) significant at 1% level; (**) significant at 5% level; (*) significant at 10% level.

Table 8: Normalized values of average unemployment rate across experiments.

	$TR_{\pi,y}$	TR_{π}	$TR_{\pi,u}$	$TR_{\pi,y,c}$
Basel II	1.0000	0.9316 *	1.1200 **	1.1758**
		(0.0162)	(0.2468)	(0.3102)
Basel III	1.0714 **	0.9516**	1.1599*	1.2301**
	(0.1932)	(0.1600)	(0.2841)	(0.3125)
$LCR + LR$	0.9695*	0.8612	1.0597*	1.1312*
	(0.0435)	(0.0385)	(0.0984)	(0.1524)
$CAR3 + CCB + LCR$	1.0456**	0.9452*	1.1395	1.1900**
	(0.1457)	(0.0854)	(0.2450)	(0.2987)
$CAR3 + CCB + LR$	0.9864*	0.8801*	1.0892	1.1587**
	(0.0954)	(0.0755)	(0.1751)	(0.2285)
$CAR3 + CCB$	1.0602*	0.9466*	1.1402*	1.2130**
	(0.0954)	(0.0854)	(0.0458)	(0.3654)
$CAR3$	0.9795*	0.8702 *	1.0675*	1.1400
	(0.0754)	(0.0597)	(0.4407)	(0.6279)
LR	0.9617*	0.8586	1.0582	1.1300**
	(0.0667)	(0.0597)	(0.4685)	(0.5218)
LCR	0.9725**	0.8694	1.0602**	1.1388*
	(0.0722)	(0.0654)	(0.5027)	(0.6425)

[a] *Note:* Absolute value of the simulation t-statistic of H0: "no difference between baseline and the experiment" in parentheses; (***) significant at 1% level; (**) significant at 5% level; (*) significant at 10% level.

Table 9: Normalized values of average inflation rate across experiments.

	$TR_{\pi,y}$	TR_{π}	$TR_{\pi,u}$	$TR_{\pi,y,c}$
Basel II	1.0000	3.2105*	1.8233**	0.7781*
		(0.3440)	(0.1687)	(0.0864)
Basel III	0.8125**	2.6572 **	1.2385*	0.6125**
	(0.0966)	(0.2854)	(0.1796)	(0.0697)
$LCR + LR$	1.2601	3.8351*	2.0614	0.9245**
	(0.4851)	(0.6854)	(0.5766)	(0.0785)
$CAR3 + CCB + LCR$	0.8867**	2.7714**	1.3145*	0.7122**
	(0.0796)	(0.3287)	(0.1985)	(0.0895)
$CAR3 + CCB + LR$	0.9105*	2.8125*	1.4864 **	0.7521**
	(0.0883)	(0.4012)	(0.1968)	(0.0907)
$CAR3 + CCB$	0.8465**	2.7241	1.2864**	0.6511**
	(0.0698)	(0.3864)	(0.1766)	(0.0776)
$CAR3$	1.2100**	3.6212 *	1.9545*	0.8125**
	(0.5120)	(0.6987)	(0.3296)	(0.1052)
LR	1.3256*	3.9012*	2.1455**	1.0264 *
	(0.5880)	(0.7655)	(0.4856)	(0.2387)
LCR	1.2385*	3.8008	2.0254*	0.8752**
	(0.5017)	(0.7554)	(0.4628)	(0.1284)

[a] *Note:* Absolute value of the simulation t-statistic of H0: "no difference between baseline and the experiment" in parentheses; (***) significant at 1% level; (**) significant at 5% level; (*) significant at 10% level.

Table 10: Normalized values of average likelihood of economic crisis across experiments.

	$TR_{\pi,y}$	TR_{π}	$TR_{\pi,u}$	$TR_{\pi,y,c}$
Basel II	1.0000	5.1672*	1.9431**	0.7614**
		(1.9872)	(0.6975)	(0.3597)
Basel III	0.5216*	3.2382*	1.1285 **	0.4131**
	(0.2875)	(1.3854)	(0.7854)	(0.1987)
$LCR + LR$	3.8211**	8.1452*	4.0314**	1.1852**
	(1.5024)	(1.5495)	(1.0258)	(0.8861)
$CAR3 + CCB + LCR$	1.6827*	7.2591*	2.1901**	0.9288**
	(0.7932)	(1.4335)	(0.7574)	(0.3854)
$CAR3 + CCB + LR$	1.6411*	7.1286*	2.0861**	0.9213*
	(0.5922)	(1.5028)	(0.8643)	(0.4025)
$CAR3 + CCB$	0.8234**	3.8820*	1.8701*	0.7102**
	(0.3125)	(1.1368)	(0.8625)	(0.4021)
$CAR3$	2.0134*	7.8713	2.2288*	1.0382**
	(1.0125)	(1.6584)	(0.6580)	(0.5461)
LR	4.2164*	8.1722**	4.5012*	1.2151*
	(1.2854)	(1.5891)	(1.0368)	(0.5687)
LCR	4.6002*	8.1924*	4.9215 *	1.2275 **
	(1.3258)	(1.6998)	(1.0351)	(0.6258)

[a] *Note:* Absolute value of the simulation t-statistic of H0: "no difference between baseline and the experiment" in parentheses; (***) significant at 1% level; (**) significant at 5% level; (*) significant at 10% level.

Table 11: Normalized values of average bank failure rate across experiments.

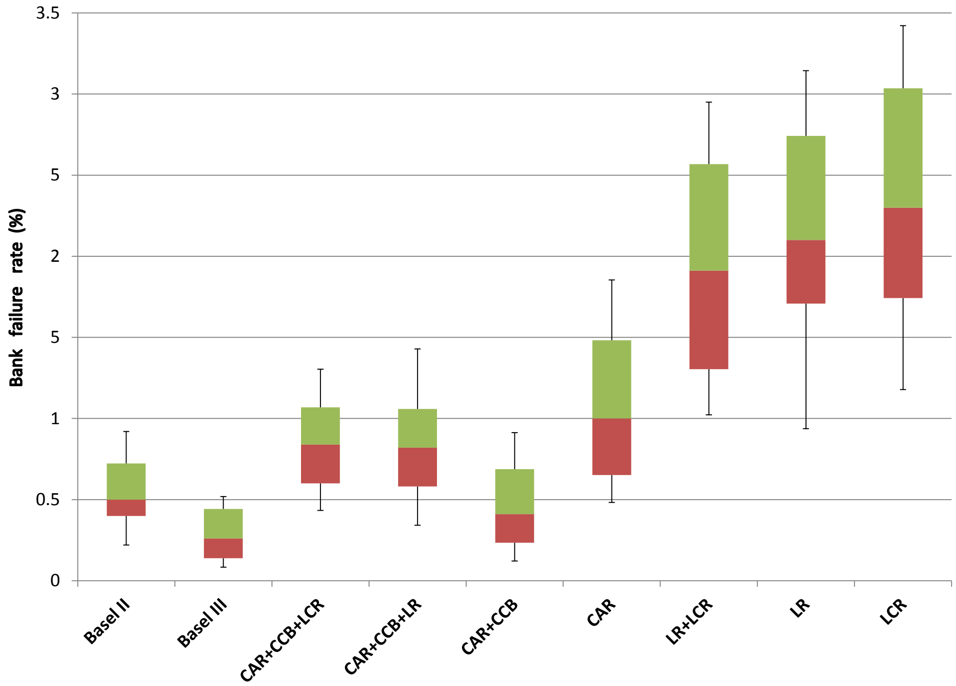


Figure 2: Boxplot comparing the impact of macro prudential tools on bank failure rate

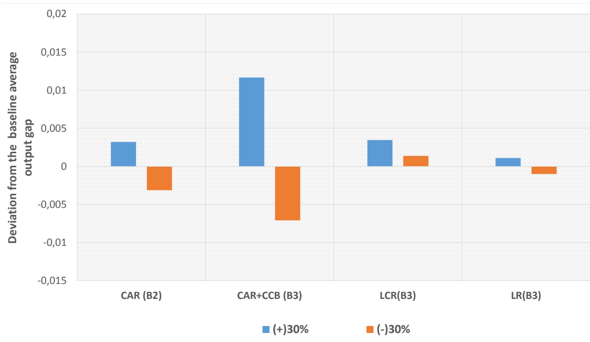
stronger than the summation of the standalone impact of each single tool (thus confirming the conjectures of Arnold et al. 2012, Ojo 2014). Such conclusions are reinforced by the non-additivity of the components of the Basel III regulation: the performance of the economy does not always improve when an additional constraint is added to the previous ones. For instance, the inclusion of the leverage requirement *or* the liquidity coverage ratio to the $CAR3 + CCB$ scenario does not improve economic performance. In the $CAR3 + CCB + LR$ scenario, the leverage ratio LR often becomes the binding constraints for banks,[20] forcing them to hold a higher proportion of liquid assets, thereby reducing the supply of credit to firms (for more details see GFMA et al. 2013). In the $CAR3 + CCB + LCR$ scenario, banks increase the liquidity coverage ratio by replacing loans with liquid assets. The result is again a reduction of the total credit supply and an adverse effect on overall economic performance.

We further spotlight the impact of different macro prudential regulation on the banking sector by employing boxplots, which report the minimum, maximum, median, first and third quartile of the bank failure rate distribution (cf. Figure 2). The plots confirm that the Basel III regulatory framework dominates Basel II, by minimizing the bank failure rate. The "second-best" results is attained when the $CAR3$ and CCB levers of Basel III are activated, even if the support of the distribution is wider and it overlaps more with the Basel II framework. In line with our previous findings, addressing only liquidity risk by implementing the liquidity requirement (LCR) or the leverage ratio (LR) as well as the combination of both ($LR + LCR$) considerably increases the instability of the banking sector.

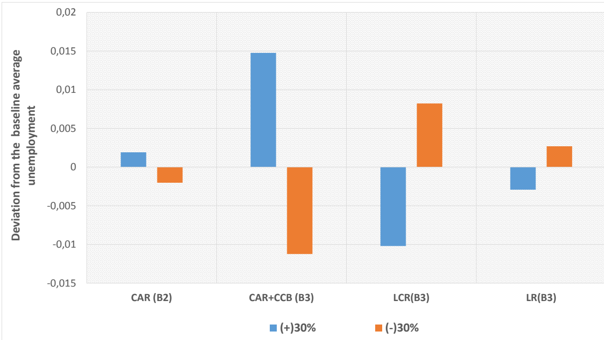
Finally, we assess the robustness of our policy conclusions by performing a sensitivity analysis

[20]Incidentally, note that a study commissioned by the Global Financial Markets Association and The Clearing House concludes that the leverage ratio would become the binding capital ratio for more than half of the institutions analyzed (see GFMA et al. 2013).

(a) output gap



(b) unemployment



(c) inflation

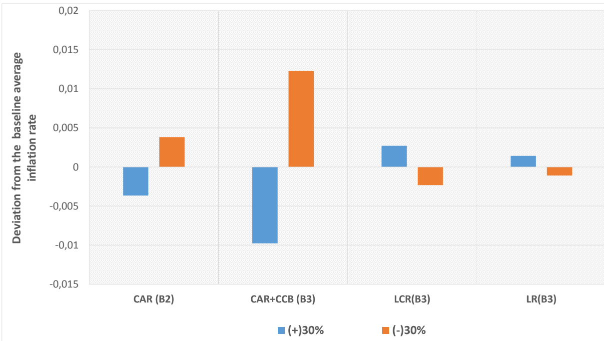


Figure 3: Impact on macroeconomic variables of macro prudential parameter perturbation

wherein we perturbate the parameters of macro prudential policy scenarios. More specifically, for each macro prudential regulation, we increase and reduce by 30% the related policy parameter and we record the deviation from the baseline average values of output gap, unemployment, and inflation. The results reported in Figures 3 suggest that the policy recommendations drawn from the model are solid: only in the $CAR3 + CCB$ scenario, the variation of the macroeconomic variables is slightly higher than 1%. In the other cases, the policy parameters appear to have a little impact on macroeconomic variables.

To sum up, we found that in the benchmark monetary policy scenario, macro prudential regulation considerably affects macroeconomic dynamics. Moreover, the Basel III and $CAR3 + CCB$ scenarios are *complementary* to monetary policy in taming macroeconomic instability by increasing the resilience of the financial system. In particular, the performance of the $CAR3 + CCB$ scenario is very close to the one of the full-fledged Basel III framework. Finally, we find that the different levers of Basel III add up in a non-linear way: the joint contribution of the instruments to the financial resilience of the economy is higher than the sum of their stand-alone impact, and adding an additional lever to an existing combination may reduce the performance of the regulatory framework (e.g. introducing the LCR or LR in the $CAR3 + CCB$ scenario). Are such results robust to alternative monetary rules? What is the best combination of monetary and prudential policies?

Monetary policy. Let us study the performance of different Taylor rules and the possible interactions with the macro prudential framework. More specifically, we run a horse-race competition among a dual-mandate Taylor rule ($TR_{\pi,y}$), where the Central Bank aims to stabilize inflation and the output gap, a "conservative" Taylor rule (TR_{π}), in which the Central Bank cares only about inflation, an unemployment dual-mandate Taylor rule ($TR_{\pi,u}$), where unemployment stabilization replaces the output gap, and a triple-mandate Taylor rule ($TR_{\pi,y,c}$), in which the interest rate is fixed taking into account credit growth. The results are spelled out in Tables 6-11.

First, we find that the rank of macro prudential rules is robust to different monetary policy regimes. The Basel III regulation returns the lowest output gap, unemployment rate, likelihood of crisis, and bank failure rate even if the Central Bank follows a "conservative" Taylor rule or responds to unemployment and credit variations. The $CAR3 + CCB$ rule ranks always second and it attains the best results in taming output gap volatility. Both the Basel III and the $CAR3 + CCB$ regulations do not minimize the average inflation rate, which nevertheless is still quite low (the minimum and maximum inflation rate attained in the simulations are respectively 1.1% and 4.7%).

How do different monetary policy rules fare once the macro prudential scenario is fixed? The results are not as crystal clear as those related to prudential regulation. The triple-mandate Taylor rule ($TR_{\pi,y,c}$) achieves the best results in terms of output gap, likelihood of economic crises, output gap volatility, and bank failure rate (see Quint & Rabanal 2014, Ghilardi & Peiris 2014). These results suggest that a "leaning against the wind" monetary policy, which also takes into account credit dynamics, allows to avoid periods of excessive credit growth, and thus increases the stability of the banking sector and the performance of the economy. However, a Central Bank that wants to minimize the average unemployment rate should fix the interest rate according to the inflation rate and the unemployment gap ($TR_{\pi,u}$). Finally, a "conservative" Taylor rule allows instead to minimize the average inflation rate (TR_{π}).

Overall, the above results suggest that the best mix between monetary policy and macro prudential regulation depends on the specific objectives pursued by regulators (stabilization of output and financial sector vs. low unemployment vs. inflation stabilization). In particular, the joint adoption of Basel III regulation and a monetary rule focused on output, inflation and credit allows to smooth credit fluctuations, thereby increasing the resilience of the banking sector and taming financial and macroeconomics instability. This is in line with the results of Jordà et al. (2015) pointing out that the joint adoption of "leaning against the wind" monetary strategy and counter-cyclical macro prudential policy allows to dampen excessive credit and leverage growth thus minimizing the risk of dangerous financially-originated recessions.

4 Conclusion

We extended the agent-based model developed by Ashraf et al. (2011) in order to study the impact on the stability of the financial sector and on the performance of the economy of different macro prudential regulations and their interactions with alternative monetary policy rules.

We first tested the capability of the model to replicate an ensemble of macroeconomic empirical regularities. Next, we performed simulation exercises to study different policy combinations. We find that monetary policy and macro prudential regulation are *complementary* in increasing the resilience of the banking sector and improving the performance of the economy. Such results can be obtained with the joint adoption of a triple-mandate Taylor rule, focused on output gap, inflation and credit growth, and a Basel III prudential regulation. Furthermore, even if the Basel III framework returns the best results in terms of financial and macroeconomic stability, similar results can be attained by adopting a simpler regulatory framework grounded on the capital adequacy ratio and counter-cyclical capital buffer. In that our paper contributes to the debates about the trade-off between complex vs. simple policy rules (for more details see Haldane 2012, Aikman et al. 2014). Finally, the joint impact on the stability of the banking sector of micro prudential tools is considerably larger than the sum of standalone levers, suggesting the complexity of the prudential framework, where additivity of different measures cannot be taken for granted.

Our work could be extended in several ways. First, an interbank market should be introduced, where credit institutions could exchange funds against collaterals (repo). This would allow us to study in more detail the impact of macro prudential and monetary policies on the stability of the banking sector. Relatedly, one could study how the network topology of the interbank network is influenced and affect the effects of different prudential and monetary policy combinations (see e.g. Gai et al. 2011). Moreover, the presence of an interbank market is a pre-requisite to analyze the possible interactions between macro prudential policies and non-conventional monetary interventions such as different declinations of quantitative easing. Second, for a given interbank structure, one could study the "too big to fail" and "too connected to fail" problems, trying to develop and test policy that could sterilizing the impact of systemically important banks on macroeconomic dynamics (see e.g. Ueda & di Mauro 2013, Castro & Ferrari 2014).

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Appendix A

Parameter	*Description*	*Value*
	Prudential Regulation Parameters	
α	Leverage requirement	0.03
γ	Liquidity requirement	1
χ_2	Minimum capital requirement in Basel II	0.08
χ_3	Minimum capital requirement in Basel III	0.045
κ	Counter-cyclical capital buffer	$[0, 0.025]$
ϑ_D	Run-off rate of deposit	0.1
ϑ_{cb}	Run-off rate of central bank loan	0.25
ϑ_L	Run-off rate of commercial loan	0.5
ϑ_b	Run-off rate of gov. bonds	0.2
	Bank Parameters	
κ	Quick ratio	0.5
ϱ	Debt-to-equity ratio	0.5
ψ	Return on assets	0.1
s	Loan spread	0.0175
h	Loan-to-value ratio	0.5
ξ	Reserve requirement	0.03
	Fiscal and Monetary Policy Parameters	
φ_π	Inflation coefficient in Taylor rule	1.5
φ_y	Output gap coefficient in Taylor rule	0.5
φ_U	Unemployment coefficient in Taylor rule	1.1
φ_c	Credit coefficient in Taylor rule	0.7
π^*	Target inflation rate	0.03
η_r	Adjustment speed of evolving real rate target	0.0075
b^*	Target debt-to-GDP ratio	0.33
λ_τ	Fiscal adjustment speed	0.054
	Worker/Consumer Parameters	
ε	Demand parameter	7.0
λ_p	Permanent income adjustment speed	0.4
θ	Frequency of innovation	100
σ	Job search probability	0.5
	Shop Parameters	
$\bar{\mu}$	Average percentage markup over wage	0.138
S	Setup cost	15
IS	Critical inventory-to-sales ratio	3.0
δ_p	Size of price cut	1.017
β	Wage adjustment parameter	0.3
Δ	Length of the contract period	12

Table 12: Parameters of the model