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

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**Abstract**

We assess the interactions between macro prudential policy-monetary policy on the one side, and standalone viz. aggregate impact of macro prudential tools on macro-dynamics on the other, on the ground of an agent-based model(ABM). The direct ancestor of the work is the model developed by Ashraf et al. (2011). Simulation results suggest that "leaning against the wind" monetary policy contributes more to the stability of the economy as a whole. We also find that macro prudential tools have limited effect on inflation at the same time lowering the unemployment, output gap and the volatility of the economy. We show that the positive joint impact of the prudential instruments is considerably larger than the sum of the individual contributions to financial stability. Finally we find that in terms of effects on macro-dynamics counter-cyclical capital requirement under Basel III accord shows the "second-best" result with respect to a complete Basel III global regulatory framework which arises the debate about the need of complex vs. simple policy driven rules. On the contrary the effects of leverage and liquidity requirements both in isolation or in combination are marginal and even negative.

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**Keywords:** Macro Prudential Policy; Basel III Regulation; Capital Adequacy; Counter-cyclical Buffer; Leverage Restriction; Financial Stability; Agent-based Model.

**JEL Classification Numbers:** C63, E52, E58, E6, G01, G21, G28.

# 1 Introduction

The recent financial crisis have demonstrated numerous weaknesses in the global regulatory framework and in banks risk management practices. As a consequence, a growing consensus is arising that one essential advancement of the reform agenda is to re-orientate banking supervision to place stronger emphasis on mitigating instability in the financial system as a whole, i.e. the invocation for macro prudential regulatory tools (Borio (2011), Blanchard et al. (2013), Zhang & Zoli (2014), Blundell-Wignall & Roulet (2014), Gualandri & Noera (2014)). In response, regulatory authorities have considered various measures to increase the stability of financial markets and prevent future negative impact on the economy.

In terms of policy, the recent financial crisis has highlighted the need to go beyond a purely micro-based approach to financial regulation and supervision. There is a growing consensus among policy makers that a macro prudential approach to regulation and supervision should be adopted. The policy debate is focusing in particular on the usage, implementation and effectiveness of macro prudential tools (Fujimoto et al. (2014),Bianchi & Mendoza (2013),Claessens et al. (2013),Arregui et al. (2013)), as well as their impact on macroeconomic outcomes and their relationship with monetary policy (Spencer (2014),Guzman & Roldos (2014),Angelini et al. (2011), Beau et al. (2012)). Until recently, only limited research and analytical tools was available to inform decisions on a macro prudential policy framework. In the wake of the financial crisis, however, macro prudential policy has attracted considerable attention among researchers, and the research literature is now growing fast.

The endogeneity of money is the crucial element of the model indirectly trying to provide the analysis of the transmission mechanism of the monetary policy. We model credit network with a stock-flow consistent structure on the level of consumers, shops, banks, central bank and government agents.

Hence, we contribute to the existing literature on financial regulation by providing an analysis of the impact of both Basel II and Basel IIIs main components (both, jointly and in isolation) on financial stability and the interactions between the monetary policy and prudential regulations and the impact of the latter on the macro performance of the economy. For this purpose, we consider the combined impact of micro and macro prudential instruments, thus, incorporating various sources of systemic risk.[1] Since one cannot simply aggregate the several standalone impacts of the instruments in order to avoid the fallacy of composition, we consider the interaction and coordination of economic agents as crucial for the analysis, especially for the impact of the macro prudential tools. Therefore, we choose an agent-based computational economic (ACE) model of the financial sector as the appropriate methodology to address the described issues.

Considering the lessons taken from the recent financial crisis (high level of the balance sheet, procyclical deleveraging, the gradual decline of the quality and quantity of the capital, not enough liquidity and the connectedness of financial institutions) we would like to investigate the role of the macro/micro prudential tool component of balance sheet on the crisis propagation mechanism, the diffusion mechanism of it from the micro to macro level and the generation of crisis. In this line we will recall Minskys financial instability hypothesis (Minsky & Kaufman (2008)) describing an endogenous crisis dynamics defining the financial fragility criteria based on a well-known balance-sheet typology. Addressing the lessons of the financial crisis the new Basel III comprehensive reform package by strengthening the global liquidity, capital standards and inputting leverage restrictions. Hence in the analysis of the first research question we would like to experiment the two regulatory frameworks: the one-dimensional regulatory approach of Basel II framework and multi tool prudential regulation Basel III (Post-crisis bank macro prudential) framework to see impact of the both mechanisms on macro level of economy. Hence we would like to answer what are the differences in effects of the Basel II vs. Basel III framework on the macro-dynamics of our artificial economy and their capabilities of achieving financial stability? Can our Agent-based economy account for possible policy interventions. How do banks' regulation macro prudential rules affect the macro performance of the economy, especially aggregate volatility and the

[1] As a micro prudential tool we refer to a static minimum capital requirement, liquidity and leverage requirements and as a macro prudential tool the countercyclical capital buffer

generation of crisis?

## 2 Brief review of recent literature on macro prudential policy

The literature on the impact/effectiveness analysis of macro prudential policy tools and the ways of interactions between the monetary and macro prudential policies is still in its *initium* and has provided very limited guidance for policy applications. Ultimately, the number of policy speeches, research papers and conferences that discuss a macro perspective on financial regulation and the efficiency of the latter has grown considerably(Angelini et al. (2014), Geanakoplos (2014), Leeper & Nason (2014), Zhang & Zoli (2014), Claessens et al. (2013), Benigno et al. (2013)).

Table 1 provides a summery of recent studies on the effects of new global macro prudential regulation as well as the interaction of the macro prudential policy with monetary one[2]. On closer examination, there are four facts which are particularly interesting to look at.

- First, there are only very few studies concerning the impact of more than one component of the post-crisis prudential regulation of Basel III accord. The majority of studies rather just consider single impact of the tools.

- Second, except for, Angelini et al. (2012),Kato et al. (2010), Krug et al. (2014) the studies above show a strict separation of the analysis of micro and macro prudential instruments. Additionally, the analysis of micro prudential tools predominates, in particular, there is a strong focus on the minimum static capital requirement in terms of capital adequacy ratio (CAR). Hence, an analysis of the impact of the new macro prudential part of Basel III is missing. Therefore, the sources of systemic risk are only partially taken into account.

[2]For detailed literature reviews see Galati & Moessner (2014) and Claessens (2014)

Table 1: Studies on the interaction of macro prudential/monetary policy and impact of macro prudential tools

| Author(s) of Contribution | Framework | Tool analyzed | impact of the tool |
|---|---|---|---|
| | **Monetary/macro prudential policy interactions** | | |
| Alpanda et al. (2014) | DSGE, CC | CAR | + |
| Fisher (2014) | CC | CAR/LCR | + |
| Jonsson & Moran (2014) | CC | CAR+CCB | + |
| Zilberman & Tayler (2014) | GE | CAR+CCB | + |
| Quint & Rabanal (2013) | DSGE | CAR | − |
| Agénor et al. (2013) | DSGE | CAR+CCB | + |
| l Brzoza-Brzezina et al. (2014) | DSGE | CAR/LTV | − |
| Smets (2013) | CC | CAR+CCB/LR/LCR | + |
| Maddaloni & Peydro (2013) | Empirical | CAR/LCR | + |
| Ozkan & Unsal (2014) | DSGE | LR/CAR+CCB | +/− |
| Angelini et al. (2012) | Empirical, CC | CAR/LCR/CCB | − |
| Beau et al. (2012) | DSGE | CAR | + |
| Kannan et al. (2012) | DSGE | CAR | − |
| Suh (2012) | DSGE | CAR/LTV | + |
| van den End & Tabbae (2012) | Empirical(MCS) | LCR | + |
| Christensen et al. (2011) | DSGE | CAR | − |
| Angeloni & Faia (2011) | DSGE | CAR | − |
| | **Impact of the prudential tools** | | |
| Brunnermeier & Sannikov (2014) | GE | LR/CAR | − |
| Krug et al. (2014) | ABM | CAR/CCB/LCR/LR | + |
| Benigno et al. (2013) | GE | CAR | − |
| Boissay et al. (2013) | GE | LCR | + |
| Lim et al. (2013) | Empircal | CAR | − |
| Shim et al. (2013) | Empirical | CAR | − |
| Adrian & Boyarchenko (2012) | DSGE | LR | + |
| Cincotti et al. (2012) | ABM | CCB | + |
| He & Krishnamurthy (2014), | DSGE | LR/CAR | + |
| Miles et al. (2013) | Empirical | CAR/CCB | + |
| Rabanal et al. (2011) | Empirical | LR | − |
| Kato et al. (2010) | Empirical | CAR/CCB/LCR | + |
| Bianchi & Mendoza (2013) | DSGE | LR | − |
| Barrell et al. (2010) | Empirical | LR/LCR | + |
| Borio & Shim (2007); | Empriccal, CC | CAR/LCR | + |
| Hilbers et al, 2007; | Empirical | LCR | + |

[a] ***Note:*** *GE = General Equilibrium Model; DSGE = Dynamic Stochastic General Equilibrium Model; CC = Constructive Criticism; MCS = Monte Carlo Simulation; ABM = Agent-based Model; CAR = Capital Adequacy Requirement;CCB-Countercyclical Capital Buffer, LCR = Liquidity Coverage Ratio; LTV-Loan-to-Value; LR-Leverage Ratio*

- The few studies which, at least partially, analyze the impact of Basel III's macro prudential overlay mainly make use of general equilibrium (GE) and dynamic stochastic general equilibrium (DSGE) frameworks. Although it is crucial especially for the analysis of macro prudential policy, the interaction and coordination among economic agents and, hence, between financial and real sector as well as within financial sector itself is completely neglected. Furthermore, the suitability of analyzing crises, i.e. out-of-equilibrium situations of the economy, with an equilibrium approach could generally be put into question. Furthermore, under the framework of the GE and DSGE model the analysis of the same tool are giving controversial results in case of different model.These conflicts depend on the nature of the shocks impacting on the economy.

- Empirical analysis on macro prudential instruments are very few because of the lack of established models of the interaction between the financial system and the macroeconomy, as well as by the scarcity of data needed to conduct empirical tests.

# 3 The Model

The model attempts to portray, the mechanism by which the macro/micro prudential policy affects on macroeconomic policy and economic activities as a whole. In particular, we aim at evaluating the impact of prudential tools subject to financial system crisis. We developed the model of Ashraf et al. (2011) so as to make it with detailed banking system with a central authority to accomplish a financial control with elements of macro/micro prudential policy in terms of the liquidity, leverage and capital requirements. Adding these new components, we have tried to make the structure comparable to the post-crises financial regulation canonical Basel III structure.

The model starts from the proposition that, in reality, almost all exchanges in an advanced economy involve a specialized trader (”shop owner”) on one side or the other of the market. The shops are producing and selling heterogeneous consumption goods using $n$ types of labor. To open and finance the production shops use firstly their own financial wealth or the ones obtained from firesale market and, secondly, the bank credit, in case if self-financement and firesale funds are not enough. Banks are also heterogeneous in terms of their balance sheets and bank failures endogenously emerge from the low pay-pack of the loans, run-off the deposit funds, etc,. Bank are implementing the role of financial funds accumulation and injections throughout the acceptance of deposits from agents. The number of the banks is fixed and the failed banks are substituted by the new ones. The central bank is responsible for a monetary policy and the financial control over the banking sector throughout the macro/micro prudential tools. The government conducts fiscal policy by gathering tax revenues and issuing bonds.

## 3.1 The conceptual framework

Our economy consists of a fixed number $N$ of people, a fixed number $n$ of different durable goods, and the same number $n$ of different types of labor. The time is discrete, the unit is the month, indexed by $t=1,\ldots,T$. We assume initially each person to have a fixed type $(i,j)$, where $i \neq j$ and $i \neq j+1$, meaning that an agent produces just one kind of commodities labeled by $i$ ("production good") and is a potential consumer of just two other commodity (different from $i$), labeled $j$ and $j+1$ ( primary and secondary "consumption good"). We assume that there is exactly one person of each type, hence the population of the economy is $N = n(n-2)$.

*Shops, production, and trading.* Since agents do not consume the commodity they produce, they form trading relationships through facilities called shops which provide both production and trading operations. There are n different types of shops. A shop of type $i$ is capable of buying $i$ type of labor with money, converting it into good $i$, and selling good $i$ for money. We just take as given that during a particular month there will exist some number $s$ of shops, each offering to trade one of the $n$ goods. Each person may have a job agreement with at most one shop in which case that shop is his employer" and he is one of its "employees" and at most one shop that deals in each of his consumption goods, in which case that shop is one of his "stores" and he is one of its "customers". Each person's trading relationships will evolve endogenously.

Each shop of type $i$ has a single owner, whose production good is $i$. Operating the shop entails a variable cost of one unit of unique type of labor per unit of good i produced. When the shop is first opened, the owner invests either the part of his financial wealth either a capital purchased from firesale markets into the shop's capital. All trade takes place at prices that are posted in advance by the shop. Specifically, each shop posts a retail price $p_{i,t}$ as after-tax markup over a marginal cost and a monthly wage rate $w_{i,t}$ as a mark-up on a nominal wage computed by the Government. Both can be adjusted with periodicity of one month.

*Banks, deposits, and loans.* There is a fixed number $m$ of banks where $m$ is a divisor of the number of goods $n$. Agents are assigned to certain bank depending on their production good and consumption good, with the same number of agents for each bank. Each agent can only deal with the bank to which it is assigned to. We keep the number of banks fixed as well, so any bankrupt bank replaced by the new one.

The main functions of the bank is to accept deposits from agents and to give out loans to shop owners. Loans are made with full recourse but are also collateralized by inventory and legacy capital. In addition to loans and seized collateral, banks can hold money and government bonds. Banks are subject to a prudential bank regulation by the central bank.

*Government and central bank policies.* In our model economy, the government conducts fiscal policy and central bank, the monetary and macro/macro prudential policy. Specifically, the government levies and gathers taxes, issues the bonds, services the interest on bonds and computes the average wage rate, which is the employment-weighted average across all shops, and announces the result to all agents. It does not purchase goods or labor but it does issue bonds, services the interest on bonds through a sales tax on every retail transaction .

Central bank, being responsible for a monetary policy, sets the nominal interest rate $i$ following the Taylor rule (classical and alternative). In addition, the central bank is engaged in forecasting the future GDP, inflation, and takes a banking system supervision and control role implementing the Basel II first and later on Basel III regulatory frameworks.

## 3.2 The behavioral rules

Each stage our model economy proceeds through the same sequence of actions consisting of seven stages: 1) entry, search and matching; 2) financial market trading; 3) labor and goods market trading; 4) monetary and macro prudential policy; 5) fiscal policy; 6) exit; and 7) wage and price setting.

### 3.2.1 Entry, search and matching

In the entry stage, each person who is not already a shop owner or a bank owner becomes a potential entrant ("entrepreneur") with a fixed probability $\theta/N$, where the parameter $\theta$ represents the supply of entrepreneurship or so called a frequency of innovation. A "potential" entrepreneur has an opportunity to open a shop provided he is able to immediately defray the setup cost of $S$ units (in total) of his consumption good which can be obtained from the entrepreneur's own legacy capital (if any), from resale markets, from stores with which the entrepreneur has a trading relationship or by acquiring a credit. If he does not have enough financial wealth to pay for the setup cost, then he will allow the entry opportunity to lapse. His financial wealth consists of money holdings, deposit holdings, and the credit limit provided by the bank. The latter equals 0 if the entrepreneur has not been granted a line of credit,and $P_h(S + LC)$ otherwise, where $LC$ is the entrepreneur's stock of legacy capital (inventories).

Each entrepreneur goes through the following process to decide whether to enter. Before entering the market the entrepreneur of $i$-type shop formulates a business plan for his prospective shop, which includes a mark-up $\mu_{i,t}$, a sales target $y_{i,t}^{trg}$ and a profit $\Pi_{i,t}$. The entrepreneur picks his mark-up randomly from a uniform distribution over $[0; 2\overline{\mu}]$, where $\overline{\mu}$, is a parameter measuring the average percentage mark-up over variable costs $w_{i,t}$, and picks his sales target $y_{i,t}^{trg}$, randomly from a uniform distribution over *[1; n]*. The price $p_{i,t}$ is defined based on after-tax markup over a marginal cost $w_{i,t}$ pricing rule. Hence

$$p_{i,t} = \frac{(1 + \mu_{i,t})}{(1 - \tau)} w_{i,t}.$$

The profit flow $\Pi_{i,t}$ of each the shop i after the choice of the mark-up, sales target and the price, reads as

$$\Pi_{i,t} = [p_{i,t} y_{i,t}^{trg} - w_{i,t} y_{i,t}^{trg}] - i^D y_{i,t}^{trg} w_{i,t} > 0,$$

where $[p_{i,t} y_{i,t}^{trg} - w_{i,t} y^{trg}]$ component represents the account profit of the shop owner and $i^D y_{i,t}^{trg} w_{i,t}$ component stands for an opportunity cost of using money for inputs for getting an income from the deposit account ($i^D$ stands for a monthly nominal interest rate on deposits). The entrepreneur decides to enter if the business plan will pass the test. Specifically if $\Pi_{i,t} > 0$(profitability condition), he enters the market, otherwise allows the entry opportunity to lapse.

To verify the entry action, the shop owner sends messages to two people, one of whom is unemployed, with the information about the potential wage and the other of whom is a prospective customer (a randomly chosen person whose primary consumption good is the same as the entrepreneur's production good) with a potential price information. Potential shop sets the wage rate $w_{i,t}$ equal to

$$w_{i,t} = W_t (1 + \pi^*) * U(\phi_1, \phi_2)$$

Where $W_t$ is the average wage rate which the government computes as a employment-weighted average across all shops, and its publicly known, $U(\phi_1, \phi_2)$ is a random number picked from a uniform distribution in interval of (0,1), and $\pi^*$ is the central bank's fixed target monthly $i$ nflation rate.

The potential employee will agree to have a employment relation with the new shop, if his effective wage (the wage experienced last period) is less when the one offered by the entrepreneur $w_t^{eff} < \frac{w_{i,t}}{(1+\pi^*)}$. The potential consumer of product $i$, will agree to buy a good $i$ if the effective price of the consumer is greater when the one offered by the shop $p_t^{eff} > \frac{p_{i,t}}{(1+\pi^*)}$.

After all this procedure, the entrepreneur makes his entry decision, if the profitability test is positive and the both messages sent to potential employee and consumer answer affirmatively to the invitation. Otherwise, the opportunity of entry lapses.

### 3.2.2 Financial market trading

While the replication of financial market stylized facts has constituted the aim of many ABMs, much less attention has been directed at emergent behavior on the balance sheet dimension of financial markets. For this reason, we endow each agent in each time period of $t$ with the schematic balance sheet structure following the logic of the Stock-flow consistency in agents level(Godley & Lavoie (2007)). Below is depicted the balance-sheet matrix representation of all the agents.

Table 2: The balance-sheet matrix of the model

| | *Consumer* | *Shop* | *Bank* | *Gov* | *CB* | $\Sigma$ |
|---|---|---|---|---|---|---|
| *Deposit* | $+D^c$ | $+D^s$ | $-(D^c + D^s), +D(R)$ | | -D(R) | 0 |
| *Loan* | | $-L^s$ | $+L^s, -L^{cb},$ | | | 0 |
| *Bond* | $+B^c$ | | $+B^b$ | -B | $+B^{cb}$ | 0 |
| *Inventory* | | $+LC, -SC^b$ | $+SC^b$ | | | $+LC$ |
| *HPM* | $+H^c$ | $+H^s$ | $+H^b$ | | $+H^{cb}$ | 0 |
| *Balance* | -W | $-E^s$ | $-E^b$ | $+GD$ | | 0 |
| $\Sigma$ | **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 or fixed capital, does not sum to zero. This is a phenomenon that is explained by the fact that tangible capital appears in the assets of shops, but they are not counterbalanced totally by the liabilities of another sector(only with the part of sized collateral).*

Following the balance sheet structure depicted in Table 2., on the assets side of banks balance sheet, each bank is endowed with commercial loans ($L^s$) which are loans made by the bank to shop owners, measured as the dollar value of principal and interest payable this month; reserves at CB ($D(R)$,) where banks are obliged to hold minimum reserves against their liabilities in the form of balances at the central bank $D(R) = \xi(D^s + D^c)$ ;

seized collateral $SC^b$ is a capital seized by the bank from defaulting shops, valued at the firesale price; $LC$ stands for a legacy capital(inventories) of the shop, cash ($H^b$) is holdings of high-powered money; government bonds ($B^b$) are bonds held by the bank, evaluated as the amount due this month.

The profit of a specific bank consists of the margin between interests on loans and on deposits, minus interest paid to the central bank:

$$\Pi_t^b = \sum_{i=1}^{n} [i_{t-k}^L L_{t-k}^s - i_{t-k}^D (D^s + D^c)_{i,t-k}] - i * L_{t-k}^{cb}$$

where $k$ counts for the months back from current month $t$. On banks incomes side determinants are $L^s$ contractual amount of commercial loans and on banks costs side ($D^s + D^c$) and $L^{cb}$: that are the accepted deposits, and loans from central authorities respectively. $i^L, i^D$ and $i$ are commercial loans, deposit and nominal interest rates respectively (defined later).

Adding up the deposits held by the shops and consumers, loans from the central bank ($L^{cb}$) and equity ($E^b$) gives liabilities.

The loans demanded by banks from central bank follow the myopic rule above;

$$L_m^{cb(Dem)} = \{\gamma_b(D_m^s + D_m^c) - B_m^b - D_m(R) - H_m^b\} * z,$$

where z=1 iff $LCR < \gamma_b$ and $z = 0$ otherwise. As indicated by equations above, when liquidity coverage ratio(LCR) defined later, falls below a minimum value (a bottom value called $\gamma_b$), banks get advances from the central bank, thus allowing them to restore the minimum $\gamma_b$ ratio.

Loans are made with full recourse but are also collateralized by inventory. Since loans are made with full recourse, if a shop owner is unable to repay his bank loan, the bank may seize all of his inventory that is collateralized and the deposits until the value of what has been seized equals the amount owed. All seized assets stay on the bank's balance sheet until sold in the firesale markets with $P_f$ price, defined as

$$P_f = 1/2 * W_t * (1 + \pi^*),$$

where $W_t$ is a average wage rate, which is employment-weighted average across all shops computed by the government, and $\pi^*$ is the central bank's monthly inflation target. Each firesale market has a queue of sellers who are either banks offering to sell foreclosed capital or former shop owners offering to sell their legacy capital. In both cases there is possibility that at time $t$ neither the bank owner nor the shop owner will be able to realize all the foreclosed capital or the inventories. Hence, we imposed an exogenous parameter of $\zeta$ on banks and shops to liquidate the foreclosed capital (banks) and inventories (shops) in firsale markets. So a bank or a shop supplies $min(Demand_i, Capital_i)$ on a firesale queue, but manages to liquidate only $\zeta * Supply_i$, where $\zeta \in [0, 1]$.[3] .

All of that capital is available at a publicly known firesale price $P_f$ (as mentioned above) that was determined during the previous month. The buyer of the firsale markets are shop owners. The shop owner is matched to the first seller (if any) in the *i-th* queue. If the first seller in the queue cannot full the whole order, he sells what he has and the turn goes to the next seller in the queue, and so on, until either the order is fulfilled or the queue runs out of sellers.

Each bank applies a haircut to collateral, that is, each month it establishes a haircut" price, $P_h$

$$P_h = h * W_t * (1 + \pi^*),$$

where $h$ stands for the loan-to-value ratio imposed by bank regulation and is measured as replacement cost-value of the collateral to the borrower. Following the "haircut" price rule, bank will lend dollars for each unit of inventory it accepts as collateral.

[3]The results of interaction between monetary and macro prudential policies presented in Section 5 are robust in case of using a random number generator for a cutoff parameter $\zeta$ on the capital liquidation in firesale maket and in case we use and extremums of parameter for values of 0.4 and 0.8

*Credit supply.* At the beginning of the stage, each bank updates its equity after the previous month's transactions and the entry stage. Before any financial market trading takes place, banks in all sectors are examined by the central bank. Banks with negative equity fail and are replaced by the new one. Next, all banks are checked for global regulation rules of Capital Requirement, Liquidity (LCR) and Leverage (LR) requirements (described in macro prudential policy section) to check if the bank is in troubled.[4] If one of those conditions is violated, the corresponding bank becomes a troubled bank. Troubled banks are not allowed to provide new loans (although they are allowed to roll over outstanding loans).

The loans are granted by bank based on the "6C" like approach of creditworthiness (Jiang (2007)) and the supply of it is restricted by the budget $M_{b,t}$.

The data about the financial and economic situation of the loan applicant are defined as financial creditworthiness prerequisites. These include a study whether the loan can be repaid in accordance with the terms and using revenue from the activity of the business entity based on borrower's accountability. The intent of "6C" analysis is to determine: 1)Can the shop owner pay? (capacity); 2)Does the shop owner have enough cash on hand to pay if a period of adversity arises? (capital); 3)Will the credit issuer be protected if the shop owner fails to repay the loan? (collateral); 4)Will the shop owner(borrower) pay? (character or credit reputation); 5)Will something adversely affect the shop owners ability to pay? (conditions); 6)Does the shop owner demonstrate an ability to make wise decisions? (common sense).

To measure the creditworthiness of the potential borrower the bank uses both credit and non-credit data, meaning, some of those measures(character, conditions and common sense) are "subjective" and are most often based on the credit grantors historical experience with their borrowers. Custom scores often use both credit and non-credit data. In such

[4]The capital requirement under the Basel II accord is constrained by the static capital adequacy ratio of 8 percent and in case of the Basel III global regulatory framework the capital requirement is represented as a sum of the static capital adequacy ratio of 4.5 percents and an addition buffer add on the static capital from 0 to 2.5 percent depending on the macroeconomic characteristics of economy(more satailed in Section. 3.2.4)

a system we account for the layering of risk across the first three Cs of credit granting: capital, capacity and collateral. The Capacity will be measured in terms of "quick ratio", and "return on assets" (ROA), the Capital by "debt to equity" ratio (DER).

$$QR_{i,t} = \frac{\text{Current Assets-Inventories}}{\text{Current Liabilities}} \geq \kappa$$

$$DER_{i,t} = \frac{\text{Total liabilities}}{\text{Equity}} \geq \varrho$$

$$ROA_{i,t} = \frac{\text{Net income(after tax)}}{\text{Total assets}} \geq \psi$$

The third "C" collateral, becomes a part of the creditworthiness analysis for pay-back of a loan. In a model loans are collateralized by inventory. Each bank applies a haircut to collateral $P_h$, and it will lend not more that $P_h$ dollars for each unit of inventory accepted as collateral.

Shop $i$ receives requested full credit whenever the bank's total credit risk exposure remains below its limit. When the credit risk associated to the credit request supersedes the bank's limit $M_{b,t}$, firm $i$ receives rejection of a request. $M_{b,t}$ is a reserve of exposures that the bank can still provide to shops in the form of loans, hence the credit supply in the current period is restricted by the budget $M_{b,t}$ :

$$M_{t,b} = \frac{1}{\chi_b} E_t^b - (L_t^s + SC),$$

where the $\chi_b$ stands for the minimum capital requirement, $E_t^b$ is the equity of the bank and the $(L^s + SC)$ bank's total exposure to credit risk.

*Interest rates.* Each bank sets the interest rate on all new commercial loans that will be issued in a month and the interest rate on all deposits $i^D$ held at the end of the stage. The deposits interest rate $i^D$ is determined as a mark-down on the base nominal interest rate $i^D = (1 - \mu^b) * i$, $0 \leq \mu^b \leq 1$, where $\mu^b$ is a mark-down on the nominal interest rate set by the monetary authority. The bank always sets interest rate so that $i^D < i < i^L$, where

$i^L = i + s/48$, $s$ is a fixed annual spread, common across all banks.

*Budget planning and Financial transactions.* There are four different income types that agents except the government and central bank in a model can possibly receive:

1. the labor income i.e. the monthly wage that an agent receives if the latter is employed. The wage depends on the wage offer that the future employer (shop owner) suggests when a worker applies for a job and the agents effective wage as described in section above. For a shop and bank owner the labor income will be presented in terms of a profit received.

2. The agents can receive interest payments from the bank for the deposits.

Each person decides on planned consumption expenditures $E$. He first adjusts his permanent income $Y^p$ according to the following adaptive rule:

$$\Delta Y^p = \lambda_p (Y - Y^p),$$

where $Y$ is actual income (either wages or profit) and $Y^p$ is permanent income from the previous period, and $\lambda_p$ is the permanent income adjustment speed.

We assume that each person gets planned consumption expenditures this month equal to a fixed fraction $\upsilon$ of total financial wealth. Thus, the planned expenditure $E$ of each person is, $E = \upsilon * A$, where the financial wealth $A$ in the formula above can be depicted as follows:

$$A = \begin{cases} Consumers : H^c + D^c + B^c + P_f * L \\ Shopowner : H^s + D^s - L^s \\ Bankowner : H^b + (E^b - \chi_b(L^s + SC) + B^b). \end{cases}$$

Having chosen $E$ (planned consumption expenditure), each agent(consumer, shop and bank owner) chooses the amount of cash $H$, taking into account the constraints he faces. Consider first an agent who does not own a bank or a shop. He enters the financial market trading stage owning $\overline{H^c}$ in cash, $\overline{D^c}$ in deposits and $\overline{B^c}$ in government bonds and must choose $H^c$, $D^c$ and $B^c$ with which to leave this stage, subject to neither being negative and subject to

$$D^c = (1+i^D)(\overline{H^c} + \overline{D^c} + \overline{B^c} - H^c) - B^c(1+i^D)$$

We use the convention of measuring $D^c$ as the amount owed by the bank at the next stage of financial market trading. If $E^c \leq \overline{H^c}+\overline{D^c}+\overline{B^c}$, the person sets $E^c = H^c$ and leaves the rest in his bank deposit account as a government bonds. Otherwise, he withdraws all of his deposits, government bonds and revises planned expenditure so that $E^c = H^c = \overline{H^c} + \overline{D^c} + \overline{B^c}$. The idea here is that he will need to have $E$ in the form of money when he visits his stores. But he does not know whether he will be paid his income before or after shopping for goods, so he plans to carry $E$ out of the financial market to ensure against being unable to fulfill his expenditure plans.

Next to consider a bank owner as a consumer. If he owns a troubled bank, that is, if even one of the central bank regulation requirements are violated: the capital requirement, leverage requirement or liquidity coverage requirements, his expenditure is bounded by current money holdings $\overline{H^b}$. If the latter exceeds $E^b$, the remaining $\overline{H^b} - E^b$, goes into the bank; otherwise, he sets $E^b = \overline{H^b} = H^b$. If the owned bank is not troubled, then he employs his financial wealth $A$ in the following way: if $E^b \leq A^b$, he sets $H^b = E^b$ and leaves the surplus $A^b - E^b$ in bank equity; otherwise, he sets $H^b = E^b = A^b$. Finally, consider a shop owner. A shop owner can hold money $H^s$ and deposits $D^s$, and can also take a bank loan $L^s$(measured as the amount owing next month) up to his credit limit. If the shop has already been granted a credit line earlier, his credit limit is set equal to the haircut value of his eligible collateral (inventories) if his bank is not troubled. The shop owners financial transaction constraint will be:

$$H^s - \overline{H^s} = \overline{D^s} - \frac{D^s}{1+i^D} + \frac{L^s}{1+i^L} - \overline{L^s},$$

where $H^s \geq 0$, $D^s \geq 0$, $L^s \geq 0$ and $L^s \leq P_h * LC(1+i^L)$. It is possible for a shop owner to satisfy all of his constraints if and only if $\overline{H^s} + \overline{D^s} + P_h * LC \geq \overline{L^s}$, otherwise, he is unable to repay his loan and will be declared bankrupt.

### 3.2.3 Labor and goods market trading.

This stage starts with trade in the firesale markets, where inventories can be purchased at a discounted price from former shop owners. Next, each person in turn engages in labor market trading (with his employer) and goods market trading (with his stores). Labor market trading proceeds as follows. If the person has an employer with positive money holdings, he offers to trade his endowment in exchange for the effective wage:

$$w^{eff} = min(w, M),$$

where $w$ is the employer's posted wage and $M$ is the employer's money holdings just prior to this trade. The employer accepts the offer unless the shop's labor input already exceeds its input target and the ratio of inventory to sales target exceeds a critical threshold value $IS > 1$.

Goods market trading happens in the following manner. First, the customer learns the price $p_s$ currently posted by each of his two stores ($s = 1, 2$). Then, when a person visits a store with positive inventory I, he can place an order for some amount $c_s$, subject to a cash-in-advance constraint. The store then sells the person an amount $c^{eff} = min(c_s, I)$ The person's effective price for that good is defined as $P_s^{eff} = P_S * c_s / c_s^{eff}$. However, if $I = 0$ or the person does not have a store for that good, the person's effective price is set to infinity.

Each customer chooses his desired consumption bundle $(c_1; c_2)$ to maximize his utility function:

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

with a "demand parameter" $\varepsilon > 0$, subject to his budget constraint: $p_1 * c_1 + p_2 * c_2 = E$, meaning if he has a relationship with a store, he spends the entire amount E on that store's good.

### 3.2.4 Monetary and macro prudential policy

***Monetary Policy***. The main functions of the central bank is to set a nominal interest rate, the central bank sets the rate of interest according to the Taylor rule. To look at the interactions of monetary/macro prudential policy we look at the 4 different types of monetary rules. In the baseline scenario the central bank follows a Taylor rule indexed upon inflation and GDP gap ($TR_{\pi,y}$). In alternative Taylor rules central bank follows "one-mandate" policy targeting inflation only($TR_{\pi}$) , "dual-mandate" rule including an adjustment to unemployment GAP and inflation ($TR_{\pi,u}$), and finally "three mandate" Taylor rule with inflation, output gap and nominal credit($TR_{\pi,y,c}$).

1. Central bank sets nominal interest rate according to a "classical" Taylor rule ($TR_{\pi,y}$):

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

   where $\varphi_\pi$ and $\varphi_y$ are fixed coefficients, $(1+\pi_t)$ is the inflation factor over the past 12 months, y is the fixed inflation target, $y_t$ is the current 3-months moving average for the weekly moving average log GDP, $y_t^*$ is the central bank's evolving estimate of weekly log potential output and $i^* = r^* + \pi^*$. The adjustment parameters on inflation and output gap are $\varphi_\pi = 1.5, \varphi_y = 0.5.$[5].

   Since the central bank cannot be presumed to know the economy's natural interest rate or potential output, it must estimate them adaptively. Accordingly, it adjusts $r$ up or down depending on whether the current inflation rate exceeds or falls short of the inflation target, with an adjustment speed $\eta_r$. It also estimates $y_t^*$ as the long-run expected value of $y$ under an AR(1) process whose parameters are re-estimated right after $r^*$ is adjusted. As mentioned previously, the central bank also calculates the

[5]See Taylor (1993), Woodford (2001)

capitalization factor required by people for planning their consumption. To this end, it estimates an AR(1) process for inflation and feeds the predictions of its estimated AR(1) processes for $y$ and $\pi$ into its Taylor rule to obtain the nominal interest rate projections.[6]

2. "One-mandate" Taylor rule with inflation level only($TR_{\pi}$):

$$ln(1+i_t) = max\{ln(1+i_t^*) + \varphi_\pi(ln(1+\pi_t) - ln(1+\pi_t^*)), 0\} \text{ where } \quad \varphi_\pi = 1.5$$

3. "Dual-mandate" Taylor rule with inflation and unemployment($TR_{\pi,u}$):

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

$$\text{where} \quad \varphi_\pi = 1.5, \varphi_U = 1.1.^7$$

4. "Three-mandate" Taylor rule with output, inflation and nominal credit growth($TR_{\pi,y,c}$):

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

$$\text{where} \quad \varphi_\pi = 1.5, \varphi_y = 0.5, \varphi_c = 0.7^8$$

***Macro Prudential Policy***. The global banking system entered the crisis with an insufficient level of high quality capital. The crisis also revealed the inconsistency in the definition of capital across jurisdictions and the lack of disclosure that would have enabled the market to fully assess and compare the quality of capital across jurisdictions. Minimum static capital requirements in terms of capital adequacy ratios are suitable to address permanent

[6]Details on estimation in "Banks, Market Organization, and Macroeconomic Performance: An Agent-Based Computational Analysis" Ashraf et al. (2011)

[7]See Dosi et al. (2013)

[8]For nominal credit adjustment parameters see Ozkan & Unsal (2013) and Verona et al. (2014)

systemic risk. But for those systemic risks that vary over time, static requirements are not enough. As a consequence, capital regulation became a central part of the existing banking regulation.

Considerable efforts are underway to draw lessons from the recent crisis. One of these lessons is the need for an overarching policy framework to address the stability of the financial system as a whole: a macro prudential policy framework. Macro prudential policy uses primarily prudential tools to limit systemic or system-wide financial risk, thereby minimizing the incidence of disruptions in the provision of key financial services that can have serious consequences for the real economy, by (i) dampening the build-up of financial imbalances; (ii) building defenses that contain the speed and sharpness of subsequent downswings and their effects on the economy; and (iii) identifying and addressing common exposures, risk concentrations, linkages, and interdependencies that are sources of contagion and spillover risks that may jeopardize the functioning of the system as a whole. As a consequence, the Basel Committee on Banking Supervision (BCBS) issued reforms to global regulatory standards, dubbed Basel III, which include the global capital framework and a global liquidity standard. The global capital framework focuses on the strengthening of capital adequacy requirements, as well as the introduction of a new liquidity, leverage requirements and countercyclical macro prudential measure. A global liquidity standards defines a Liquidity coverage ratio as guarantee of resilience to potential liquidity disruptions.[9]

To have a picture of evolution of prudential policies in terms of financial stability and the impact on macro dynamics we first will evaluate the effects of pre-crisis prudential policy in terms of Basel II accord and later on the Basel III as a post-crises prudential policy framework.

*Basel II Accord.* The central bank takes a banking system supervision and control role implementing the Basel II first (current bank control regime that we take as a baseline),

[9]See BCBS (2011) Basel III: A global regulatory framework for more resilient banks and banking systems,Basel Committee on Banking Supervision, June 2011

where capital adequacy ratio is equal to 0.8.[10] The previous Basel II regulatory framework has proposed the total minimum capital requirement according to which the total capital ratio(TCR) must be no lower than 8 percent:

$$CAR_{b,t}^{B2} = TCR_{b,t} = \frac{TotalCapital}{RWA_{b,t}} = \frac{Tier1 + Tire2}{L_t^s + SC} \geq \chi^2.^{11}$$

*Basel III Global Regulatory Framework.* The Basel Committee is raising the resilience of the banking sector by strengthening the regulatory capital framework. The latter is underpinned by a leverage ratio that serves as a backstop to the risk-based capital measures, is intended to constrain excess leverage in the banking system and provide an extra layer of protection against model risk and measurement error. Finally, the Committee is introducing a number of macro prudential elements into the capital framework to help contain systemic risks arising from procyclicality.

- *Minimum static capital requirement* $CAR_{b,t}^{B3}$ . A key element of the new definition of capital is the greater focus on common equity, the highest quality component of a banks capital. Following to Basel III regulation the Common equity Tire 1 must be at least 4.5percent of risk-weighted assets at all times:[12]

$$CAR_{b,t}^{B3} = \frac{Tier1}{RWA_{b,t}} = \frac{Tier1}{L_t^s + SC} \geq \chi^3$$

  where $RWA_{b,t}$ stands for risk weighted assets and $L_t^s + SC$ stands for a sum of loans given out to shops and seized collateral.

  *Countercyclical capital buffer(CCB).* The CCB (Drehmann & Tsatsaronis (2014), Behn et al. (2013), Drehmann & Gambacorta (2012)) aims to achieve the broader

[10]The Basel II capital requirement in terms of capital adequacy ratio is taken as a current bank control regime that we take as a baseline

[11]Tire 1 capital is a balance.sheet capital without the earning form a firesale market liquidations and Tire 2 includes the firesale market liquidation earning

[12]The Tire 1 capital includes the capital component of balance sheet subtracted the earnings for the liquidation of the seized collateral in firsale markets.

macro prudential goal of protecting the banking sector from periods of excess aggregate credit growth that have often been associated with the buildup of system wide risk. The main rationale for adopting countercyclical buffer is to lean against the wind and reduce procyclicality .

The process of capital buffer calculation follows the three steps below:

1. Calculation of aggregate private sector (shops) credit-to-GDP ratio;

2. Calculation of the credit-to-GDP gap as a difference between the credit-to.GDP ratio and its long-run trend;[13]

3. Transforming the credit-to-GDP gap into the guide buffer add-on. The size of the buffer add-on (in percent of risk-weighted assets) is zero when the credit-to-GDP gap ($G_t$) is below a certain threshold $J$. It then increases with the $G_t$ until the buffer reaches its maximum level when the GAP exceeds an upper threshold H. Basel committee analysis has found that an adjustment factor based on $J = 2$ and $H = 10$ provides a reasonable and robust specification based on historical banking crises.

$$\beta = CCB_{b,t} = \begin{cases} 0, & \text{if } G_t < J \\ \frac{(G_t - J)}{(H-J)} * 2.5, & \text{if } J \leq G_t \leq H \\ 2.5, & \text{if } G_t > H. \end{cases}$$

In other words, the size of the buffer add-on (in percent of risk-weighted assets) is zero when $G_t$ is below a certain threshold ($J$). It then increases with the $G_t$ until the buffer reaches its maximum level when the $G_t$ exceeds an upper threshold ($H$). To be more clear, the guidance suggests increasing capital if credit to GDP rises substantially above its trend value, e.g., up to 2.5 percent of risk-weighted assets

[13]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.

if credit-to-GDP gap rises above 10 percentage points, with room for discretion whether and when to invoke (and an ability to impose a higher CCB).

- *Leverage requirement(LR).* One of the underlying features of the crisis was the build-up of excessive on- and off-balance sheet leverage in the banking system. Therefore, the Committee agreed to introduce non-risk based leverage ratio that is calibrated to act as a credible supplementary measure to the risk based capital requirements (Jarrow (2013),Cornford (2013), Kiema & Jokivuolle (2010)).

$$LR_{b,t} = \frac{Tire1}{TotalAssets} \geq \alpha$$

.

- *Liquidity requirement(LCR).* The crisis again drove home the importance of liquidity to the proper functioning of financial markets and the banking sector. Hence, the Basel Committee introduced internationally harmonised global liquidity standards in terms of liquidity coverage ratio(LCR) (Calomiris et al. (2014), De Nicolò et al. (2012), Bindseil & Lamoot (2011)). The LCR builds on traditional liquidity coverage methodologies used internally by banks to assess exposure to stress events. The LCR requires that a banks stock of unencumbered high-quality liquid assets (HQLA) be larger than the projected net cash outflows (NCOF) over a 1 month-long stress scenario.

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

where $HQLA_t^b$ and $NCOF_t^b$ stand for a high liquid assets and for expected net cash outflows of a month stress scenario relatively.[14] High-quality liquid assets include central bank reserves, government bonds and the cash. Total expected cash outflows

[14]The "expected" net cash outflow refers to a special terminology of Basel III rule's definition. In practice it does not refer to expectations in "classical" meaning of the word. The "expectation of net cash outflow refers to a computation of the possible cash outflows of bank balance sheet components computed on a base of run-off rates of assets and liabilities

are calculated by multiplying the size of liabilities and assets by the rates at which they are expected to run off or be drawn down in the stress scenario.[15]

Two types (or levels) of assets can be applied towards the HQLA pool in the numerator of a banks liquidity coverage ratio. Level 1 assets include cash ($H_t^b$) and central bank reserves ($D_t(R)$) by 0 percent capital risk weight under Basel III regulatory. Level 2 assets include bonds. Level 2 assets may comprise no more than 40 percent of a banks total HQLA. In other words, the quantity of Level 2 assets included in the HQLA calculation can be at most two thirds of the quantity of Level 1 assets. In addition, Level 2 assets are subject to a 15 percent haircut when added to HQLA. 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). Hence, a stock of high-quality liquid assets can then be written as:

$$HQLA_t^b = Level1 + min(0.85 * Level2; 0.75 * Level1) =$$

$$= D_t(R) + H_t^b + min(0.85 * B_t^b; 0.75 * (D_t(R) + H_t^b)$$

The outflow and inflows of funds associated with the stress scenario depend on the run-off and default rates specified in the LCR rules for the different types of liabilities and assets. Using $\vartheta_e$ to denote the run-off rate for liabilities and $\vartheta_a$ the run-off rate of assets respectively and letting $O_t^{b(-)}$ and$O_t^{b(+)}$ denote contractual outflows and inflows, we have the formula of expected cash-outflows/inflows:

$$Ex[O_t^{b(-)}] = O_t^- + \sum_{e=1}^{n} \vartheta_e * Liab_t^e = \vartheta_D * (D^s + D^c) + \vartheta_I * L_t^{(l)} + \vartheta_{cb} * L_t^{cb} + O_t^-$$

[15]The run-off rates of liabilities as well as the default rates of assets are fixed by Basel committee of bank supervision and are general for all banks (similar to the computation of risk weighted assets). For more see "Basel III: The Liquidity Coverage Ratio and liquidity risk monitoring tools", BCBS, January 2013 and "On the liquidity coverage ratio and monetary policy implementation1", Bech,M., Keiste, T., 2013 )

$$Ex[O_t^{b(+)}] = O_t^+ - \sum_{a=1}^{n} \vartheta_a * Asset_t^a = O_t^+ - \vartheta_L^s + \vartheta_H * H_t^b + \vartheta_b * B_t^b + \vartheta_{D(R)} * D^b(R)_t$$

### 3.2.5 Fiscal Policy

In our artificial economy the government conducts fiscal policy and mainly has redistributive functions. Specifically, it levies an sales tax $\tau$ on shops and income tax on banks, issues the bonds, services the interest on bonds and computes the average wage rate Wt, which is the employment-weighted average across all shops, and announces the result to all agents. The governments fiscal deficit, which we called GD is equal to balance between all interest payments on all kinds of debt and revenue in terms of tax receipts. There are different ways in which the governments management of its debts can be described. We assume central bank acts as the residual purchaser of government bonds. Likewise the government supplies bonds on demand to consumers. The change in the supply of bonds is the difference between Government debt and the yield value of the current period issue of bonds. The government pegs the interest rate on its bonds by buying or selling whatever quantity the banks, consumers and the central bank wish to hold at that rate. It adjusts this rate every month according to the same Taylor rule as reproduced in the central bank case.

### 3.2.6 Exit

At the end of each period (month) a shop exits if it fails and goes bankrupt, i.e. the sum of financial wealth and Legacy capital is negative: since he is unable to repay his liabilities of credit to bank:

$$A_t^s = H_t^s + D_t^s + (LC - SC_b) - L_t^s < 0$$

If the shop is declared bankrupt and previously had a credit, than the bank seizes the collateralized inventories and capital, and in case of necessity (if the seized capital is not covering the liabilities of the credit) nullifies his deposits. The workers hired during the operation of the shop will be fired and will be counted as unemployed. After the exit of the bankrupt shop there is a one-to-one replacement in order to keep the number of shops constant.

Bank faces losses whenever even one of their clients goes bankrupt, is not able to pay back the loan or withdraws a sufficient friction of deposits. Hence, banks with negative equity fail.

$$A_t^b = L_t^s + H_t^b + B_t^b - (D_t^s + D_t^c) - L_t^{cb} < 0$$

### 3.2.7 Wage and price setting

Every month each shop has an opportunity to update its posted retail price. Each shop first updates its sales target $y_{i,t}^{trg}$, setting it equal to the current month's actual sales. Then, it proceeds to update the shop's retail price. Every month, each shop has an opportunity to revise its retail price. Its "normal" price is,

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

which would equate its after-tax price to its wage times its desired markup, corresponding to the rule discussed earlier. The shop will choose this normal price unless its inventories are too far from the desired level, namely its target sales. Specifically, it will set

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

Thus, the frequency of price change will be endogenous. A shop will change the price when its inventory-to sales ratio passes one of the critical thresholds IS and 1/IS. When the ratio rises above the upper threshold, the shop cuts its price by the factor $\delta_p$. When the ratio falls below the lower threshold, it raises its price by the factor $\delta_p^{-1}$.

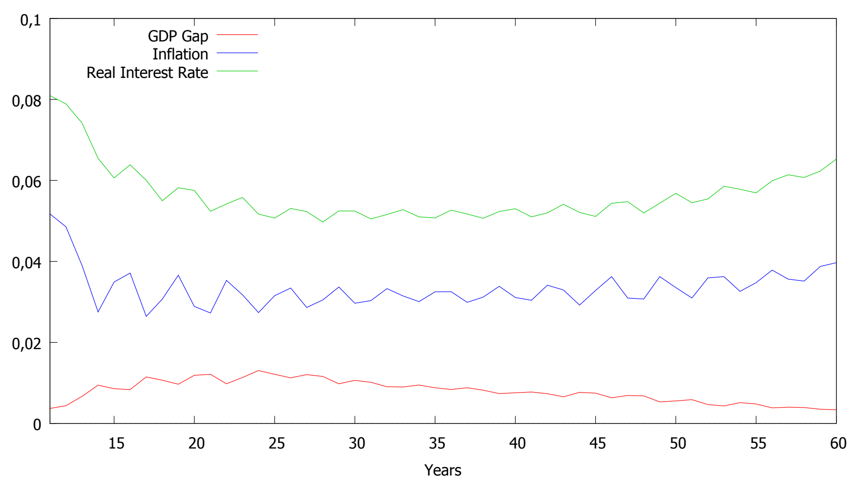
# 4 Empirical results

The model is solved via computer simulations running a Monte Carlo exercise compose of 150 Monte Carlo independent runs, each of them evolving in 60 years time span. Before claiming that the model is able to shed light on some facts or address policy questions, we first of all need to study whether the benchmark setup of the model is empirically validated, and is able to reproduce a wide spectrum of stylized facts,

Table 3: U.S. data vs.average outcome of the model

| *Variable* | *U.S.Data* | *Model* |
|---|---|---|
| GDP gap | 1.073 | 0.753 |
| GDP gap volatility | 2.0-3.2 | 1.625 |
| Inflation | 3.0 | 3.279 |
| Inflation volatility | 1.3 | 1.401 |
| Unemployment | 6.1 | 7.616 |
| Real interest rate | 1.8 | 3.20 |
| Bank failure rate | 0.51 | 1.401 |

Figure 1: The time series of GDP Gap, Inflation and Real interest rate(60 Years)




*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*

The simulated data appears to be able to reproduce the main stylized facts of macro data. Particularly the cross correlation matrix (see Table 3) of the main macroeconomic

Table 4: Cross-correlation structure of output and other macro variables. Simulated series have been detrended with HP filter ($\lambda = 1600$)

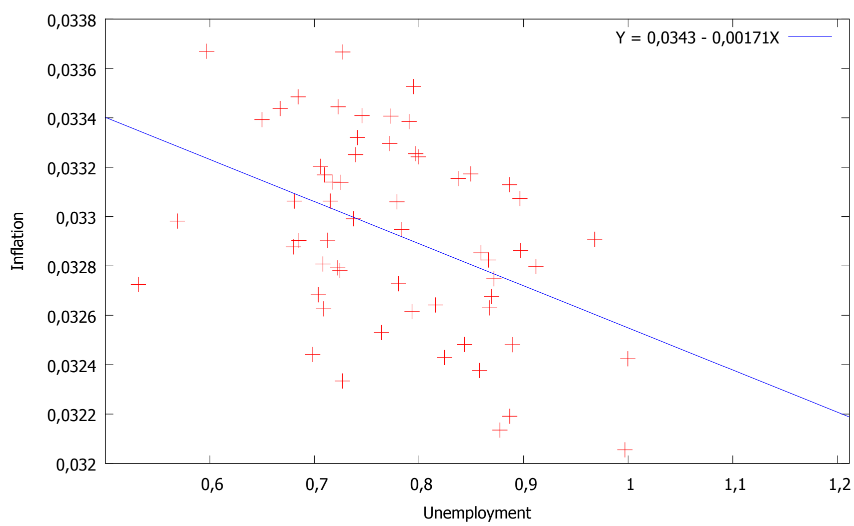
| Variable | St. Dev | t-4 | t-3 | t-2 | t-1 | t | t+1 | t+2 | t+3 | t+4 |
|---|---|---|---|---|---|---|---|---|---|---|
| GDP | 1.44 | -0.0629 | 0.3532 | 0.5245 | 0.8612 | 1 | 0.8612 | 0.5245 | 0.3532 | -0.0629 |
| Inflation | 0.32 | 0.3493 | 0.3314 | 0.28625 | 0.2185 | 0.2091 | 0.2598 | 0.3054 | 0.2950 | 0.1895 |
| Unemployment | 0.66 | -0.2101 | -0.4982 | -0.7647 | -0.8512 | -0.7512 | -0.4726 | -0.1383 | 0.1954 | 0.4117 |
| Consumption | 1.01 | -0.1156 | 0.0643 | 0.3061 | 0.6418 | 0.7248 | 0.5164 | 0.3203 | 0.1542 | 0.0462 |
| Inventories | 1.61 | 0.14876 | 0.6602 | 0.6413 | 0.5652 | 0.2472 | 0.1611 | 0.1054 | 0.0278 | -0.3751 |
| Credit | 1.85 | -0.1723 | 0.1102 | 0.2712 | 0.3618 | 0.3945 | 0.3451 | 0.2672 | 0.1687 | 0.0954 |

[a] ***Source:*** *Stock & Watson (2003)*

variables witness that the inflation, consumption, inventories and credit is procyclical and on the contrary the unemployment is countercyclcal. Moreover the simulated date is able to generate the a Philips and Okun's curve type of relations:

- Inverse relationship between rates of unemployment and corresponding rates of inflation (Phillips curve kind relation)

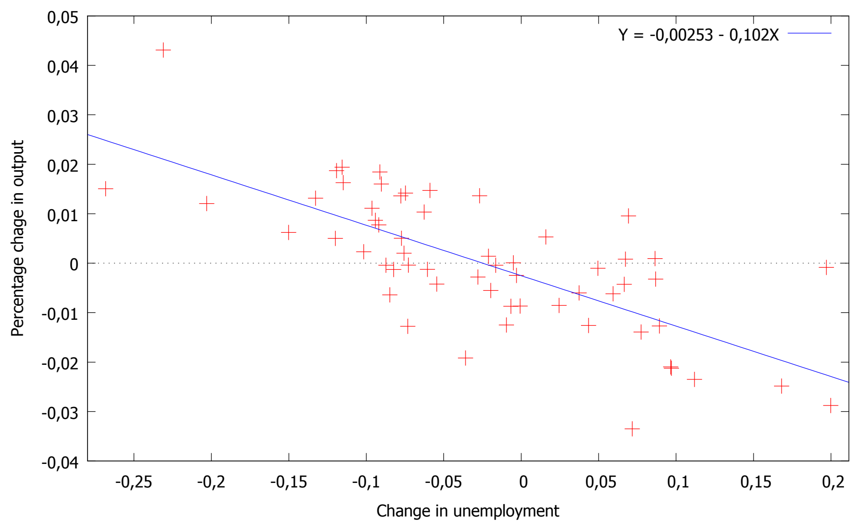
Figure 2: Philips curve relation




*Note: Inflation over Unemployment (with a line of least squares, $R^2 = 0,184030$, $p < 0.01$, statistical significance at the 1 percent level (***).*

- Relationship between Output and unemployment change (Okun's law)

Figure 3: Okun's law relation




*Note: Percentage change in GDP over the percentage change in Unemployment (with a line of least squares,* $R^2 = 0,520186$*,* $p < 0.01$*, statistical significance at the 1 percent level (***).*

# 5 Monetary and Macro Prudential Policy Interactions

In this section we primarily focus on the impact of different combinations of jointly and standalone composed prudential tools (corresponding to a Basel II and Basel III accords) and monetary policy on a range of target variables. These include the GDP gap, GDP gap volatility, inflation, unemployment (which allow to evaluate the effect of the policy combinations on business cycle frequencies) and bank failure rate and likelihood of crisis (as a measure of financial system resilience). Thus, we provide an analysis of the impact of both Basel II and Basel IIIs main components on financial stability and macro performance of economy in an agent-based computational economic (ACE) model. Each entry of the tables reported below is the ratio between the Monte Carlo average of the macroeconomic variable under a given prudential and monetary policy combination and the one generated by the scenario with the baseline case .[16].

[16]The tables are reported under firesale market liquidation parameter taken from a random number generator in uniform (0.1) interval. The results are robust under extreme 1 (total liquidation of sized collateral) and 0.4 (40 percent liquidation) cutoff parameters.

Table 5: *Normalized values of average GDP Gap across experiments.*
Absolute value of simulation t-statistic of *H0*: no difference between baseline and the experiment in parentheses; *Prudential tools*: total capital to risk weighted assets more than 8% (Basel II); liquidity coverage ration under Basel III regulation(LCR); Leverage ration under Basel 3(LR); Capital adequacy ratio under Basel III regulatory, i.e. ratio between the Tire 1 capital and risk weighted assets more than 4.5% ($CAR_{B3}$) and contercyclical capital buffer(CCB): the sum of $CAR_{B3}$, $CCB$, $LCR$ and $LR$ (Basel III). *Monetary policies:* "classical" Taylor rule($TR_{\pi,y}$);Taylor rule indexed on inflation only($TR_{\pi}$); "dual-mandate" Taylor rule i($TR_{\pi,u}$); "three-mandate" Taylor rule ($TR_{\pi,y,c}$).

| | $TR_{\pi,y}$ | $TR_{\pi}$ | $TR_{\pi,u}$ | $TR_{\pi,y,c}$ |
|---|---|---|---|---|
| **Basel II** | 1 | 1,45983** | 1,016832* | 0,99453** |
| | ( 0.02104) | (0.020194) | (0.00497 ) | (0.01785) |
| **Basel III** | 0,80370** | 1,21943** | 0,81201* | 0,78858** |
| | ( 0.00764) | (0.01649) | (0.00466) | (0.00522) |
| $LCR + LR$ | 1,06085* | 1,48943* | 1,06418** | 1,03717** |
| | ( 0.00851) | (1.45723) | (0.01864) | (0.00820) |
| $CAR_{B3} + CCB + LCR$ | 0,83626** | 1,25075** | 0,84362 | 0,82695** |
| | (0.01117) | (0.01576) | (0.00520) | ( 0.00458) |
| $CAR_{B3} + CCB + LR$ | 0,83009** | 1,24848 | 0,83114** | 0.82019** |
| | ( 0.01125) | (0.01563) | ( 0.00509) | (0.00048 ) |
| $CAR_{B3} + CCB$ | 0,81895** | 1,23966* | 0,82824** | 0,80746** |
| | ( 0.01769) | (0.01675) | (0.00487) | ( 0.00457) |
| $CAR_{B3}$ | 0,97643* | 1,36938* | 0,99063** | 0.95402 |
| | ( 0.00448) | (0.00452) | (0.01533) | (0.01665) |
| $LR$ | 1.185941** | 1,547041* | 1,198731 | 1,15616* |
| | (0.03281) | ( 0.00641) | (0.00432) | (0.0423) |
| $LCR$ | 1.23621** | 1.65302* | 1.42514* | 1.17001* |
| | (0.02115) | ( 0.16890) | (0.00211) | (0.00385) |

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

Table 6: *Normalized values of average GDP gap volatility across experiments.*

| | $TR_{\pi,y}$ | $TR_{\pi}$ | $TR_{\pi,u}$ | $TR_{\pi,y,c}$ |
|---|---|---|---|---|
| **Basel II** | 1 | 4,23486** | 1,36989* | 0,79567** |
| | ( 0.00623) | (0.02222) | (0.00597 ) | (0.00996) |
| **Basel III** | 0,76729** | 3,79190** | 1,12070* | 0.54571** |
| | ( 0.00541) | ( 0.02013) | (0.00556) | (0.00562) |
| $LCR + LR$ | 2,58902* | 5,80846* | 2,94098* | 2,41328** |
| | (0.00652) | (0.07515) | (0.00881) | (0.00740) |
| $CAR_{B3} + CCB + LCR$ | 0,88774** | 4,01457** | 1,24736* | 0,62322** |
| | (0.00641) | (0.02089) | (0.00600) | (0.00578) |
| $CAR_{B3} + CCB + LR$ | 0,85910** | 3,98624* | 1,21541** | 0,60317** |
| | (0.00623) | (0.01997) | (0.00616) | ( 0.00061) |
| $CAR_{B3} + CCB$ | 0,83905* | 3,97501* | 1,18736** | 0,59088** |
| | (0.02040) | (0.02129) | ( 0.00657) | (0.00665) |
| $CAR_{B3}$ | 0.95854 | 4,09211 | 1,30663* | 0,71071* |
| | ( 0.00448) | (0.00452) | (0.01533) | (0.01665) |
| $LR$ | 3,36026 | 6,49518 | 3,70473* | 3,19700** |
| | (0.02142) | (0.02238 ) | (0.00669) | (0.00671) |
| $LCR$ | 3.47115* | 7.04407 | 3.97562* | 3.1475** |
| | (0.02231) | ( 0.02347) | (0.00657) | (0.00682) |

Table 7: *Normalized values of average unemployment rate across experiments.*

| | $TR_{\pi,y}$ | $TR_{\pi}$ | $TR_{\pi,u}$ | $TR_{\pi,y,c}$ |
|---|---|---|---|---|
| **Basel II** | 1 | $3,05041^{**}$ | $0,64832^{*}$ | $0,72044^{**}$ |
| | | (4.03223) | (0.11596) | (0.10833) |
| **Basel III** | $0.71515^{**}$ | $1,85211^{*}$ | $0,44176^{*}$ | $0,41724^{**}$ |
| | (0.08848) | (0.15659) | ( 0.47211) | (0.00533) |
| $LCR + LR$ | $1.35414^{*}$ | 3,41433 | 1.03589 | $1,06846^{**}$ |
| | (0.00816) | (0.01615) | (0.01597) | (0.00363) |
| $CAR_{B3} + CCB + LCR$ | $0,92075^{**}$ | 2,91695 | $0.56112^{*}$ | $0,65154^{**}$ |
| | ( 0.00740) | (0.14269) | (0.00457) | (0.00543) |
| $CAR_{B3} + CCB + LR$ | $0,87470^{**}$ | $2,90112^{*}$ | $0.51082^{*}$ | $0,59887^{**}$ |
| | ( 0.00736) | (0.01464) | (0.00903) | ( 0.00509) |
| $CAR_{B3} + CCB$ | $0,85829^{**}$ | $2,87689^{*}$ | $0.48174^{*}$ | $0,55207^{**}$ |
| | (0.00849) | (0.01620) | (0.05013) | ( 0.00047) |
| $CAR_{B3}$ | $0,94003^{*}$ | 3,02938 | $0,59063^{*}$ | $0,68071^{*}$ |
| | ( 0.00448) | (0.00452) | (0.01533) | (0.01665) |
| $LR$ | $1,62992^{*}$ | 3,57765 | $1.16063^{*}$ | $0,8762^{*}$ |
| | (0.00951) | ( 0,45620) | (0.00452) | (0.21385) |
| $LCR$ | $1,67495^{*}$ | 3,74810 | $1.21005^{*}$ | $1,29587^{*}$ |
| | (0.00891) | ( 1.32564) | (0.00512) | (0.00452) |

Table 8: *Normalized values of average inflation rate across experiments.*

| | $TR_{\pi,y}$ | $TR_{\pi}$ | $TR_{\pi,u}$ | $TR_{\pi,y,c}$ |
|---|---|---|---|---|
| **Basel II** | 1 | $0,91012^{*}$ | $1.16163^{**}$ | $1,18062^{***}$ |
| | | (0.01108) | (0.01821) | ( 0.01844) |
| **Basel III** | $1.13452*$ | $1,03886^{*}$ | $1,30142^{**}$ | $1,31316^{**}$ |
| | (0.31454) | ( 0.34144) | ( 0.81653) | ( 0.91940) |
| $LCR + LR$ | $0,97275^{*}$ | 0,88662 | 1,14071 | $1,15785^{*}$ |
| | (1.53984) | ( 1.30711) | (1.041014) | (2.00898) |
| $CAR_{B3} + CCB + LCR$ | $1,06431^{*}$ | $0,98057^{*}$ | 1,23148 | $1,24379^{**}$ |
| | (0.34825) | (0.43011) | ( 1.41788) | (0.81707) |
| $CAR_{B3} + CCB + LR$ | $1.06695^{*}$ | 0,98962 | 1,24963 | $1,25145^{**}$ |
| | (0.35984) | (0.42818) | (1.61878) | (1.00191 ) |
| $CAR_{B3} + CCB$ | $1,12821^{**}$ | $1,03038^{*}$ | $1,28063^{*}$ | $1.30157^{***}$ |
| | ( 0.44805) | (0.45281) | (1.51533) | (1.51665) |
| $CAR_{B3}$ | $1,02172^{**}$ | $0,93238^{*}$ | $1,19003^{**}$ | $1,20871^{**}$ |
| | ( 1.44851) | (1.35248) | (1.81533) | (2.01665) |
| $LR$ | $0,94867^{*}$ | 0.85962 | 1.10821 | 1,13114 |
| | (2.50458) | ( 1.60432) | (1.50965) | (2.80891) |
| $LCR$ | $0.94385^{*}$ | 0.85226 | $1.10005^{**}$ | 1.13498 |
| | (2.61492) | (2.0462 ) | (2.00712) | (3.31096) |

Table 9: *Normalized values of average likelihood of economic crisis across experiments.*

| | $TR_{\pi,y}$ | $TR_{\pi}$ | $TR_{\pi,u}$ | $TR_{\pi,y,c}$ |
|---|---|---|---|---|
| **Basel II** | 1 | 2.29993** | 1.94750** | 0.86924* |
| | (0.11574) | (0.23841) | (0.06874) | (07796) |
| **Basel III** | 0.79021** | 2.08158* | 1.73874* | 0.65411** |
| | (0.06309) | (0.16854) | (0.08002) | (0.06846) |
| $LCR + LR$ | 1.24852 | 2.49875** | 2.14965 | 1.06832** |
| | (0.09023) | (0.86065) | (0.08684) | (0.01940) |
| $CAR_{B3} + CCB + LCR$ | 0.92009** | 2.17865** | 1.82008** | 0.74025* |
| | (0.12684) | (0.43084) | (0.07112) | (0.06547) |
| $CAR_{B3} + CCB + LR$ | 0.91598* | 2.17073** | 1.77850** | 0.72012** |
| | (0.15765) | (0.50123) | (0.07618) | (0.07054) |
| $CAR_{B3} + CCB$ | 0.85952** | 2.11074** | 1.76398** | 0.66085** |
| | (0.15865) | (0.51845) | (0.07627 ) | (0.07054) |
| $CAR_{B3}$ | 0,94003** | 2,20938** | 1,79063** | 0,75071** |
| | ( 0.00448) | (0.00452) | (0.01533) | (0.01665) |
| $LR$ | 2.14841* | 3.36885* | 2.96754** | 1.95991* |
| | (0.21558) | (0.95643 ) | (0.08054) | (0.09641) |
| $LCR$ | 2.15101* | 3.41345 | 2.98846* | 1.97992* |
| | (0.35581) | (0.58421) | (0.05338) | (0.07941) |

Table 10: *Normalized values of Average bank failure rate across experiments.*

| | $TR_{\pi,y}$ | $TR_{\pi}$ | $TR_{\pi,u}$ | $TR_{\pi,y,c}$ |
|---|---|---|---|---|
| **Basel II** | 1 | 11,80330* | 1,34770** | 0,89344** |
| | (0.16816) | ( 2.79224) | ( 0.07540) | ( 0.10176) |
| **Basel III** | 0,45812** | 3,95746** | 0,89039** | 0,43659** |
| | ( 0.02251) | ( 0.02029) | ( 0.08627) | (0.09653) |
| $LCR + LR$ | 1,19249** | 4,68443* | 1,62262* | 1,16644** |
| | (0.07101) | (5.92078) | (0.02507) | (0.02866) |
| $CAR_{B3} + CCB + LCR$ | 0,75653* | 4,20918* | 1,18266** | 0,72862** |
| | (0.07235) | (0.28444) | (0.09747) | (0.08650) |
| $CAR_{B3} + CCB + LR$ | 0,73901** | 4,16018* | 1,15277** | 0,69403** |
| | ( 0.07274) | (0.27644) | (0.09188) | (0.00796 ) |
| $CAR_{B3} + CCB$ | 0,68897** | 4,10143** | 1,09815** | 0,64074** |
| | (0.17721) | ( 0.19263) | (0.080355) | (0.08032) |
| $CAR_{B3}$ | 0,79003* | 4,20938** | 1.20063* | 0,75071** |
| | ( 0.00448) | (0.00452) | (0.01533) | (0.01665) |
| $LR$ | 2,09771** | 5,51634* | 2,44485* | 2,05262** |
| | (0.21085) | (0.20954 ) | (0.09005) | (0.22821) |
| $LCR$ | 2.10961* | 5.54951* | 2.45617* | 2.09542** |
| | (0.23861) | ( 0.21005) | (0.25684) | (0.22954) |

We will analyze the effect of different prudential (macro or micro) rules under the certain monetary policy rule (see section 4). As a baseline scenario we use a state of art combination of US economy under the Basel II regulation and "classical" Taylor rule.[17]. Let's start the analyzes of the impact of prudential tools on macro and financial performance of economy from the baseline monetary policy scenario ($TR_{\pi,y}$). The $LCR+LR$, $LR$, $LCR$ have a strong negative impact on the performance of economy by increasing the unemployment output gap volatility, the likelihood of economic crisis and the bank failure rate. The latter at the end of the days increases the output gap. Such a picture of interactions is due to the fact that both the attempt to cut down the financial leverage (without the underpinning of countercyclical buffer component) and the liquidity constraint may translate into a credit crunch, resulting constraints on shop spending, production and hereafter the fall in economic activity. The marginal negative effect of static component of countercyclical capital requirement under Basel III accord can be explained by the propagation mechanism to generate procyclic behavior explained by the fact the the credit supply is attached only to a capital. On the contrary, the prudential policy scenarios that have a coutercyclical capital buffer on the top of the static capital requirement performs better with respect to baseline combination of Basel II and "classical" Taylor rule. Such a set up creates a financial accelerator effect (that is in a core of Ashraf et al. (2011) model) on the supply side of funding where the lending constraint is relaxed when banks net worth increases.

Financial accelerator mechanisms can foster inefficient economic fluctuations (such as excess volatility in lending and output) which can be mitigated by macro prudential policy tools that increase (reduce) the cost to banks of extending (shrinking) credit in good (bad) times. In such scenario, macro prudential measures appear to usefully complement monetary policy. Countercyclical macro prudential policy helps to reduce macroeconomic volatility. The results also demonstrate the importance of capital flows and financial stability for cyclical fluctuations as well as the role of supply-side financial accelerator effects in the amplification

[17]Other entries of the tables are normalize with respect to baseline scenario

and propagation of shocks.

In alternative scenario experiments central bank applies a modified Taylore rule which 1)reacts only to inflation ($TR_{\pi}$) and 2) dual-mandate Taylor rule which adjusts the interest rate in response to unemployment and inflation ($TR_{\pi,u}$ ) in line with recent monetary policy strategy of Federal Reserve. On closer examination of tables we see that under the $TR_{\pi,u}$ monetary strategy unemployment, GDP gap, bank failure rate and the likelihood of crisis is lower. On the contrary, for every combination of monetary and prudential rule dual-mandate Taylor rules increase the inflation: the lowest level of inflation is performed under the one-mandate $TR_{\pi}$ rule. In case of this couple of monetary rules the effects of prudential tools are follows: Basel III combination of the tools as well as the total Basel III regulatory increase the inflation, but in any case the average inflation rate remeins small (average change is inflation is very small, see Table 8) at the same time decrease the unemployment, GDP gap, bank failure rate and likelihood of crisis.

In the last type of monetary rules monetary authorities decide to adjust the the monetary rule with respect credit growth so protecting the financial sector from the periods of excess credit growth that often associates with build-up of system-wide risk. The Results show that the "leaning against the wind" strategy of monetary authorities that combines the "classical" Taylor rule with macro prudential policy implementations, appears to be an optimal monetary rule for our setup ($TR_{\pi,y,c}$ monetary rules with combination with prudential tools performs better in comparison to other rules). Hence the "leaning against the wind" monetary policy that combines the "classical" Taylor rule with macro prudential policy implementations is the optimal monetary rule to make the macro prudential policy to reach it's goal: financial stability.

So one of the result we obtain is that macro prudential policy in the form of countercyclical capital regulation is a powerful tool in increasing the resilience of the financial system and the economy as a whole. The transmission mechanism of such an impact can be explained by the decrease in the volatility of the banks capital and therefore in the leverage ratio.

This affects the real economy through the amount of lending and consequently the amount of investment. As a consequence, this reduces the volatility in the real economy and it may help to prevent the classic boom and bust cycle.

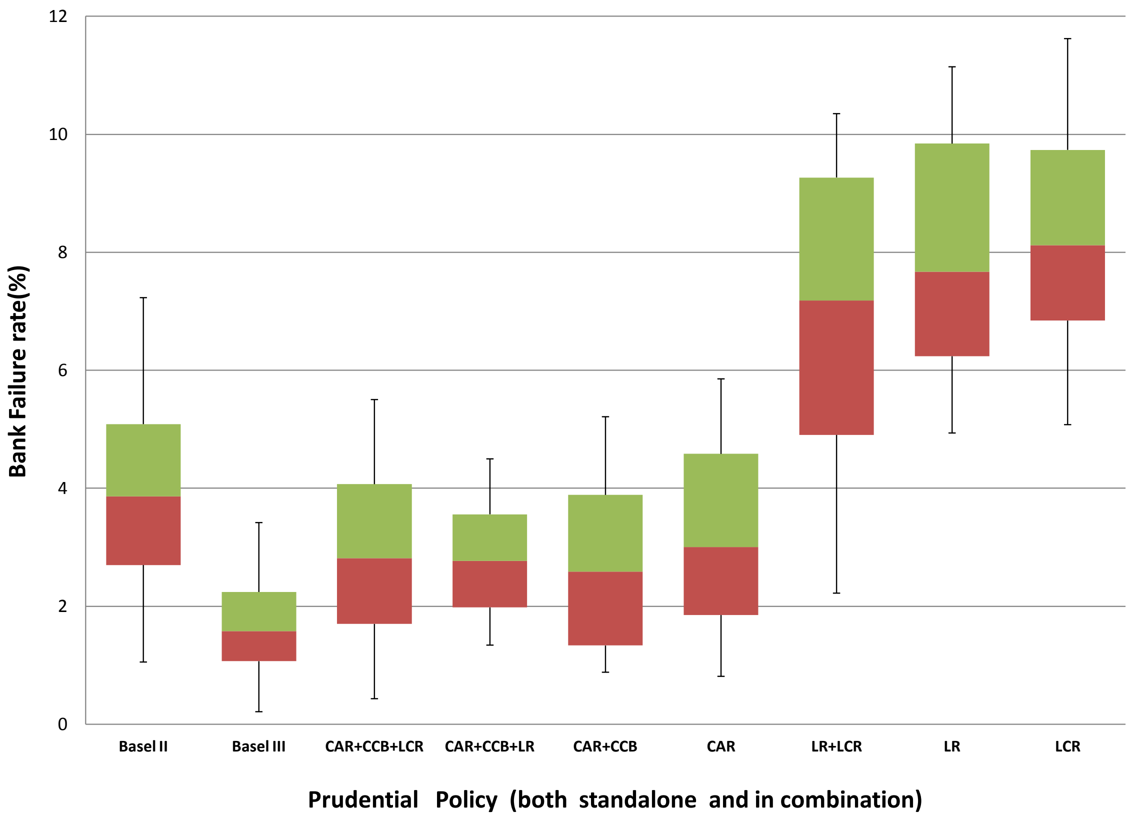
On a closer examination we see that the $CAR_{B3} + CCB$ performs second-best result after the Basel III global regulatory accord entire toolkit effect. Hence we can point the idea of Andrew G. Haldane (Haldane & Madouros (2012)) about the trade off between the necessity of complex vs a simple policy driving rules. On the contrary to the expectations the $CAR_{B3}+CCB+LCR$ rule has the forth best after the $CAR_{B3}+CCB+LR$ prudential rule. Here the relevant issue is the connectedness between liquidity and capital standards. When a bank changes the composition of its balance sheet to meet the $LCR$ requirement, it increases its holdings of high-quality assets, lowering its risk weighted assets (RWA); this reduces the capital that must be held to satisfy the capital requirements.

We find that under a given monetary policy regime the positive joint impact of the macro prudential instruments is considerably larger than the sum of the individual contributions to stability, i.e. the standalone impacts are not additive (see Table(5-10). However, except for the capital adequacy ratio together with a countercyclical buffer ($CAR_{B3}+CCB$ raw) which indeed represents an indispensable instrument to counteract agents procyclical behavior, the macro prudential overlays impact is either marginal or even negative ($LR$, $LCR$ and $LR + LCR$ rows).

We find that the strengthening of the macro prudential regulation contributes substantially to the resilience of the financial system (the difference in results between Basel II and Basel III) and overall macroeconomic performance of economy.

The boxplot above shows the average impact of Basel II and Basel III accords (both in combination and standalone). The boxplot illustrates the impact of the prudential tools on financial stability by a standardized way of displaying the distribution of data based on the five number summary: minimum, first quartile, median, third quartile, and maximum. The results can evidence that The Basel III global regulatory instrument package (Basel

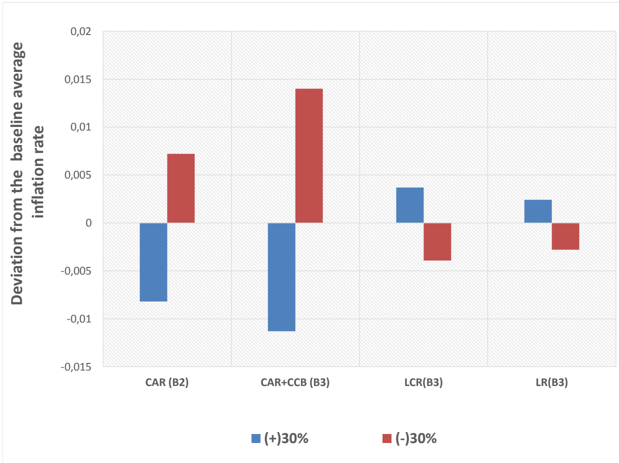
Figure 4: Boxplot with whiskers comparing the impact of Basel II and Basel III prudential tools on financial stability



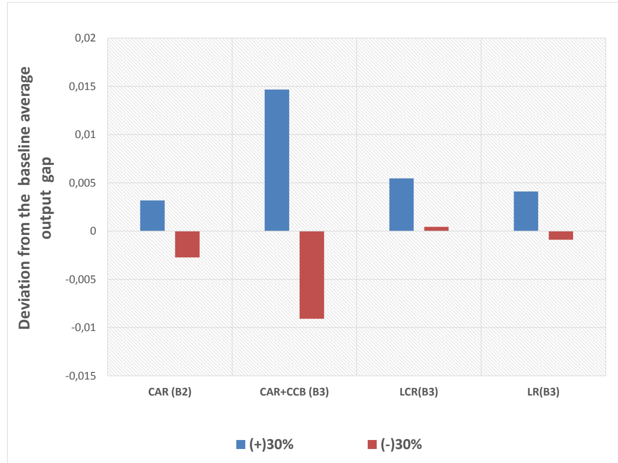

III) contributes the most to the financial stability. The adjustment of only the minimum capital requirement from the 8 percent(Basel II) to 4.5 percent of Basel III together with countercyclical capital buffer of 2.5 ($CAR_{B3} + CCB$) would lead a "second-best" efficient improvement of the bank failure rate outcome. In line with that finding, addressing only liquidity risk by implementing the liquidity requirement($LCR$) and the leverage ratio ($LR$) as well as the combination of both ($LR + LCR$) would have a marginal and even negative impact.

However, strengthening the resilience of the system requires a combined implementation of both micro prudential instruments since the positive joint impact of the micro prudential instruments is considerably larger than the sum of the individual contributions to stability. This confirms the expectations of Ojo (2014) and Arnold et al. (2012) about the impact of

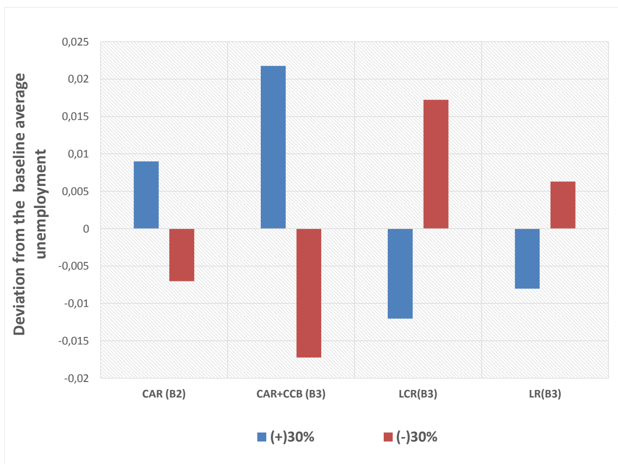
(a) Effect on average Inflation from perturbating macro prudential parameters




(b) Effect on average GDP gap from perturbating macro prudential parameters




(c) Effect on average unemployment from perturbating macro prudential parameters




the Basel III accord which both states that an appropriate implemented liquidity regulation.

We performed a sensitivity analysis by perturbing each of macro prudential policy (both Basel II and Basel III) tool parameters, first setting it higher than the baseline value and then setting it lower, and recorded deviation from the baseline average value of the 50-year average output gap, unemployment, GDP Gap and inflation.[18] For all parameters, the perturbation was either plus or minus 30 percent of the baseline value.

The figures above show the effects of varying each prudential regulations standalone

[18]The baseline values of the prudential tools are the ones indicated in the calibration table. W4e have computed the deviations from the parameters not accounting the 10 transient years of learning

parameter on the average output gap, unemployment and inflation. There is a just one prudential parameter that can raise/reduce the output gap (i.e., reduce/rise output), inflation and unemployment by more than 1 percentage, namely the $CAR_{B3} + CCB$ under the Basel III regulatory framework. Two of the parameters (leverage and liquidity requirement) appear to have little effect on average macro performance of output gap and inflation, instead the liquidity requirement under the Basel III accord rises/reduces the unemployment rate more than 1 percent. The latter can be explained by the financial accelerator effect on credit supply side of funding.

# 6 Conclusion

The model is studied via Monte-Carlo computer simulations. The simulated data of the model appears to be able to reproduce the main stylized facts of macro data.

Simulation reveals the following results:

1. The "leaning against the wind" monetary strategy where the central bank, except the inflation and output gap, indexes Taylor rule also upon credit growth, we have a lower unemployment, output Gap and volatility of economy ( see Ghilardi and Peiris, 2014; Quint and Rabanel, 2013 ).

2. Simulation results reveal that Basel III has a stabilizing effect on the financial side of economy since the bank failure rate and the likelihood of economic crisis is the lowest under Basel III regulation. At the same time macro prudential tools have limited effect on inflation (Suh, 2014; Spencer 2012).

3. The static capital requirement together with CCB mechanism under Basel III accord shows the second-best result after the combined instruments of Basel III. It arises a question about the trade off between the complex vs. a simple policy driven rules (Aikman, 2014; Haldane, 2012).

4. The effects of leverage and liquidity requirements in isolation as well as the combination of both is marginal or negative, i.e. both of them increase the unemployment, output gap volatility, the likelihood of economic crisis and the bank failure rate. The latter at the end of the day transmits to increase the output gap.

5. The joint impact of micro prudential tools is considerably larger to the financial stability issue than the sum of the individual ones, i.e. the standalone impacts are not additive. This demonstrates an example that the whole is indeed greater than the sum of its parts if interaction among agents is taken into consideration.

# Appendix A

There are a total of 30 parameters, which we have categorized as personal parameters, shop parameters, bank parameters, fiscal-monetary policy parameters and prudential reulation parameters. These are listed in Table 11 along with their assigned values.

Table 11: Parameters of the model

| | *Parameter* | *Value* |
|---|---|---|
| | ***Prudential Regulation Parameters*** | |
| $\alpha$ | Leverage requirement | 0.03 |
| $\gamma$ | Liquidity requirement | 1 |
| $\chi_2$ | Minimum capital requirement in Basel II | 0.08 |
| $\chi_3$ | Minimum capital requirement in Basel III | 0.045 |
| $\beta$ | Countercyclical capital buffer | $[0, 0.25]$ |
| $\vartheta_D$ | Run-off rate of deposit | 0.1 |
| $\vartheta_{cb}$ | Run-off rate of central bank loan | 0.25 |
| $\vartheta_L$ | Run-off rate of commercial loan | 0.5 |
| $\vartheta_b$ | Run-off rate of gov. bonds | 0.2 |
| | ***Fiscal and Monetary Poliy Parameters*** | |
| $\varphi_\pi$ | Inflation coefficient in Taylor rule | 1.5 |
| $\varphi_y$ | Output gap coefficient in Taylor rule | 0.5 |
| $\varphi_U$ | Unemployment coefficient in Taylor rule | 1.1 |
| $\varphi_c$ | Credit coefficient in Taylor rule | 0.7 |
| $\pi^*$ | Target inflation rate | 0.03 |
| $i^*$ | Target interest rate | 0.025 |
| $\tau$ | Tax rate | 0.10 |
| $\eta_r$ | Adjustment speed of evolving real rate target | 0.0075 |
| | ***Personal Parameters*** | |
| $\varepsilon$ | Demand parameter | 7.0 |
| $\lambda_p$ | Permanent income adjustment speed | 0.4 |
| $\theta$ | Frequency of innovation | 100 |
| | ***Shop Parameters*** | |
| $\kappa$ | Quick ratio | 0.5 |
| $\varrho$ | Debt-to-equity ratio | 0.5 |
| $\psi$ | Return on assets | 0.1 |
| $\bar{\mu}$ | Average percentage markup over wage | 0.138 |
| $S$ | Setup cost | 15 |
| $IS$ | Critical inventory-to-sales ratio | 3 |
| $\delta_p$ | Size of price cut | 1.017 |
| | ***Bank Parameters*** | |
| $s$ | Loan spread | 0.0175 |
| $h$ | Loan-to-value ratio | 0.5 |
| $\xi$ | Reserve requirements | 0.03 |

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