Universidade de Brasília

Faculdade de Economia, Administração, Contabilidade e Gestão de Políticas Públicas

Programa de Pós-Graduação em Economia

Interações entre políticas monetária e macroprudencial: evidências de um modelo baseado em agentes

Autor: Gustavo Libório Rocha Lima

Orientador: Prof. Dr. Daniel Oliveira Cajueiro

Brasília, DF

2023

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Gustavo Libório Rocha Lima
Interações entre políticas monetária e macroprudencial: evidências de um modelo baseado em agentes/ Gustavo Libório Rocha Lima. – Brasília, DF, 2023-
36 p. : il. (algumas color.) ; 30 cm.

Orientador: Prof. Dr. Daniel Oliveira Cajueiro

Dissertação – Universidade de Brasília , 2023.

1. Economia. 2. Sistema bancário. I. Prof. Dr. Daniel Oliveira Cajueiro. II. Universidade de Brasília. III. Programa de Pós-Graduação em Administração. IV. Interações entre políticas monetária e macroprudencial: evidências de um modelo baseado em agentes

Classificação JEL: C22 B123

Gustavo Libório Rocha Lima

Interações entre políticas monetária e macroprudencial: evidências de um modelo baseado em agentes

Dissertação apresentada ao Departamento de Economia da Universidade de Brasília como parte dos requisitos necessários à obtenção do título de Mestre em Economia.

Trabalho aprovado. Brasília, DF, 10 de fevereiro de 2023:

Prof. Dr. Daniel Oliveira Cajueiro
Orientador

Dr. Régis Augusto Ely
Convidado 1

Dr. Gervásio Ferreira dos Santos
Convidado 2

Brasília, DF
2023

Resumo

Este trabalho visa investigar o comportamento dos agentes financeiros em um cenário complexo onde interagem e aprendem sobre o ambiente. Utilizando a abordagem *bottom-up* dos modelos baseados em agentes, simulamos uma situação em que bancos, depositantes, um banco central, empresas e uma câmara de compensação compõem um sistema financeiro artificial sob diferentes cenários relativos a instâncias de política monetária e macroprudencial em condições de países desenvolvidos e emergentes. Os bancos são capazes de aprender com os resultados e definem, de forma endógena, a taxa de juros de mercado. As principais conclusões são: relativamente ao mercado de crédito, (i) as políticas reforçam os efeitos uma da outra sobre a oferta de crédito quando ambas são restritivas. Relativamente ao comportamento de tomada de risco dos bancos, temos que (ii) a política monetária expansiva aumenta os empréstimos dos bancos e o risco da sua carteira. Finalmente, (iii) as instâncias restritivas em ambas as políticas, uma vez que promovem mais capital e menos risco no balanço, são capazes de reduzir o risco agregado em certa medida. Combinadas da forma correta, as medidas podem melhorar a estabilidade global do sistema.

Palavras-chave: Modelos baseados em agentes, Sistema bancário, Política macroprudencial, Política monetária
JEL: G21, G28, E58.

Abstract

This work aims to investigate the behavior of financial agents in a complex setting where they interact and learn about the environment. Using the bottom-up approach of agent based models, we simulate a situation where banks, depositors, a central bank, firms and a clearing house compose an artificial financial system under different scenarios regarding monetary and macroprudential policy instances and emerging and developed countris realities. Banks are able to learn from the outcomes and endogenously set the market interest rate. The main conclusions are: concerning the credit market, (i) the policies reinforce each other's effects on credit supply when they are both restrictive. Regarding banks' risk taking behavior, we have (ii) that expansive monetary policy increases banks' loans and their portfolio risk. Finally, (iii) restrictive instances in both policies, while promoting more capital and less risk in the balance sheet, are able to reduce risk to certain extent. Combined in the right way, these may improve overall system stability.

Key-words: Agent-Based Model, Banking, Monetary Policy, Prudential Policy
JEL Code: G21, G28, E58.

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List of abbreviations and acronyms

ABM	Agent-based model
DSGE	Dynamic Stochastic General Equilibrium

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1 Introduction

Banks and the financial system function as intermediaries in the economic environment, connecting savings and investments while also leveraging the deposits and reducing uncertainty (ALLEN; CARLETTI; GU, 2014). One of the main aspects of their activity is lending resources to finance consumption and investment. Monetary policy, in the form of a risk-free interest rate set by a central bank, is a widespread tool used to reduce inflation that works by directly influencing this dimension of banking. Another aspect of the banking system, which was drawn to attention after the financial crisis in 2008, is that the agents interact and form networks, and those networks are determinants of performance and efficiency. The interaction among banks shapes how risk is distributed in the system, and how likely a financial crisis is (IORI et al., 2015). Prudential policy emerged as a tool to prevent large-scale crisis by imposing restrictions to banks' balance sheet and risk decisions.

With these aspects of the banking system in mind, we develop a model to explore how different monetary and prudential policies impact on interest rates, risk-taking behavior and system stability. Due to the complexity of the system, these policies may have impacts on each other's goals, raising the important question of how and to what extent these interactions between policies take place. To answer this question, our model simulates banks, firms, depositors and a central bank interacting in a real sector and an interbank credit market, using an agent-based approach. We bring in new features to the model presented by Barroso et al. (2016) and Adão et al. (2022), that study stability and risk-taking in the banking system. In particular, we introduce the banks' ability to set interest rates charged to the real sector through the choice of a markup pricing rule. This enables banks to gain experience and learn about the effectiveness and profitability of different pricing rules, resulting in a system with competition and endogenous interest rates.

Other relevant variables, such as credit supply and banks' risk portfolio are also endogenous and defined by a learning process made by agents. This enables us to analyze how they respond to different scenarios, and we investigate how expansive and restrictive interest rate settings as monetary policy affect the system outcomes, as well as what are the impacts of prudential regulation (such as minimum capital requirements, suggested by the Basel Committee (BIS, 2019)). We analyze the simulated data, particularly looking for potential conflicts and unsuspected relationships between the variables, taking into account the realities of developed and emerging countries when it comes to risk, interest rate levels and other aspects of the financial system.

In general, our results point to a relevant risk reduction derived from prudential policy, in the form of lower insolvency levels and less overall risk, even though the high-risk to standard-risk loan ratio had a slight increase. Minimum capital requirement also had a restrictive effect on the credit supply, and the effect was greater when monetary policy was expansive. There is potential for conflict and complementarity between the policies, so coordination is required to minimize conflicts and maximize their results.

Our results contribute to the emerging literature on interactions between macroprudential and monetary policy. The literature about this subject is relatively new, and empirical analysis has yielded mixed results so far. Aiyar, Calomiris and Wieladek (2016) find that there is no relevant impacts between the policies, while others find both evidence of complementary effects (BRUNO; SHIM; SHIN, 2017; ZHANG; TRESSEL, 2017) and conflicts(KIM; MEHROTRA, 2018). From a theoretical point of view, the evidence shows that the coordination of the two policies increases stability (LUBIS; ALEXIOU; NELLIS, 2019; KIM; MEHROTRA, 2018) to the macroeconomic and financial environment. Garcia Revelo and Levieuge (2022) and Angelini, Neri and Panetta (2014), using DSGE model, point to possible conflicts when coordination fails. Hence, our work is inserted in the theoretical literature and introduces a different methodological approach to the situation, reinforcing the possible conflicts and the need for coordination.

Having introduced our work, the following sections are organized this way: section 2 presents a literature review of relevant themes, such as agent based models of banking and the work related to monetary and prudential policies. Section 3 presents our methodology, the model and its functioning. Sections 4 and 5, respectively the results and conclusion sections, bring the simulations outcome and the relationships that can be inferred from them.

2 Literature Review

Our work utilizes an agent based approach, where the model is built from the bottom up. In this approach, the relevant agents are initially defined, as well as a simple set of behaviors with which they are endowed. Then, the interactions between agents are established, observing the institutional and structural constraints. Finally, the model is simulated computationally and the emerging behavior is analyzed, including both aggregate and individual variables (ANDERSON; ANDERSON; PINES, 1988; HOLLAND; MILLER, 1991; ARTHUR; DURLAUF; LANE, 1997; BONABEAU, 2002; BLUME; DURLAUF, 2005; TESFATSION, 2006; DAWID; FAGIOLO, 2008; FARMER; FOLEY, 2009; GALLEGATI; KIRMAN, 2012; GATTI et al., 2018; STEINBACHER et al., 2021). Using this methodology, we can explore non-linear and complex interactions and avoid the assumption strong rationality, rules or equilibrium. Steinbacher et al. (2021) provide an in-depth review of ABMs in the social sciences.

In order to establish an outlook of the usage of ABMs in the field of economics, specially in the study of the banking system, some lines of research must be explored. An important landmark in an adjacent subject is the work about complex networks developed by Albert and Barabási (2002), which set the foundation for further studies characterizing social and economic network, of which relevant ones are the banking systems. Iori, Jafarey and Padilla (2006), notably before the financial crisis of 2008, present a model to investigate whether an interbank loan network stabilizes the system or creates a default propagation mechanism. Employing an ABM, they find that interbank markets have effects on stability, since increasing connectivity in the bank network lowers the individual default probability, but allows defaults to propagate. This approach is further developed by Nier et al. (2007), that study other impacts of connectivity, pointing specially that its effects are non-monotonic, since small increases tend to create more defaults and, passed a certain threshold, connectivity decreases risk. Nier et al. (2007) also find that a concentrated bank network is more resilient to contagion. The mentioned articles, as well as others, investigate the implications of network topology in the credit market and system stability. A review on the subject is found in Bardoscia et al. (2021).

The economic system, and specially the credit market, is deeply influenced by interest rates. Modern central banks around the world employ this connection as monetary policy to manage credit availability and households' demand in order to control general prices (KASHYAP; STEIN et al., 1997; MORENO et al., 2008). Essentially, when the central bank sets a monetary policy interest rate that remunerates government bonds and serves as standard to other financial agents, it increases the return of savings, effectively reducing consumption on the households' budget. On the banks' side, the interest rate raise the attractability of liquidity, decreasing the amount of loans supplied (BERNANKE; GERTLER, 1995). There's also evidence that interest rates affect other aspects of bank behavior. For example, low interest rates cause increased risk in banks' loan portfolio (ADÃO et al., 2022; GAMBACORTA, 2009; ANGELONI; FAIA; DUCA, 2015). Also, banks tend to require less collateral for loans when monetary policy is expansive (JIMÉNEZ et al., 2014).

Since the financial crisis, new policies were introduced aiming the reduction of systemic risk and financial contagions. An example is the class of prudential policies, ones that limit the risk exposure and liquidity requirements of banks. The most relevant one for this study is the requirement of a risk weighted capital coverage (BAKKER et al., 2012). These measures are effective when it comes to reducing risks in lending and increasing financial stability (LORENČIČ; FESTIĆ, 2022; CLAESSENS, 2014). Ely, Tabak and Teixeira (2021) find that capital based requirements are able to reduce banks' leverage using empirical data, and Davis, Liadze and Piggott (2019) use a DSGE model to show that systemic risks are reduced by these measures. On the other hand, there's evidence that capital requirements and other prudential policy tools reduce credit growth and increase borrowing constraints (BROCKMEIJER, 2012; CERUTTI; CLAESSENS; LAEVEN, 2017), hence having an anti-cyclical effect. In general, the literature finds that macroprudential measures are effective in curbing the excess of credit creation and risk taking behavior during the expansive economic phases, dampening the procyclicality of banking activity.

Another important point that emerges from the observation of macroprudential policy is its interaction with monetary policy. The prudential measures may have implications on credit and economic activity, interfering with the goal of monetary policy, which is to control these variables (AGENOR; JACKSON, 2022). Naturally, the interference also may exist on the other side, since monetary policy impacts risk taking and financial stability, the goals of prudential policy. Alexandre and Lima (2020) find that a cyclical prudential policy rule brings more stability to the system, but may lose its efficacy when combined with some interest rate rules. On the other hand, Bruno, Shim and Shin (2017),Revelo, Lucotte and Pradines-Jobet (2020) and Gambacorta and Murcia (2020) observe complementary effects of monetary and loan to value restrictions, which is a form of macroprudential regulation. Inserted in this literature, our work explores the possible interactions of the cited policies.

3 Methodology

3.1 The model

The model we present is an agent based model constructed within a game theoretical setting, meaning that each agent is endowed with a objective functions and a set of strategies, and faces the problem of evaluating strategies in a repeated manner. Having bounded rationality, imperfect and incomplete information, they do not know other agents' moves or payoffs, and are assumed to use past experiences to measure strategy performance instead of analyzing the game and reaching a set of Nash equilibria. As in Barroso et al. (2016), an experience-weighted attraction (EWA) mechanism is employed (based on Camerer and Ho (1999)), which is further explained in the next section.

3.2 Learning process

The EWA mechanism in this model connects past outcomes and future employed strategies by weighting how frequent, recent and positive or negative the outcome to certain strategy was or could have been. It encompasses actual and simulated effects; where actual effects are the basis for reinforcement learning, as Roth and Erev (1995) state, and bring the idea that if a strategy is chosen and yields high payoff, its probability of being chosen again increases. In its turn, simulated effects are the increased likelihood of strategies that were not chosen and would have yielded a positive outcome of being chosen (FUDENBERG; LEVINE, 2018). Adding the diminishing effects of experience over time, the EWA learning mechanism is complete.

In order to mathematically explore these concepts, we must define some notation. First, consider a game populated with n agents indexed by $(i = 1, \dots, n)$ endowed with strategy sets given by $S_i = \{s_i^1, s_i^2, \dots, s_i^j, \dots, s_i^{m_i-1}, s_i^{m_i}\}$. A general period is denoted by t, and a player i chooses the strategy $s_i(t)$ and receives a payoff given by the function $\pi_i(s_i(t), s_{-i}(t))$, where the vector of strategies played by all players $-$ except i $-$ is given by $s_{-i}(t)$.

The intelligent agents observe an attraction level defined for each of their strategies, that is transformed in a probability of being played. At any time $t > 0$, the attraction level of a strategy j and player i is given by:

$$A_i^j(t) = \frac{\phi \cdot N_i(t-1) \cdot A_i^j(t-1) + [\delta + (1-\delta) \cdot I(s_i^j, s_i(t))] \cdot \pi_i(s_i^j, s_{-i}(t))}{N_i(t)}, \tag{3.1}$$

where ϕ is the parameter that depreciates past attractions. The value δ weights the foregone payoffs and $I(s_i^j, s_i(t))$ is an indicator function that assumes 1 if $s_i^j = s_i(t)$ [1]. In this setting, δ is crucial as it describes how actual and simulated effects are weighted: if a strategy is not played, it only receives a fraction (δ) of the attraction it would receive if it were actually played. $N(t)$ is the measure of experience, which is updated by:

$$N_i(t) = \rho \cdot N(t-1) + 1, \tag{3.2}$$

where ρ is the fading of experience. ρ and ϕ account for cognitive phenomena like forgetting and consciously discounting old experiences due to the changing environment. Note that if we assume $\rho = 0$ and $\delta = 0$, we have the pure reinforcement learning model. On the other hand, assuming $\delta = 1$ and $\rho = \phi$ leads us to the belief-based model ((CAMERER; HO, 1999)).

In order to gain some important intuition about equation (3.1), we must analyze $N(t)$. Essentially, it works as a weighted counter: while $\rho = 1$ means that $N_i(t)$ is an ordinary counter, $\rho < 1$ implies that $N_i(t)$ is a dampened counter. All past information is stored in parameter $A_i^j(t-1)$, which is weighted in equation (3.1) by $N_i(t)$, and then averaged with the new information brought in by $\delta + (1-\delta) \cdot I(s_i^j, s_i(t))] \cdot \pi_i(s_i^j, s_{-i}(t)$. If ρ is small, the past knowledge has little impact when compared with the incoming knowledge.

The actual choice made by the intelligent agents is given by a mixed strategy resulting from a logit model in form of the following equation:

$$P_i^j(t+1) = \frac{e^{\lambda \cdot A_i^j(t)}}{\sum_{k=1}^{m_i} e^{\lambda \cdot A_i^k(t)}}, \tag{3.3}$$

for all player i and strategy j. The parameters λ is the sensitivity to attractions.

We follow Pouget (2007), Barroso et al. (2016) and Adão et al. (2022) in the parameters setting, assigning the values described in Table 1. With this set of parameters, Eq. (3.1) becomes the following:

$$A_i^j(t) = \phi A_i^j(t-1) + \pi_i(s_i^j, s_{-i}(t)). \tag{3.4}$$

3.3 Agents

The relevant agents are described in the following sections, along with their strategy sets and payoff functions. These characteristics define their behavior, which in turn shape how the aggregate variables behave.

[1] that is, if s_i^j is actually played in period t

Table 1 – EWA parameters

Parameter	Meaning	Value
ρ	Retrospective discount factor	0
ϕ	Discount factor of previous attractions	0.9999
$N(0)$	Initial experience	1
δ	Weight given to past payoffs	1
$A(0)$	Initial attraction	0
λ	Sensibility to attractions	1

3.3.1 Banks

Banks are the main target of attention in this framework, as they act as the financial intermediaries of the system and control several important variables. The banks define their balance sheets using a two parameter strategy: the first is α, which represents the ratio of capital to other liabilities. This ratio determines how leveraged the bank is and how exposed it is to losses. The second is β, the proportion of liquid assets related to illiquid assets (loans), and determines the amount of liquidity kept by banks, that may be withdrawn by depositors without any trouble. The model also has γ as another strategy, besides the first two. It describes risk taking behavior, representing the ratio of high risk real sector loans with respect to total loans. This parameter captures how inclined the bank to increasing portfolio risks. The total value of banks' assets is given by an exogenous parameter T_b for each bank b. These are the parameters included in the models of Barroso et al. (2016) and Adão et al. (2022).

Our model adds yet another dimension to the set of strategies to enhance its explanatory ability. We introduce variables to manage the interest rate spread setting behavior. Banks' strategy, in that sense, must account for how the interest rate depends on the associated credit risk. In order to develop the financial choice pattern, a model for risk taking must be taken into consideration. We consider the following maximization, representing the credit supply choice:

$$\max_{I} \qquad (1-p)(1+i(I))I - cI$$

This represents a monopolist financial institution credit supply decision, where c is the average capital cost, p is the default probability and $i(I)$ is the credit demand. The first order condition, equivalent to equating marginal revenue and marginal cost, yields the following pricing rule:

$$(1+i(I)) = \frac{c}{(1-p)} i'(I)I$$

Rearranging the equation to write it in the mark-up rule form, we can rephrase it in the following way:

$$(1 + i^*) = \frac{c}{(1-p)} \frac{1}{1+\epsilon^D}$$

where $\epsilon^D = \frac{Ii'(I)}{1+i}$ is the elasticity of credit demand relative to the interest rate. The strategy we introduce to enable endogenous price setting is the mark-up rate $\mu = \frac{1}{1+\epsilon^D}$. Therefore, banks choose a mark-up rate in order to define the charged interest rate in the process of trying to maximize profit. The real sector and interbank market have different mark-up rates, meaning that, if a bank chose a pair of mark-up rates μ_R and μ_{IB}, the interest rates at which it offers its credit are:

$$(1 + i_R) = \frac{c}{(1-p)} * \mu_R \qquad \text{and} \qquad (1 + i_{IB}) = \frac{c}{(1-p)} * \mu_{IB} \tag{3.5}$$

where the value p is the client's default risk, assumed to been known to the bank; and c is the cost of the banks funds, which is essentially an average of deposit costs and capital costs.

We define the entire strategy set, in general, as a vector[2] $(\alpha, \beta, \gamma, \mu_R, \mu_{IB}) \in [0, 1]^5$, defining the banks' choice

Table 2 summarizes this setup.

Table 2 – Banks' strategy list

	Item	Strategy
Liability	Capital deposit ratio	$\alpha \in [0, 1]$
Asset	Liquid illiquid asset ratio	$\beta \in [0, 1]$
Asset	High/low risk loans ratio	$\gamma \in [0, 1]$
Interest	Real sector mark-up	$\mu_R \in [0, 1]$
Interest	Interbank sector mark-up	$\mu_{ib} \in [0, 1]$

The payoff function is given by the bank's return on equity (ROE), measured at the end of each cycle. Banks evaluate profit as the difference between final and initial capital.:

$$\Pi = K^2 - K^0, \tag{3.6}$$

The banks' objective function, the one it maximizes, is then:

$$ROE = \frac{\Pi}{K^0}. \tag{3.7}$$

Another important bank variable is the Capital Adequacy Ratio (CAR), which is the ratio of capital related to Risk-Weighted Assets (RWA). The calculation of RWA in

[2] We denote $[0, 1]^n$ as the Cartesian product of the set $[0, 1]$ n times.

this model does not include liquid assets, as they're considered riskless assets. For a bank b, F_b is the set of firms in its lending portfolio. Then we have:

$$CAR_b = \frac{K_b}{w_{IL} IL_b + \sum_{f \in F_b} R_{b,f} \cdot w_f}, \tag{3.8}$$

The metric above has two purposes: they are the perceived risk by depositors and are also a target of central banks' regulation.

3.3.2 Firms

The real sector behavior is quite simple. The most relevant feature is its sensitivity to the interest rate, and to justify this, an investment optimization model is is necessary. Consider the following problem:

$$\max_I (1-p) F_{success}(I) + (p) F_{failure}(I) - (1+i)I$$

where I is the amount of investment and i a given interest rate. The equation above simply represents the expected profit under a two-scenario setting, where production can either be a success, with probability p, or a failure. Without loss of information, we may consider that $F_{failure}(I)$ is 0, and the first order condition will then yields a credit demand curve described by the equation:

$$1 + i = (1-p) F'_{success}(I)$$

The firm will be endowed with credit demand equation justified by the reasoning above that represents the totality of the firms' behavior in this model. Specifically, in our simulation the credit demand function is linear, in the form: $I = A - b(1 + i)$.

3.3.3 Depositors

Depositors act as noisy agents. It is an unintelligent behavior, where the decision to withdraw the deposit on an early date (which is the primary cause of liquidity shocks in this model) is purely stochastic, as in Gabbi et al. (2015). The depositors consistently create liquidity shocks and create imediate liquidity needs to banks, leading them to resort to the interbank credit market.

Depositors act as noisy agents, exhibiting unintelligent behavior. The decision to withdraw their deposits at an early date, which is the primary cause of liquidity shocks in this model, is purely stochastic, as in Gabbi et al. (2015). Consequently, depositors consistently create liquidity shocks and immediate liquidity needs for banks, leading them to resort to the interbank credit market.

3.3.4 Central bank

The central bank works as a lender of last resort and as a system regulator. It imposes minimum CAR as a regulatory measure and a risk-free interest rate as a monetary policy tool. For the purpose of this work, the central bank is seen more as an exogenous agent and is described by fixed parameters regarding the cited actions, which can are used in a comparative way to explore policy scenarios. The central bank also enforces the capital requirement policy by making banks sell risky assets and comply with current rules.

3.3.5 Clearing house

The clearing house operates as a connector of borrowers and lenders. It takes all the credit suppliers and organize them from lowest to highest spread; and the borrowers from riskiest to least risky. This enables the banks to compete for best clients and also set their interest rates low enough to be able to lend at all. This process happens both in the real sector market and in the interbank market.

3.4 Simulation timeline

The simulation happens in cycles consisting in three steps, denoted by $\tau = 0, 1, 2$. This procedure is also seen in Allen and Gale (1998) and Allen and Gale (2000). At the beginning of each cycle ($\tau = 0$), there is no interbank activity. At first, all agents define their strategies in a probabilistic manner based on the mixed strategies given by the EWA learning mechanism. In this moment, banks choose their initial balance sheet, credit supply and interest rate markup rule. Still in $\tau = 0$, the real sector credit market takes place, matching firms and banks and creating a loan network. In the next step, $\tau = 1$, depositors withdraw their money, creating liquidity shocks, and banks must use liquid assets or resort to the interbank credit market in order to fulfill the withdrawals. Banks with excess of liquidity provide credit to those with liquidity needs. The central bank then analyzes the balance sheets and enforces the prudential policy, if active, by making banks with $CAR > CAR_{min}$ sell their risky assets in order to reach $CAR = CAR_{min}$.

In the final step, $\tau = 2$, banks collect their loans and pay the interests to their creditors. If they are insolvent, with losses superior to their capital, the central bank liquidates and punishes them, implicating further losses. With their final profits or losses, banks apply the EWA mechanism to update attractions and then the simulation moves to next cycle. It's worth mentioning that if debtors don't pay their interbank loans they may cause other banks insolvency, causing a financial contagion.

When the cycle is finished, agents only carry their acquired knowledge to next cycle, in the form of attraction for each strategy. All other variables are reset to their default values. No banks are erased nor created in this process.

The simulation is generated by repeating the cycle 8000 times, ensuring that the agents may learn with the experience and reach optimal strategy for the simulation. Banks' strategies, which are the most important, are computationally implemented via a grid of vectors of five dimensions. For each individual strategy parameters ($\alpha, \beta, \gamma, \mu_r$ and μ_{IB}) the interval [0,1] is divided in 15 parts. This yields 15^5 strategy options for each bank. In other to minimize the idiosyncrasies of simulations and provide additional robustness, we use the Monte Carlo method, running each scenario 10 times and aggregating the results.

4 Results

4.1 Parameter Calibration

For parameter calibration, we gathered financial data from IFM databases [1] and split them between developed and emerging countriesfor establishing expansive and restrictive monetary policy interest rates for developed and emerging countries. In order to calibrate the demand function parameters, we used market interest rates from the same database, paired with the monetary policy, and ran test simulations to reach a reasonable result.

The data from the IMF databases describe default rate, monetary policy rates, lending rates and inflation from several countries. The IMF itself categorizes countries into developed and emerging [2], and we divide countries the same way. In order to calibrate the parameters for expansive and restrictive monetary cycles, we consider only the period between 2009 and 2022 and we calculate the tenth and ninetieth percentiles for each country, to remove outliers. The values are averaged within the groups to give us baseline values for high and low interest rate regimes in the different country setting. These parameters are summarized by table 3.

Table 3 – Financial data description.

	Developed Country			Emerging Country		
Variable	Median	10th percentile	90th percentile	Median	10th percentile	90th percentile
Monetary policy interest rate	1.389	0.0578	3.652	5.074	2.592	8.241
Lending rate	4.301	3.034	5.808	9.914	7.112	13.832
Default rate	1.118	0.314	1.454	5.836	1.460	5.517

For the prudential policy's CAR_{min} level, the Basel III CAR recommendations for Tier 1 Capital (BIS, 2011; BIS, 2019) are used. Other financial variables that are relevant for the model are calibrated based on the results similarity with the data gathered and values used in the literature. The number of firms and depositors, especially, is set to be high enough to prevent big losses happening due to concentration of loan portfolios in a single firm and also prevent extreme liquidity shocks. Both the loan portfolio and the depositors, for each bank, must be diverse and large so that the probability of default actually converges to the parameters set in the model.

Table 4 presents the values of the financial parameters for the two different scenarios and the two interest rate regimes effectively used in the simulations.

[1] Financial Soundness Indicators (FSI) and International Financial Statistics (IFS)
[2] The full description of groups may be found here

Table 4 – Financial parameter's values.

Parameter	Description	Developed Country		Emerging Country	
		Low Interest	High Interest	Low Interest	High Interest
N_B	Number of banks	50	50	50	50
$N_{F_{HR}}$	Total number of high corporate clients	100	100	100	100
$N_{F_{LR}}$	Total number of corporate clients	100	100	100	100
N_D	Number of depositors per bank	100	100	100	100
i_d	Monetary policy interest rate	0.005	0.02	0.05	0.09
CAR_{min}	Minimum capital adequacy ratio	0.08	0.08	0.08	0.08
P_W	Probability of withdrawal	0.1	0.1	0.1	0.1
$P_{D_{HR}}$	High risk corporate loan default rate	0.1	0.1	0.15	0.15
$P_{D_{LR}}$	Low risk corporate loan default rate	0.005	0.01	0.01	0.05
w_i	Interbank loan risk weight	0.5	0.5	0.5	0.5
w_{HR}	High risk corporate loan risk weight	3.5	3.5	3.5	3.5
w_{LR}	Low risk corporate loan risk weight	1.5	1.5	1.5	1.5
T_b	Bank size parameter	1	1	1	1

We present, in the following sections, the simulation results from the different scenarios, namely the cases of expansive and restrictive monetary policy and the combinations with the presence or absence of capital requirements, in the form of a minimum CAR imposition. As stated, we have set the parameters for emerging and developed countries realities. We organize the results into two categories, credit market and financial stability, to explore the policy impacts on these aspects of the financial sector, especially paying attention to how policies interact and impact each other's objectives.

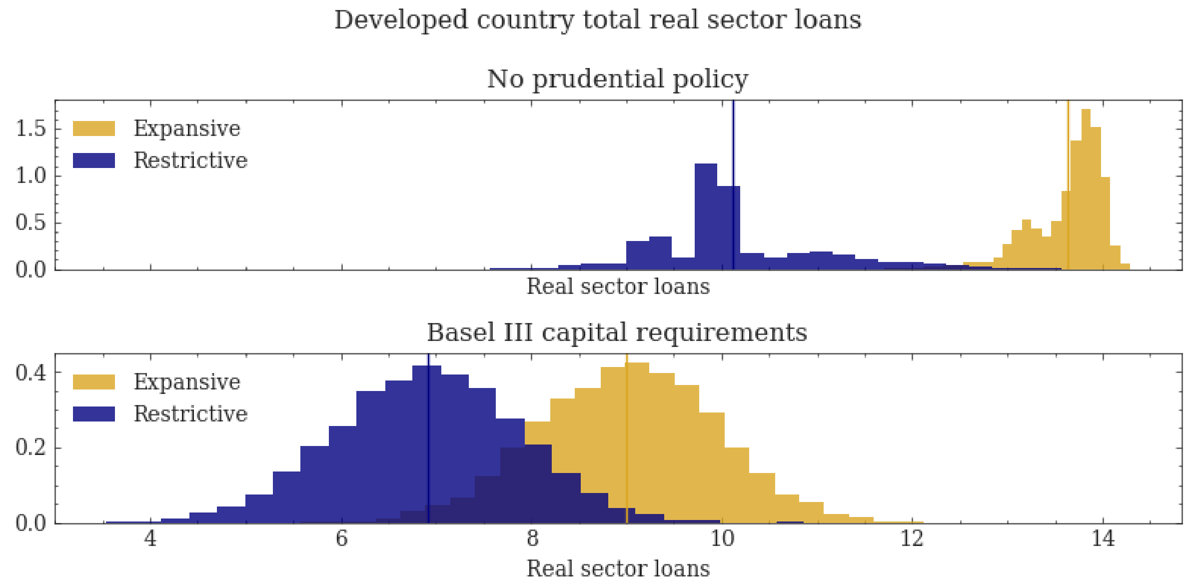
4.2 Credit market and interest rates

Monetary policy aims to control price levels using interest rates to reduce consumption and investment, reducing economic activity and prices (KASHYAP; STEIN et al., 1997; MORENO et al., 2008), and in our model, this is captured the total amount of loans offered. Since financial stability is not a primary goal for monetary policy, it may have secondary, sometimes unwanted, impacts in that area. On the prudential dimension, the goal is to improve financial stability, in the form of less financial crisis and insolvencies, and the opposite can be said: not being the main goal of prudential policy, credit and economic activity (and even inflation) may suffer secondary effects from the pursuit of financial stability.

4.2.1 Credit supply

Our simulation finds interesting results in the credit market, pointing to some degree of conflict between monetary and prudential policies. As figure 1 shows, monetary policy tightening has the restrictive effect on the total amount of loans offered by banks in a developed country setting. Prudential policy reduces total loans when in the expansive monetary policy instance, showing reduction in the credit expansion and reducing the effect of monetary loosening. When monetary policy is restrictive, the credit supply is also reduced, and the impact has a similar magnitude, possibly causing an over reduction of credit supply.

Figure 1 – The distribution of total credit supplied in the last 3000 simulation cycles of a developed country

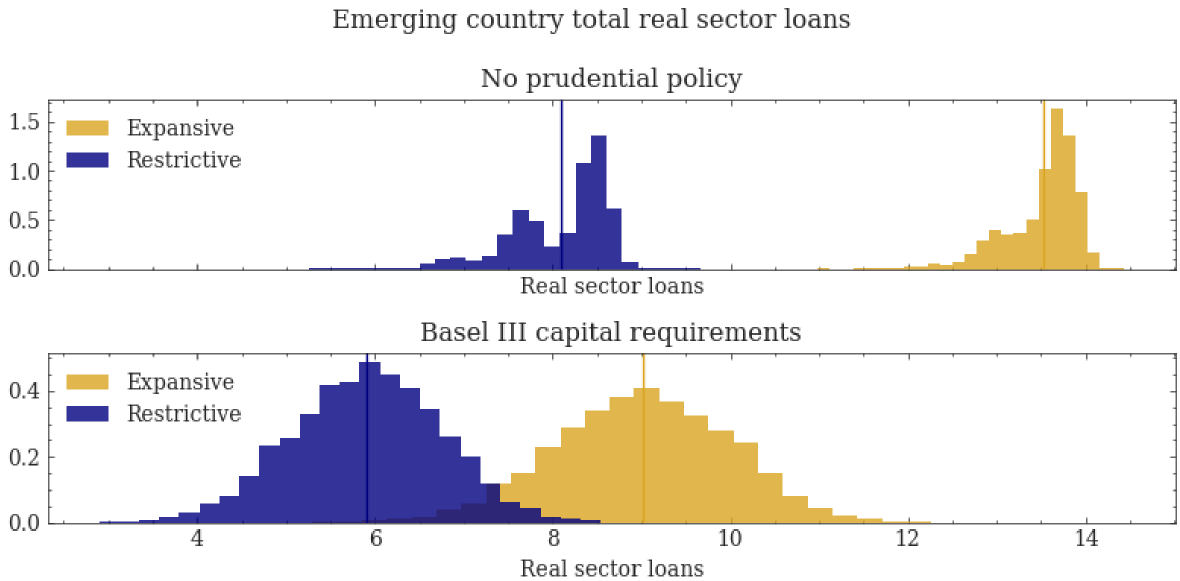


The presence of the Basel III CAR requirement in a developed country setting caused, on average, a reduction of 30% on total loans conceded. This contractionist effect of prudential policy on credit is backed by empirical evidence (BROCKMEIJER, 2012; ELY; TABAK; TEIXEIRA, 2021).

The credit reduction operates, within the model mechanics, through two channels. The first, as stated, is the increased profitability of liquid assets when risk free interest rates are high. Banks then keep more liquid assets and take less risks. The second is the effect of capital requirements, that forces banks to sell the excess of loans, effectively reducing credit supply.

This phenomenon also happens in the emerging country environment, when risks and interest rates are higher. In this scenario, the credit reduction is significantly larger during monetary policy tightening. In that case, loans decrease by 25% on average, while they recede by 34% when interest rates are lower.

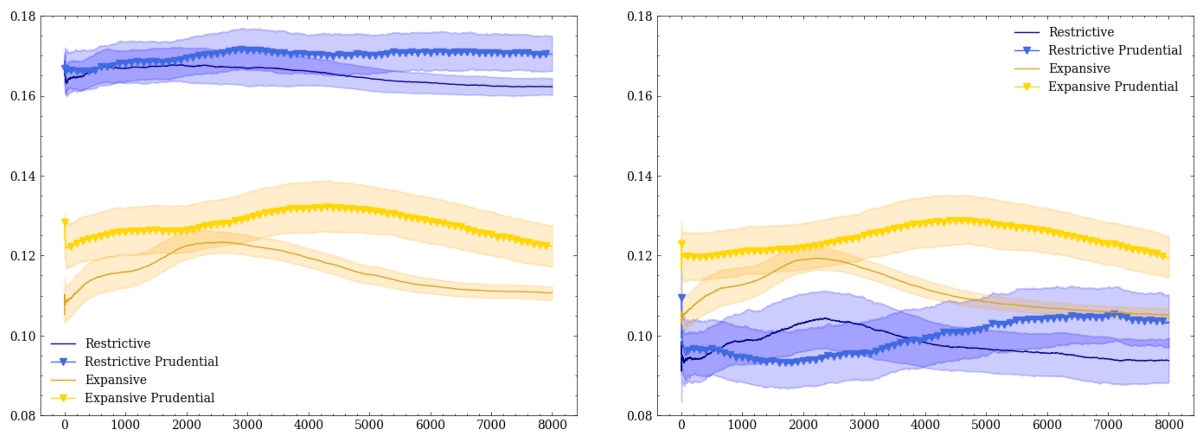
Figure 2 – The distribution of total credit supplied in the last 3000 simulation cycles of a emerging country



4.2.2 Market interest rates

Turning to market interest rates, we observe a similar behavior. Prudential policy made market interest higher, as credit supply diminished. CAR requirement also functions as a tax on capital imposed to banks and yield higher market interest rates. When analyzing the difference between, we notice that in the developed country setting, where risk free interest rates and risks are lower, the difference is less expressive, even the increase in interest rates caused by restrictive monetary policy. There are two sides to this: as risk are lower in the developed country, banks choose to charge less to their clients; but the opportunity cost of lending is larger due to the higher monetary policy rate. The results is mixed in the simulations, as the charts below show.

Figure 3 – The dynamics of market interest rates in different policy setting and country scenarios



(a) Emerging country (b) Developed country

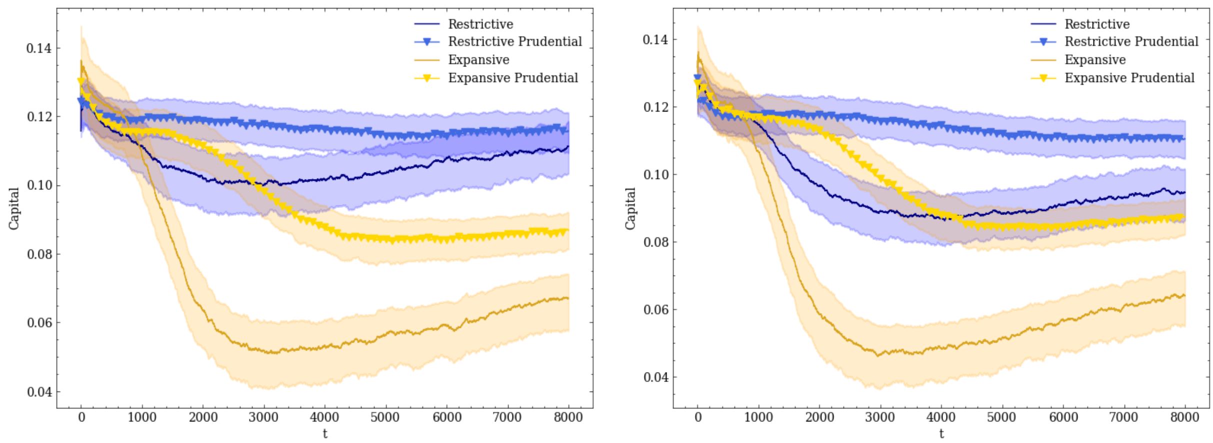
4.3 Banks behavior and financial stability

Another dimension of the credit market, related to system stability, is the behavior of banks when defining their balance sheet, in terms of capital, asset portfolio and loan risks. The ratio of liquidity assets, for instance, determines how resilient a bank is to early withdrawals. Capital, in its turn, makes banks more resistant to losses, if they happen, and prevents insolvency. Finally, higher loan risks increase instability and the occurrence of defaults, but may bring risk premia. Since prudential policy aims to reduce systemic risk, these variable are very important. Once again, monetary policy might interfere in a conflicting or unsuspected way. The evidence from our simulation, regarding financial stability, does not point to great conflict between the analyzed policies.

4.3.1 Capital

Both monetary and macroprudential policies affect banks' capital and liquidity. Monetary policy increases the return of capital by raising risk-free interest rate and also raises the cost of deposits., while prudential policy forces a higher amount of capital in order to allow a bigger loan portfolio. Figure 4 illustrates this situation.

Figure 4 – The dynamics of capital to total liabilities ratio in different policy setting and country scenarios



(a) Emerging country (b) Developed country

With the developed country parameter setting, the simulation shows that capital requirements yields a greater capital level difference when the monetary policy is expansive, with an average 30% increase. When the monetary policy is restrictive, the increase is 8%. In figure 5 the distribution is drawn in detail.

In the emerging country scenario the impacts are very similar, as figure 6 shows.

The increased capital favors financial stability, as it protects banks from becoming insolvent after defaults and losses. Capital also determines how profitable a bank can be,

Figure 5 – The distribution of capital to liabilities ratio in the last 3000 simulation cycles of a developed country

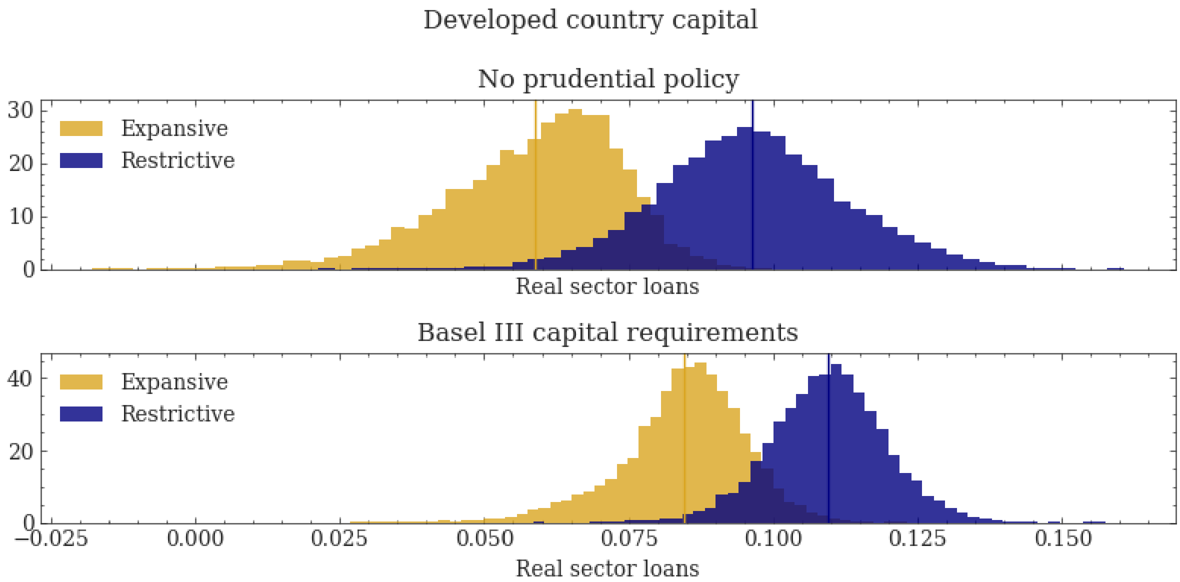
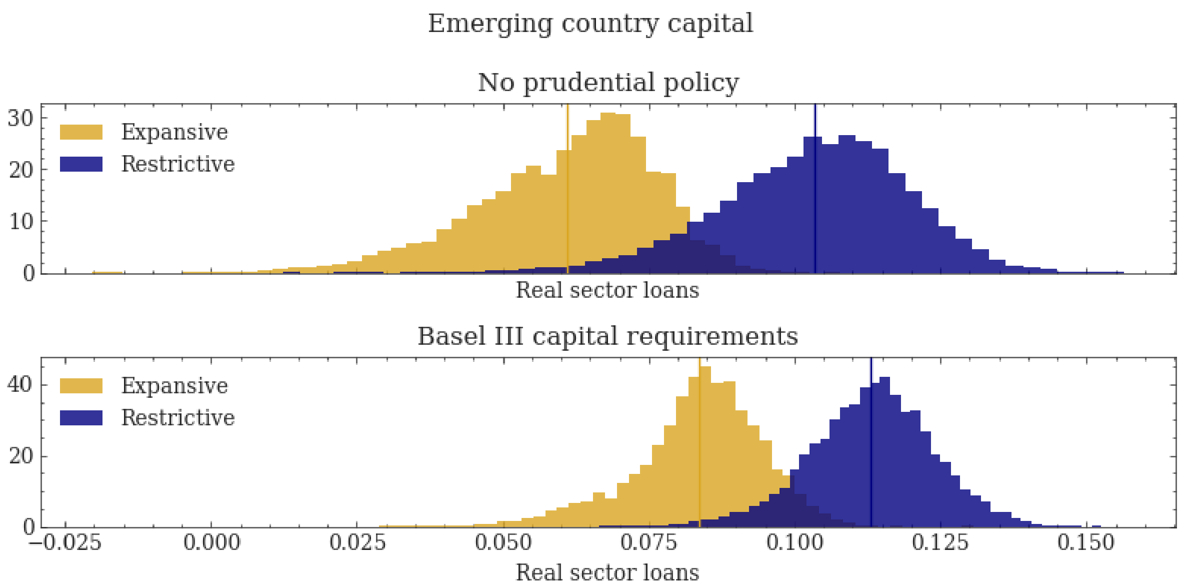


Figure 6 – The distribution of capital to liabilities ratio in the last 3000 simulation cycles of a emerging country



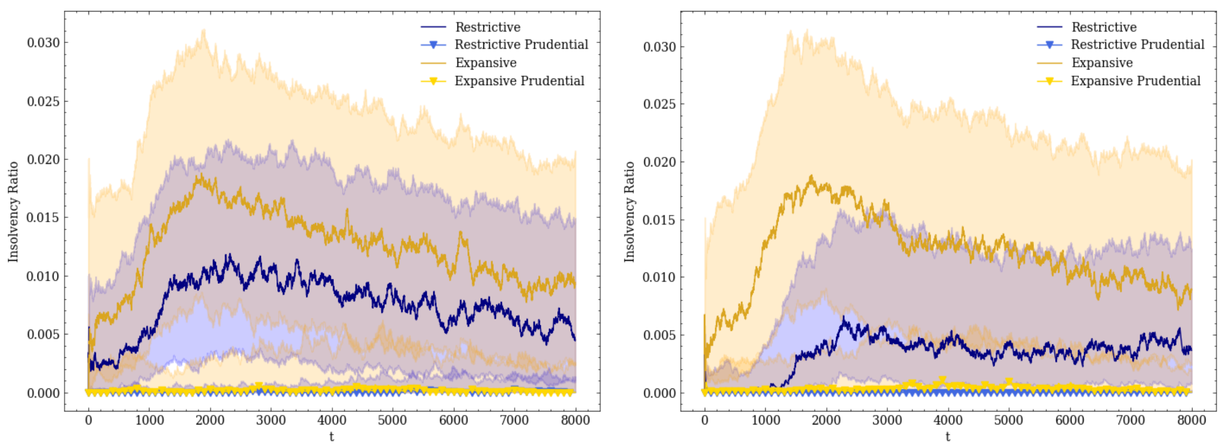
since it defines the amount of money invested in it, and is an important variable in the financial system.

4.3.2 Risk taking behavior and insolvency

Regarding stability, the first observation to be made is that CAR requirement is effective in its goal of reducing leverage and insolvencies, thus increasing financial stability. This result is in line with many work in the literature that show many aspects of risk reduction caused by macroprudential policy.(ELY; TABAK; TEIXEIRA, 2021; LORENČIČ; FESTIĆ, 2022; CLAESSENS, 2014; DAVIS; LIADZE; PIGGOTT, 2019). Figure 7 shows how insolvencies respond to capital requirements in a the environments of developed and emerging countries, being drastically and consistently reduced in the presence of CAR requirements. This is explained mainly by the increased capital held by banks, that works as protection against defaults, and the increased liquidity in the balance sheet, preventing punishment for being illiquid.

Figure 7 also shows that a restrictive monetary policy decreases insolvency, although it has a small impact. Such implies that high interest rates favor bank stability, preventing financial crisis. This resonates with the literature (RUBIO; YAO, 2020; ADRIAN; SHIN, 2008; ADÃO et al., 2022; MORAES; MONTES; ANTUNES, 2016; DELIS; KOURETAS, 2011) and also our model, that state that low interest rates may lead to excessive risk taking and financial crisis. This is more pronounced in emerging countries, where default rates are higher, causing instability.

Figure 7 – The dynamics of insolvency ratio of a developed country



(a) Emerging country

(b) Developed country

Turning to risk taking behavior itself, the simulations indicate, on one hand, show the cited relationship between low interest rates and increased risk in banks portfolio; and on the other hand, that there is an unusual result between risk taking behavior, indicating the capital requirements leads banks to higher risks. This result finds some contrary evidence in the literature (ELY; TABAK; TEIXEIRA, 2021), but has some logic and narrative that may corroborate it when taking into account the model construction. Since banks are maximizing profit, one may argue that the constraints over capital makes banks search for more risk premia via high-risks while keeping the total amount of loans low, with capital buffer prevent insolvency. The figure 8 show the ratio of high risk loans to total loans in each scenario in the developed environment.

Figure 8 – The distribution of high risk loan to total in the last 3000 simulation cycles of a developed country

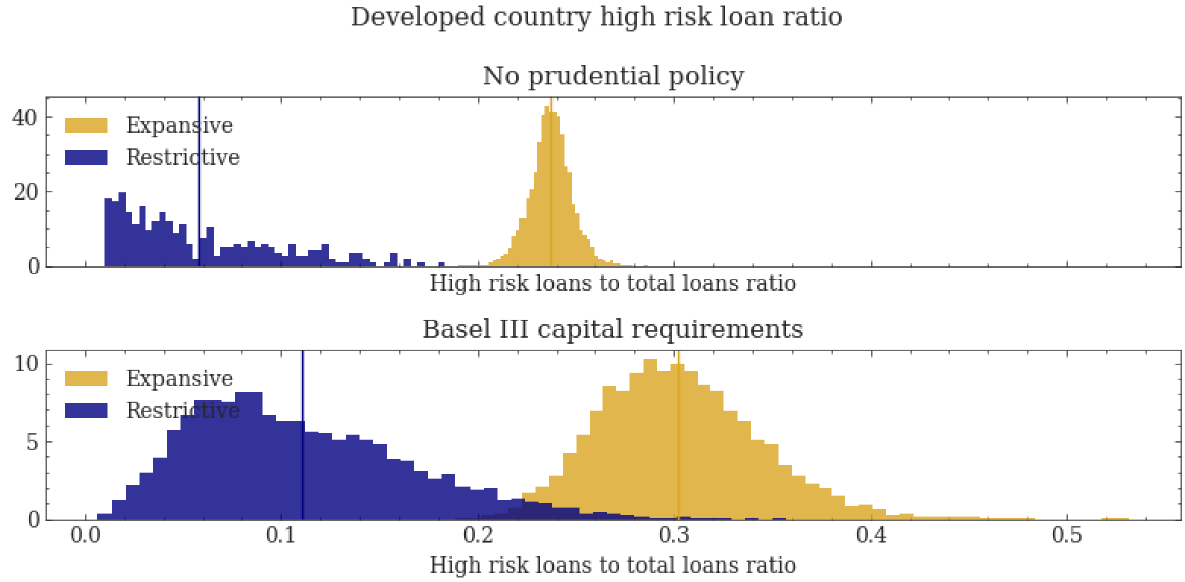
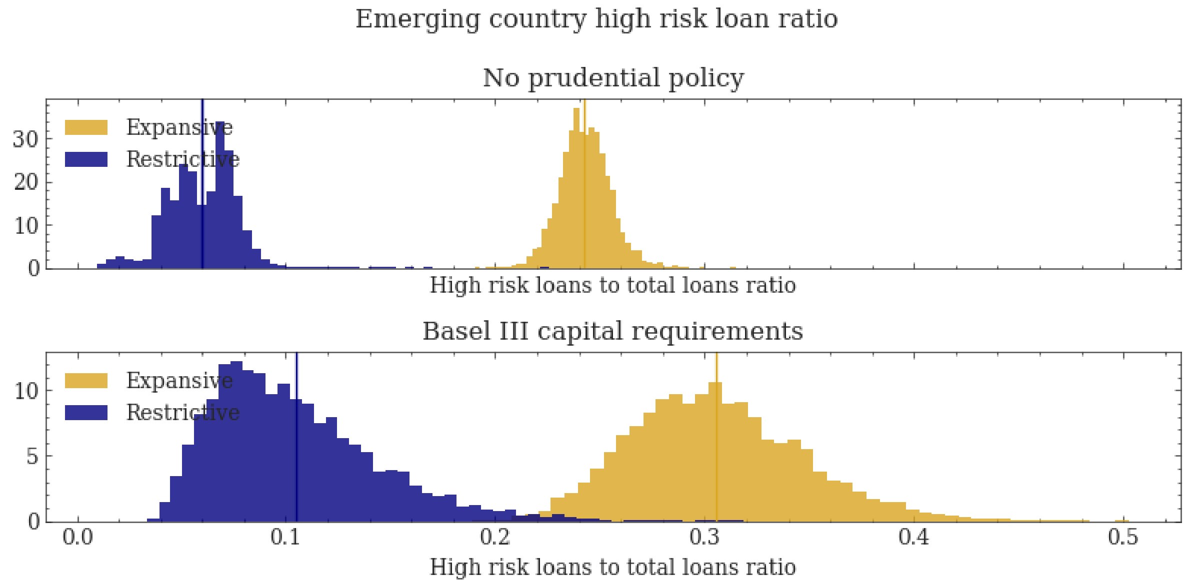


Figure 9 – The distribution of high risk loan to total in the last 3000 simulation cycles of a emerging country



5 Conclusion

Using an agent-based model of the banking system we build the results present here, simulating different scenarios [1] They resonate with other models (IORI et al., 2015; GABBI et al., 2015). We focus on the impacts and interactions of monetary policy, in the form of a risk-free interest rate set by the central bank; and macroprudential policy, as a minimum capital adequacy ratio requirement, building an outlook of the financial system. Financial stability, credit market size and interest rates are the main object of analysis.

The simulations bring some valuable insights. First, the amount of credit conceded is negatively affected by a policy tightening in both analyzed policy dimensions. In other words, both a raise in the risk-free interest rate and the minimum CAR requirements lead to contraction in credit. This result is intuitive, since on one hand high interest raise the opportunity costs of lending money by improving the return of liquidity assets, and on the other hand capital requirement impose restrictions to loan amounts. This result is consistent with both empirical and theoretical literature (KASHYAP; STEIN et al., 1997; MORENO et al., 2008; ADÃO et al., 2022; GAMBACORTA, 2009; ANGELONI; FAIA; DUCA, 2015; BERNANKE; GERTLER, 1995). The contractionary effect of prudential policy is not symmetrical in different monetary policy regimes, and is stronger when the interest rates are low. This also translates to market interest rates, as the credit supply is diminished, and we find higher market rates when the prudential policy is active. This result points to some conflict between minimum CAR and monetary expansion, since they cause opposite movement in the credit market.

Second, the financial stability can be looked at through different output variables. The first is a direct one: the number of insolvencies. Capital requirements, as expected and intended, reduce the frequency of insolvency, since banks reduce their amount of loans and keep more capital. Monetary policy, when restrictive, causes a slight reduction in insolvencies. Another important variable is the risk taking behavior, measured by the ratio of high risk loans to standard loans. This variable's response to monetary policy shows that banks take more risk when interest rates are low, negatively affecting stability. This result is backed by literature on the subject (ADRIAN; SHIN, 2008; DELIS; KOURETAS, 2011; MORAES; MONTES; ANTUNES, 2016; RUBIO; YAO, 2020; ADÃO et al., 2022). The evidence from our model shows that coordination between monetary-macroprudential policies, since both of them have implications on both credit supply and financial stability. Emerging countries benefit more from prudential policies, since the level of instability and insolvencies is higher.

[1] Namely the presence or absence of macroprudential regulation; restrictive or expansive interest rates and the parameters values of a developed or emerging country.

This work contributes to the growing literature about the interaction of macroprudential and monetary policies. The results resonate with Bruno, Shim and Shin (2017), Gambacorta and Murcia (2020), Revelo, Lucotte and Pradines-Jobet (2020), that find that there's a complementary effect between the policies when the monetary policy is restrictive, reducing instability and credit supply. The path remains open to further the analysis, studying price level stability, empirical differences between emerging and developed countries, bankruptcy data and economic cycles. For this specific class of agent-based models, improvements in the analysis could be made by endowing the model with a more detailed real sector, so that price and cycle analysis can be endogenous.

Bibliography

ADÃO, L. F. et al. The impacts of interest rates on banks' loan portfolio risk-taking. *Journal of Economic Dynamics and Control*, p. 104521, 2022. ISSN 0165-1889. Citado 6 vezes nas páginas 11, 14, 16, 17, 29, and 31.

ADRIAN, T.; SHIN, H. S. Financial intermediaries, financial stability, and monetary policy. *FRB of New York staff report*, n. 346, 2008. Citado 2 vezes nas páginas 29 and 31.

AGENOR, P.-R.; JACKSON, T. P. Monetary and macroprudential policy coordination with biased preferences. *Journal of Economic Dynamics and Control*, v. 144, p. 104519, 2022. ISSN 0165-1889. Disponível em: <https://www.sciencedirect.com/science/article/pii/S0165188922002238>. Citado na página 14.

AIYAR, S.; CALOMIRIS, C. W.; WIELADEK, T. How does credit supply respond to monetary policy and bank minimum capital requirements? *European Economic Review*, v. 82, p. 142–165, 2016. ISSN 0014-2921. Disponível em: <https://www.sciencedirect.com/science/article/pii/S0014292115001609>. Citado na página 12.

ALBERT, R.; BARABÁSI, A.-L. Statistical mechanics of complex networks. *Rev. Mod. Phys.*, v. 74, p. 47–97, 2002. Citado na página 13.

ALEXANDRE, M.; LIMA, G. T. Combining monetary policy and prudential regulation: an agent-based modeling approach. *Journal of Economic Interaction and Coordination*, Springer, v. 15, n. 2, p. 385–411, 2020. Citado na página 14.

ALLEN, F.; CARLETTI, E.; GU, X. The Roles of Banks in Financial Systems. In: *The Oxford Handbook of Banking, Second Edition*. [S.l.]: Oxford University Press, 2014. ISBN 9780199688500. Citado na página 11.

ALLEN, F.; GALE, D. Optimal financial crises. *Journal of Finance*, v. 53, p. 1245–1284, August 1998. Citado na página 20.

ALLEN, F.; GALE, D. Financial contagion. *Journal of Political Economy*, v. 108, p. 1–33, February 2000. Citado na página 20.

ANDERSON, P.; ANDERSON, P. W.; PINES, D. (Ed.). *The Economy as an Evolving Complex System*. [S.l.]: Westview Press, 1988. Citado na página 13.

ANGELINI, P.; NERI, S.; PANETTA, F. The interaction between capital requirements and monetary policy. *Journal of money, credit and Banking*, Wiley Online Library, v. 46, n. 6, p. 1073–1112, 2014. Citado na página 12.

ANGELONI, I.; FAIA, E.; DUCA, M. L. Monetary policy and risk taking. *Journal of Economic Dynamics and Control*, Elsevier, v. 52, p. 285–307, 2015. Citado 2 vezes nas páginas 14 and 31.

ARTHUR, W. B.; DURLAUF, S. N.; LANE, D. A. (Ed.). *The Economy as an Evolving Complex System II*. [S.l.]: Addison-Wesley, 1997. Citado na página 13.

BAKKER, M. B. B. et al. *Policies for macrofinancial stability: How to deal with credit booms*. [S.l.]: International Monetary Fund, 2012. Citado na página 14.

BARDOSCIA, M. et al. The physics of financial networks. *Nature Reviews Physics*, Nature Publishing Group, p. 1–18, 2021. Citado na página 13.

BARROSO, R. V. et al. Interbank network and regulation policies: an analysis through agent-based simulations with adaptive learning. *Journal of Network Theory in Finance*, v. 2, p. 53–86, November 2016. Citado 4 vezes nas páginas 11, 15, 16, and 17.

BERNANKE, B. S.; GERTLER, M. Inside the black box: the credit channel of monetary policy transmission. *Journal of Economic perspectives*, v. 9, n. 4, p. 27–48, 1995. Citado 2 vezes nas páginas 14 and 31.

BIS. *Basel III: A global regulatory framework for more resilient banks and banking systems*. [S.l.], 2011. Citado na página 23.

BIS. The basel framework. *Bank for International Settlements, Basel Committee on Banking Supervision*, 2019. ISSN 978-92-9259-237-0. Citado 2 vezes nas páginas 11 and 23.

BLUME, L. E.; DURLAUF, S. N. (Ed.). *The Economy as an Evolving Complex System, III: Current Perspectives and Future Directions*. [S.l.]: Oxford University Press, 2005. Citado na página 13.

BONABEAU, E. Agent-based modeling: Methods and techniques for simulating human systems. *Proceedings of the National Academy of Sciences*, v. 99, n. suppl 3, p. 7280–7287, 2002. Citado na página 13.

BROCKMEIJER, J. The interaction of monetary and macroprudential policies — background paper. International Monetary Fund, 2012. Citado 2 vezes nas páginas 14 and 25.

BRUNO, V.; SHIM, I.; SHIN, H. S. Comparative assessment of macroprudential policies. *Journal of Financial Stability*, v. 28, p. 183–202, 2017. ISSN 1572-3089. Citado 3 vezes nas páginas 12, 14, and 32.

CAMERER, C.; HO, T. Experience weighted attraction learning in normal form games. *Econometrica*, v. 67, p. 827–874, 1999. Citado 2 vezes nas páginas 15 and 16.

CERUTTI, E.; CLAESSENS, S.; LAEVEN, L. The use and effectiveness of macroprudential policies: New evidence. *Journal of Financial Stability*, v. 28, p. 203–224, 2017. Citado na página 14.

CLAESSENS, M. S. An overview of macroprudential policy tools. International Monetary Fund, 2014. Citado 2 vezes nas páginas 14 and 29.

DAVIS, E. P.; LIADZE, I.; PIGGOTT, R. Assessing the macroeconomic impact of alternative macroprudential policies. *Economic Modelling*, v. 80, p. 407–428, 2019. ISSN 0264-9993. Citado 2 vezes nas páginas 14 and 29.

DAWID, H.; FAGIOLO, G. Agent-based models for economic policy design: Introduction to the special issue. *Journal of Economic Behavior & Organization*, v. 67, n. 2, p. 351–354, 2008. Agent-based models for economic policy design. Citado na página 13.

DELIS, M. D.; KOURETAS, G. P. Interest rates and bank risk-taking. *Journal of Banking & Finance*, v. 35, n. 4, p. 840–855, 2011. ISSN 0378-4266. Crete Conference 2010: The Future of Universal Banking. Citado 2 vezes nas páginas 29 and 31.

ELY, R. A.; TABAK, B. M.; TEIXEIRA, A. M. The transmission mechanisms of macroprudential policies on bank risk. *Economic Modelling*, v. 94, p. 598–630, 2021. ISSN 0264-9993. Citado 4 vezes nas páginas 14, 25, 29, and 30.

FARMER, J.; FOLEY, D. The economy needs agent-based modelling. *Nature*, v. 460, p. 685–686, 2009. Citado na página 13.

FUDENBERG, D.; LEVINE, D. K. *Theory of Learning in Games*. MA: MIT Press, 2018. Citado na página 15.

GABBI, G. et al. Financial regulations and bank credit to the real economy. *Journal of Economic Dynamics and Control*, v. 50, p. 117–143, 2015. ISSN 0165-1889. Crises and Complexity. Citado 2 vezes nas páginas 19 and 31.

GALLEGATI, M.; KIRMAN, A. Reconstructing economics: Agent based models and complexity. *Complexity Economics*, v. 1, n. 1, p. 5–31, 2012. Citado na página 13.

GAMBACORTA, L. Monetary policy and the risk-taking channel. *BIS Quarterly Review December*, 2009. Citado 2 vezes nas páginas 14 and 31.

GAMBACORTA, L.; MURCIA, A. The impact of macroprudential policies in latin america: An empirical analysis using credit registry data. *Journal of Financial Intermediation*, v. 42, n. C, p. S1042957319300361, 2020. Citado 2 vezes nas páginas 14 and 32.

Garcia Revelo, J. D.; LEVIEUGE, G. When could macroprudential and monetary policies be in conflict? *Journal of Banking& Finance*, v. 139, p. 106484, 2022. ISSN 0378-4266. Citado na página 12.

GATTI, D. D. et al. *Agent-Based Models in Economics: A Toolkit*. Cambridge: Cambridge University Press, 2018. Citado na página 13.

HOLLAND, J. H.; MILLER, J. H. Artificial adaptive agents in economic theory. *American Economic Review*, v. 81, n. 2, p. 365–71, 1991. Citado na página 13.

IORI, G.; JAFAREY, S.; PADILLA, F. G. Systemic risk on the interbank market. *Journal of Economic Behavior & Organization*, v. 61, n. 4, p. 525–542, 2006. Citado na página 13.

IORI, G. et al. Networked relationships in the e-mid interbank market: A trading model with memory. *Journal of Economic Dynamics and Control*, v. 50, p. 98–116, 2015. Citado 2 vezes nas páginas 11 and 31.

JIMÉNEZ, G. et al. Hazardous times for monetary policy: What do twenty-three million bank loans say about the effects of monetary policy on credit risk-taking? *Econometrica*, Wiley Online Library, v. 82, n. 2, p. 463–505, 2014. Citado na página 14.

KASHYAP, A. K.; STEIN, J. C. et al. The role of banks in monetary policy: A survey with implications for the european monetary union. *Economic Perspectives-Federal Reserve Bank of Chicago*, v. 21, p. 2–18, 1997. Citado 3 vezes nas páginas 13, 24, and 31.

KIM, S.; MEHROTRA, A. Effects of monetary and macroprudential policies—evidence from four inflation targeting economies. *Journal of Money, Credit and Banking*, v. 50, n. 5, p. 967–992, 2018. Citado na página 12.

LORENČIČ, E.; FESTIĆ, M. The impact of macroprudential policy on financial stability in selected eu countries. *Public Sector Economics*, Institut za javne financije, v. 46, n. 1, p. 141–170, 2022. Citado 2 vezes nas páginas 14 and 29.

LUBIS, A.; ALEXIOU, C.; NELLIS, J. G. What can we learn from the implementation of monetary and macroprudential policies: A systematic literature review. *Journal of Economic Surveys*, v. 33, n. 4, p. 1123–1150, 2019. Citado na página 12.

MORAES, C. O. de; MONTES, G. C.; ANTUNES, J. A. P. How does capital regulation react to monetary policy? new evidence on the risk-taking channel. *Economic Modelling*, v. 56, p. 177–186, 2016. Citado 2 vezes nas páginas 29 and 31.

MORENO, R. et al. Monetary policy transmission and the long-term interest rate in emerging markets. *BIS papers*, v. 35, p. 61–80, 2008. Citado 3 vezes nas páginas 13, 24, and 31.

NIER, E. et al. Network models and financial stability. *Journal of Economic Dynamics and Control*, v. 31, n. 6, p. 2033–2060, 2007. ISSN 0165-1889. Tenth Workshop on Economic Heterogeneous Interacting Agents. Citado na página 13.

POUGET, S. Adaptive traders and the design of financial markets. *The Journal of Finance*, v. 62, p. 2835–2863, November 2007. Citado na página 16.

REVELO, J. D. G.; LUCOTTE, Y.; PRADINES-JOBET, F. Macroprudential and monetary policies: The need to dance the tango in harmony. *Journal of International Money and Finance*, v. 108, n. C, 2020. Citado 2 vezes nas páginas 14 and 32.

ROTH, A. E.; EREV, I. Learning in extensive-form games: Experimental data and simple dynamic models in the intermediate term. *Games and Economic Behavior*, v. 8, n. 1, p. 164–212, 1995. Citado na página 15.

RUBIO, M.; YAO, F. Bank capital, financial stability and basel regulation in a low interest-rate environment. *International Review of Economics & Finance*, Elsevier, v. 67, p. 378–392, 2020. Citado 2 vezes nas páginas 29 and 31.

STEINBACHER, M. et al. Advances in the agent-based modeling of economic and social behavior. *SN Business & Economics*, v. 1, n. 99, p. 1–24, 2021. Citado na página 13.

TESFATSION, L. Agent-based computational economics: A constructive approach to economic theory. In: TESFATSION, L.; JUDD, K. (Ed.). *Handbook of Computational Economics*. [S.l.]: Elsevier, 2006, (Handbook of Computational Economics, v. 2). cap. 16, p. 831–880. Citado na página 13.

ZHANG, Y.; TRESSEL, T. Effectiveness and channels of macroprudential policies: lessons from the Euro area. *Journal of Financial Regulation and Compliance*, v. 25, n. 3, p. 271–306, July 2017. Citado na página 12.