Banking Stability and Prudential Regulation Interactions in DSGE Model for Tunisia

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Abstract. Since the last financial crisis, the financial system has taken and continues to be on guard against these unexpected shocks. In this direction, this article focused with these decision-makers as well as his researchers on a more advanced macroeconomic modeling, based on the integration of different hazards (economic, social, cultural, environmental…), the concept of micro-foundations, of the different types of imperfect competition accompanied by some price rigidities. We are proposing a new Dynamic Stochastic General Equilibrium (DSGE) model tailored to the banking sector in Tunisia. Our model captures the role played by prudential regulations in correcting fluctuations in the business cycle and restoring macroeconomic and financial stability.

Keywords: Conventional banks · DSGE models · Basel accords · Macro-prudential policies · Tunisia

1 Introduction

During the past decades, the strong development of the financial system has created different types of activities and financial instruments diverse and complex. In this context, developments in the financial sector seem to have played an important role in the configuration, and sometimes the amplification of macroeconomic fluctuations.

Consequential concerns an “excessive” variability in the financial system have highlighted the need to put in place measures for prudential regulation, accounting, and risk measurement, or monetary policy to consolidate the financial system and macroeconomic stability (Mizraei and Aguir 2020).

However, even though the various regulations accompanied by strong supervision aim to guarantee the risk management functions of banks as well as the liquidity management that continuously contribute to financial stability, the risks of instability can’t be solved (D’Orazio 2019). Also, only central banks can provide liquidity when necessary.

In fact, during the 1990s, the formulation of economic policy is based for the most part on the pursuit of maintaining financial stability. Thus, a financial system is part of a zone of stability when it can facilitate without hindrance the performance of the
economy while having the possibility to reduce financial imbalances, Schinasi (2006). In reality, financial stability is the maintenance of confidence in the financial system.

Thus, to ensure financial stability, the different actors of the system must have a solid accompanied by proper operation, an exchange rate regime, and good performance to other economic actors, in particular, the state, households, and non-financial firms. In this balance, credit institutions, alongside their traditional intermediation function and their growing involvement in capital markets, play an important role. There are also other financial institutions such as insurance companies, investment companies, and pension funds.

Also, it is still important to take into account the behavior of the financial markets, especially the equity, and foreign exchange markets. The opening of the financial markets, which are at the origin of international capital movements as well as significant volatility of the prices of the assets, is considered as an important risk-taking.

This leads us to ask the following questions: What is the impact of banking regulation on financial and macroeconomic stability? The problem developed is to analyze the impact of banking regulation and macro-prudential policy to mitigate banking risks and moral hazard problems. Hence the importance of our work in proposing a new dynamic and stochastic general equilibrium model (DSGE) adapted to the Tunisian banking sector. Our model accounts for the role played by prudential regulation in correcting fluctuations in the economic cycle and restoring macroeconomic and financial stability.

This study is structured with abstract as the beginning part, followed by an introduction. The main body of this study includes different sections presented in order such as literature review, research model and impulse responses to shocks and business cycle amplification, discussion, conclusion. The last part is the references.

2 Literature Foundations

“Financial stability refers to a bank’s ability to withstand significant shocks and the resolution of macroeconomic imbalances, thereby reducing the probability of a break in the financial intermediation between savings and investment” BCEAO (2006).

Financial stability is a factor in the proper functioning of the economy. The main aims of this notion are towards economic development, and the assurance of good intermediation between economic agents, through the channeling of financing flows efficiently towards the most growth-enhancing sectors. Indeed, the stability of financial institutions is the absence of tension that can lead to major economic crises whose effects are not limited to economic agents alone. In this context, financial stability requires two main conditions, Salameh (2013):

- The main institutions of the financial system must be stable so that there is sufficient confidence to continue to fulfill their contractual obligations without necessarily having external assistance or interruption.
- The main markets must be stable so that each actor can trade with confidence at prices reflecting the fundamental data on the market.
All of this shows that the definition of financial stability is not limited to banking stability alone, but affects the entire financial system since the financial stability of the banking sector is a factor in the soundness of all financial corporations.

Several factors that determine financial stability and can be broken down into three categories:

- **Macroeconomic conditions**: To maintain or restore financial stability, macroeconomic policies must be strengthened with appropriate structures. When the economic environment is affected by difficulties, the banks suffer the consequences. Indeed, economic stability depends on the specificities of a country’s relationship with the outside world. When a country is highly dependent on foreign aid century, it is exposed to significant risks, particularly as regards public finances, external financing, or the performance of the private sector. However, this situation mainly affects developing countries or countries with fragile economic conditions.

- **Internal Financial Institutions and Markets Management Systems**: A stable financial system is always accompanied by an adequate institutional and regulatory framework whose components and functioning determine the potential risks that financial institutions face.

- **The effectiveness of the regulatory system and supervision of financial institutions**: when the institutional framework is efficient and the financial system can adapt to different innovations and changes in the environment, there will automatically be financial stability.

Thus, a financial system is considered stable when it can facilitate the efficient allocation of economic resource and financial and economic processes; evaluates allocates, and manages financial risks (Icard 2007).

Also, the financial system and the banking system represent, through their roles and their vocations, reliable indications of the health of an economy, while allowing investors and the various economic players to plan their actions in advance and effectively manage their capital flows. This reflects the importance of banking institutions in the economy as well as the major interest granted by public authorities to these institutions.

For the Tunisian case, the banking system is characterized by an accumulation of an important amount of assets of uncertain quality. These assets represent one-quarter of the total amount of loans granted by commercial banks to companies (Central Bank of Tunisia, December 2005).

Besides, with the liberalization of the economy, the gradual disappearance of the monopoly has the effect of increasing the probability of vulnerability of the companies and their non-commitment to the bank. Therefore, banks have a ratio that detects the vulnerability of companies to better control credit risk.

Since the crisis of 2009, the Tunisian banking sector suffers from many economic problems. Also, “the spring Arab” and the revolution 2011 have deepened the fragility of the economic system and have added new pressure on the Tunisian economy. Also, these events have affected the indicators of economic development (Abdelli and Belhadj 2015). For example, the evolution of inflation has recorded from 4.9% in 2014 to 7.4% in November 2018 (National Institute of Statistics 2018).
Banking is a fundamental element of any economy, and particularly in linking lenders and borrowers (providers and investors). However, even in performing the role of financial intermediation, the activities of banks depend to a large extent on the stability of all financial mechanisms. It is for this reason; the latter constitutes one of the highest priorities of the public authorities. Indeed, these authorities are in a position where they are forced to organize the banking sector through specific regulations, including “prudential banking regulations”.

Thus, the Regulatory Committee focuses on researching the quality and effectiveness of banking supervision according to four different principles (Basel Committee on Banking Control 2003):

- Strengthen the security and reliability of the financial system,
- Establish minimum standards for prudential supervision,
- Disseminate and promote best banking practices and monitoring,
- Promote international cooperation in prudential supervision.

The prudential regulation applies to the control of financial risks and arises as a consequence of different crises and their impact on the solvency of financial institutions. Under the impetus of the work carried out by the supervisory authorities of several industrial countries, prudential regulation has evolved enormously over the last twenty years.

In the event of a crisis, the financial markets are no longer able to function normally and, as a result, the banks can no longer refinance and stop providing loans. Therefore, the latter will be unable to finance productive activities; consumption will decline and subsequently curb economic growth.

Indeed, for a long time, the monetary authorities have sought ways to impose prudential constraints on banking activities to formulate not only the security but also the soundness of the banking system which is at the heart of the financial system.

Prudential regulation has continued to evolve through various provisions aimed at improving or eliminating old rules or introducing new standards. The financial system is experiencing developments posing as many challenges for both credit institutions and regulators (Evanoff 2019).

Also, the various financial crises that have followed one another, as well as the recent global financial crisis, have led regulators, notably the Basel Committee, to constantly review the Basel agreements. For example, the Basel III agreement which is intended to enhance the Basel II brought new regulations to strengthen the requirement for capital and liquidity of banks while aiming to weaken the leverage. However, financial instability, regardless of the level of regulation, strongly impacts the smooth running of banking activities, including exposure to different banking risks.

To summarize the impacts of Basel regulations on risk control and balance sheet, Saidane (2011) has drawn up the following Table 1:

In the Tunisian case, it is possible to check the important investment to develop the banking sector. This country has decided to put in place payment and control strategies for the control of security and banking supervision. However, Tunisia still faces a climate of uncertainty, particularly because of the “Arab Spring” which weighs on the short-term macroeconomic prospects (World Bank 2016).
Table 1. The impacts of Basel regulations Basel I Basel II Basel III

|                                | Basel I                                                                 | Basel II                                                                 | Basel III                                                                 |
|--------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|
| The scope of the measure       | Basel I comes after a transition from a debt economy to a market       | The regulator has followed a micro-prudential approach (control of risk specific to an institution) to securing deposits | It begins a transition to a new macro-prudential logic aimed at stabilizing the financial system as a whole |
|                                | economy and deregulation of credit. It aims primarily to frame a        |                                                                        |                                                                         |
|                                | growing market activity                                                |                                                                        |                                                                         |
| Impact in terms of mastery     | - Risk of market ++                                                    | - Risk of market ++                                                    | - Risk of market +++                                                  |
| risks                          | - Risk credit +                                                        | - Risk of credit +++                                                   | - Risk of credit +++++                                                |
|                                | - Requirements of own funds +                                          | - Funding requirements own +                                           | - Requirements of own funds +++                                       |
|                                |                                                                        | - Operational risk ++                                                  | - Operational risk ++                                                 |
|                                |                                                                        |                                                                        | - Risk in liquidity +                                                 |
|                                |                                                                        |                                                                        | +++++                                                                 |
| Impact on the balance sheet    | Low impact: assets, equity, off Balance-sheet                          | Strong impact on assets                                               | Strong impact on assets and liabilities and very strong on equity and off Balance-sheet |
|                                |                                                                        |                                                                        |                                                                         |

+ Low, ++ Medium, +++ High, and ++++ Very high. (Source: Saidane 2011, P33).

For prudential rules, the law reinforces and consolidates the role of the Central Bank. The aim is to bring banks in line with international standards, particularly with the Basel II and Basel III rules. “The Central Bank has the power to subject banks and financial institutions to more stringent prudential requirements in the regulatory texts when the risk profile justifies it” (Central Bank 2017). Also, the banks are obliged to inform the Central Bank on any outsourcing or external support operation to avoid any conflict of interest and any risk of misrepresentation (Hu and Di 2019).

The new banking law also aims to fight against financial drifts and to establish the milestones of a transparent banking market and envisages measures in favor of better transparency, more competition, and better protection of the customers. Financial institutions are required to inform the Central Bank in advance of the marketing of any financial product or service or the institution of any new commission.

However, the successive financial crises confirm the inadequacy of the policies implemented. Indeed, while monetary, fiscal, structural, or exchange rate policies aim to optimize financial stability, macro-prudential policy is also an important tool for ensuring the stability of the financial system by avoiding systemic risk.

Macro-prudential policy tends to achieve a dual purpose. First, it was established to combat the “procyclicality” of financial systems. In fact, by amplifying economic cycles,
financial systems tend to underestimate risks. This situation can result, for example, in a sudden reversal of the economic cycle.

Second, the macro-prudential policy aims to maximize the resilience of the financial system, that is, its ability to shelter with financial or economic shocks even without serious repercussions. In this case, the prudential policy mainly concerns institutions whose bankruptcies or financial crises may endanger the entire financial system. This is not to prevent bankruptcy altogether, but rather to avoid it because the gravity could not be borne by the financial system (Diamond and Dybvig 1983).

The macro-prudential policy also tends to limit the phenomena of collective failures. In this context, the assessment of financial stability (Nair and Anand 2020) using macro-prudential policy tools requires three clearly defined steps: Analyze and monitor the economic and financial situation, diagnose systemic risk, and put in place appropriate response measures.

3 Model

The model presented in this section is constructed on various models. The principal features outcome from the model of Bernanke et al. (1999) and the model of Rannenberg (2016). The model includes price rigidities and financial market imperfections in the context of the financial accelerator mechanism of Bernanke et al. (1999). This mechanism captured the accumulation of risk during the expansion period and its strength in the recession in the opposite situation. To match the financial framework, the model adds the banking sector and the financial market. Taking into account the place occupied by the bank in financial stability, the model analyzes the firm’s balance sheet channel of Bernanke et al. (1999), and the bank capital channel of Badarau and Levieuge (2011, 2013) and constructed a boom-bust process inspired by Bernanke and Gertler (2000), and Svensson and Tetlow (2005). Thus, the model features a more or less standard model layout with various nominal and real frictions to which second financial friction and portfolio choice are added.

The model of Rannenberg (2016) is well suited to understand the effects of financial frictions and financial intermediation on the propagation and the exploration of demand and supply shocks. Also, it is well adapted to show the impact of negative bank capital - in the context of different value of bank leverage ratio on the dynamics of real and financial variables.

3.1 Exogenous Perturbations

The exogenous shocks follow an AR(1) process of the type:

\[ \log(\varepsilon_{zz,t}) = \rho_j \log(\varepsilon_{t-1}) + \varepsilon_{zz,t} \]

With \( \rho_j \in [0,1] \) and \( \varepsilon_t \) is independent and identically distributed with mean 0 and standard deviation equal to \( \sigma^2_{zz} \). \( \varepsilon_{zz} = \{A, \emptyset, b, z, g\} \) identifying the shock of productivity, leverage regulation, capital asset growth rate, and public spending respectively.
3.2 Calibration

The model parameters are set to broadly match the quarterly data of the Tunisian economy from 2000 Q1 to 2020 Q1. All series are referred to as the Central bank of Tunisia (CBT) and from the National Statistics Institute of Tunisia (INS).

However, if parameters cannot be available from data their value is calibrated from similar model mechanisms. Hence, the choice of parameter values that we will use for our quantitative analysis consists of two sets. The first set contains those that are often used in the relevant literature and are considered conventional values. The second set, on the other hand, is those that meant to capture the economic features of the Tunisian economy during the tested period.

We set the discount factor of households, $\beta$, at 0.983. For the retail sector, we fix, $\xi_p$ equal to 0.75, which is amply classic in the DSGE literature. This signifies an average time of four quarters. The monitoring cost, $\mu$, is set to respect the bankruptcy costs estimated by Carlstrom and Fuerst (1997). Finally, we assume that retailers have to wholly pre-finance their capital and labor costs via working capital loans, thus $\psi_k$ and $\psi_l = 1$.

The capital elasticity of output ($\alpha$), the depreciation rate of capital, $\delta$, and the elasticity of work disutility, $\varphi$, are fixed at 0.35, and 0.025 and 0.25 respectively as cited by Abdelli and Belhadj (2015).

| Parameters | Description                                             | Value   |
|------------|---------------------------------------------------------|---------|
| $\varphi$  | The elasticity of work disutility                       | 0.25    |
| $\beta$    | Subjective discount factor                              | 0.985   |
| $\mu$      | Monitoring cost                                         | 0.298   |
| $\alpha$   | The capital elasticity of output                        | 0.35    |
| $\xi_p$    | Calvo parameters                                       | 0.75    |
| $\delta$   | Capital depreciation rate                               | 0.025   |
| $\gamma_p$ | Degree of price indexation                              | 0.3     |
| $\psi_l$   | Share of wage bill that retailers finance by loan       | 1       |
| $\psi_k$   | Share of capital bill that retailers finance by loan    | 1       |
| $R^k - R$  | The spread of the loan rate to the nominal risk-free rate | 1.40%   |
| $(1 - \theta)$ | The probability of bankruptcy                           | 0.1%    |
| $N^b$      | Banks leverage ratio                                    | 1/0.125 |
| $L$        | Bank capital ratio, percent                             | 5.694%  |

Some of the parameters relating to the various frictions in the banking and entrepreneurial sector are calibrated such that the steady-state values of the key financial variables in the model match to their averages in the real data. This methodology is also applied by Rannenberg (2016), Christiano et al. (2010a, b, c), Meh and Moran (2010), and Bernanke et al. (1999), the standard deviation of an idiosyncratic productivity shock, $\sigma$, is equal to 0.35, according to Rannenberg (2016).
The leverage ratio by which Tunisian banks were subject since 1999 is set at 8%. The spread $RL - R$ is calibrated such that the quarterly interest rate margin is equal to 1.40%\(^1\). This percentage is attached to that estimated by Levin et al. (2006) for 796 firms and over the period 1997Q1–2004Q4. The target $\frac{N_b}{T}$ is calculated according to the Basel I agreement, which represents the average ratio between tangible common equity (TCE) and the total credit granted to the economy. Since the banking sector is supported by the Tunisian central bank, so, we set the probability of bank death $1 - \theta$ to 0.01%.

It is concretely supposed that firms have a higher default probability than banks, that is why we set the steady-state probability of firms failure, $1 - \gamma$ at 10%, Jouini and Rebei (2013). The share of assets delivered to the new banks, $W^b$, is set to 0.0001\(^2\). We calculate, on the same sample period, the bank capital ratio, $\frac{N_b}{T}$, with noted the average ratio between the bank net worth, available in the dataStream database, and the total debts. To correspond to the data this ratio is set to 5.694%.

For the policy rule, we following the same parameters used by Alimi et al. (2019). We set the inflation coefficient, $\psi_\pi$, equal to 1.53, the output gap coefficient, $\psi_\gamma$, equal to 0.48, and the smoothing parameters, $\rho_\gamma$, equal to 0.3.

4 Impulse Responses to Shocks and Business Cycle Amplification

In this section, we analyze the results of the model under different types of shocks. We provide how business cycle amplification is affected by the regulation in the financial sector. We adopt productivity shock as a benchmark, as it represents one of the main drivers identified by the DSGE literature on the business cycle.

4.1 Adverse Productivity Shock

We adopt productivity shock as the benchmark to analyze the key transmission mechanism at work in the model. Each variable’s response in the IRF below is presented as the percentage deviation from its steady-state, except for rate variables, which are in percentage points.

In response to adverse productivity shock, firms drop the investment demand which negatively affects their net worth. The lower investment leads to reduce global output and then aggregate consumption. To respond to this reduction, the central bank applies its policy of lowering the interest rate and makes capital less profitable. At the same time, adverse productivity shock increases inflation trough the increases in firms’ marginal costs.

Since the solvency of the firms measured by its net worth thus the reduction of this later make the firms relatively risky, this situation forces banks to tighten the conditions of the credits or to apply the credit crunch policy. In absence of regulatory constraints on the leverage ratio, this policy requires banks to fall their exposure towards the entrepreneur,

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\(^1\) The net interest rate margin presented as the cost of external finance. It’s equal to 3.9% at the end of 2018, which is equivalent to 1.40% per quarter $\left(RL - R\right)^{1/4}$ according to the report of the central bank in 2018.

\(^2\) We set $W^b$ very small to show that their value does not impact the macroeconomic dynamic.
which is riskier than retailers. The obligation to adapt to leverage regulation, instead, pushes banks to drop their asset growth to decrease loan supply, setting the stage for a regulatory trade-off (Fig. 1).

![Fig. 1. Productivity shock. Baseline impulse responses of selected key variables, with the benchmark leverage](image)

4.2 Government Spending Shock

The Tunisian state has taken drastic measures to avoid the COVID-19 pandemic. It mobilized 3 billion dinars (1 billion US $) to mitigate the impact of economic operators’ shortfall. In 2020, exceptionally, the state budget amounts to 47 billion TND (or 17 billion US $), compared to 40.861 billion TND in 2019. 6% of this budget was benefited by the Ministry of Health. Certainly, this increase would have an impact on Tunisian economic activity. In what follows we will analyze the repercussions of different economic agents following the increase in public expenditure, g, of 15.02%, which presents the policy rate, the growth rate between 2019 and 2020.

Figure 2 analyzes the impact of expansionary government policy. The dynamics of the keys variables follow the government spending increase is ambiguous: In the short term, the investment, GDP increase follow the decrease of the policy rate. This improves the Firm’s net worth, the capital price and makes entrepreneurs solvent toward the bank which increases credit. After 5 periods this effect is contradicted by the increase of
the policy rate which crowds out private investment and thus overall production. The drops of investment explain the decline of the firm’s net worth which raises the default probability and then reduces the credit return and the bank capital.

4.3 Regulation Shock

We assume that the bank leverage ratio shock follows AR(1) stochastic process with 0.2 persistence and standard deviation equal to 0.1.

The regulation shock measured in practice by the tighten leverage in the banking sector which has a positive effect on the screening effort by commercial banks, Lubellou and Rouabah (2017). The severity of the moral hazard behavior is mitigated and then the probability of offering loans to firms, which presents risky credits, decreases. A tighter leverage ratio regulation implies that banks need to increase their capital to keep loan supply unchanged. Thus, increasing filtering is the only way to ensure capital accumulates faster.

Exerting costly effort to increase capital reduces the supply of loans due to the partial ability of commercial banks to meet the regulation constraint only by increasing the filtering effort. As a consequence, the adjustment to the regulation ratio passes through
the reduction of loans to risky firms (entrepreneurs) and then reduce the non-performing loan probability (Fig. 3).

Figure 4 shows the monetary policy shocks effect, in the case where the Central bank uses the interest rate as the main instrument of the monetary policy and in the case where the Tunisian central bank introduces the macroprudential tool. In both cases, we assume that the Central Bank applies a policy of increasing the interest rate. This tightening of monetary policy has a direct effect on the net worth of large firms as the monetary policy is used as the riskless interest rate. Thus, an increase in the policy rate hurts large firms’ net worth, which worsens their ability to finance capital purchases via internal finance. As a consequence, large firms’ demand for credit to banks increases, which increases the lending rate and improves the intermediation prospects of the banking system.

To cope with the increase in the cost of funding, commercial banks increase filtring to improve the likelihood of the project to be successful. Thus, as described above, the severity of the moral hazard behavior is mitigated. For banks, this tightening increases the policy rate (deposit rate), lending spread increases, and interest revenue increases. The increase in deposits leads to a further increase in credit. Because of an increase in the policy rate, the cost of production increases, and it leads to increasing inflation. With an increase in credit, consumption rises, and GDP improves.
If the central bank of Tunisia introduces the macroprudential tool (leverage ratio tightening) in its monetary policy rule, it succeeds in ensuring financial stability, i.e., the credit market stability. As we show in the above figure, the use of a mixed policy is more adequate to mitigate credit spread volatility and to improve the bank capital. This will have a positive long-term effect on investment and GDP than the standard use of the interest rate, as the main instrument.

5 Discussion

The potential impacts of banking regulation and macro-prudential policy on financial and macroeconomic stability are not new, Saidane (2012), Rannenberg (2016), Peter and Lixn (2015), Nair and Anand (2020), Mizraei and Aguir (2020). The importance of our work in simulating a new dynamic and stochastic general equilibrium model (DSGE) adapted to the Tunisian banking sector. The model accounts for the role played by prudential regulation in correcting fluctuations in the economic cycle and restoring macroeconomic and financial stability.

First, we test the effect of the negative productivity shock on the financial and macroeconomic dynamics. The simulation shows that, on the real side, this shock increases inflation, drops the investment demand which negatively affects their net worth, and reduces the global output. This pushes the central bank of Tunisia to lower its policy rate and makes capital less profitable. On the financial side, this shock makes firms risky and forces banks to use a credit crunch policy. In absence of regulatory constraints on the leverage ratio, this policy requires banks to fall their exposure towards borrowers, which is riskier than retailers. The obligation to adapt to leverage regulation pushes
banks to drop their asset growth to decrease loan supply which has a dramatic effect on the survival of the bank. This situation encourages the central banks of Tunisia to include financial variables in its monetary policy rule or adopt a macroprudential policy to mitigate the financial market volatility and thus make real activity tend to remain more stable.

We assume that policy implemented does not simply rely on the policy rate but also a combination of macroprudential policy to suppress financial market vulnerability. The simulations prove that in the event of a restrictive monetary policy shock, the use of a mixed policy is more adequate to mitigate credit spread volatility and has a positive long-term effect on GDP than the standard use of the interest rate, as a monetary policy instrument. This concludes also that the implementation of a policy mix reduces risk appetite among Tunisian banks, which makes GDP tend to remain more stable.

6 Conclusion

The recent financial crisis and the subsequent Great Recession have changed the way of economists’ think, mostly about the importance of the banking system and its interaction with the rest of the economy. Only recent standard DSGE models have started to incorporate a fully-fledged financial sector with banks assumed to be the only financial intermediary.

In our paper, we take a step forward by examining the endogenous bank leverage ratio in the Tunisian banking system. The objective of this paper is twofold: first, we analyze the effects of a real and financial shock in the Tunisian economy. Second, we study the impact of banking regulation and macro-prudential policy on real and financial stability.

As shown under the impulse response of regulation shock, the tighten of leverage in the banking sector has a positive effect on the screening effort by banks. The severity of the moral hazard behavior is mitigated and then the probability of offering loans to firms, which presents risky credits, decreases. Increasing filtering is the only way to ensure capital accumulates faster. Exerting costly effort to increase capital reduces the supply of loans due to the partial ability of banks to meet the regulation constraint only by increasing the filtering effort. As a consequence, the adjustment to the regulation ratio passes through the reduction of loans to risky firms (entrepreneurs) and then reduce the non-performing loan probability. Which supports bank profitability and stability.

Analysis of the impulse response function of the model showed that the transmission of monetary and macroprudential policy is as follows: an increase in the policy rate hurts on large firms’ net worth, which worsens their ability to finance capital purchases via internal finance. As a consequence, large firms’ demand for credit to banks increases, which increases the lending rate and improves the intermediation prospects of the banking system.

To cope with the increase in the cost of funding, commercial banks increase filtering to improve the likelihood of the project to be successful. Thus, as described above, the severity of the moral hazard behavior is mitigated. Therefore, the macroprudential policy helps to decrease the severity of the moral hazard problem by inducing banks to rise the filtering intensity of the projects they finance.
Appendix

A Model Presentation

A.1 Households

The economy features by a representative household who is infinitely-lived and determine their consumption, $C_t$, and labor supply, $l_t$, so that to maximize its Constant Elasticity of Substitution (CES) utility function:

$$E_t \left\{ \sum_{i=0}^{\infty} \beta^i \left[ \ln(C_{t+i} - hC_{t+i-1}) - \frac{\varphi}{1 + \varphi} (l_{t+i}^r)^{1+\varphi} \right] \right\}$$ (1.1)

Where $E_t$ is the expectation operator, $\beta^i$ is the household’s subjective discount rate and $h$ denotes the degree of internal habit formation. $\varphi$ is the intertemporal elasticity associated with labor supply.

The household saves by depositing funds with banks and by buying government bonds at a nominal risk-free rate. The household is subject to the following budgetary constraint:

$$P_t C_t = w_t P_t l_t + P_t prof_t + R_{t-1} B_{t-1}^T - B_t^T - P_t T_t$$

where $P_t$, $C_t$, $w_t$, $prof_t$, and $T_t$ denote the price level, consumption, the real wage, real profits, and real lump sum taxes, respectively.

The household receives the real wage, $w_t$ from supplying labor to retailers and derive profit income from their ownership of retail firms and capital goods producers. $B_t^T$ is the financial assets (deposit and government bonds) owned by the households at the end of period $t - 1$ remunerated in period $t$ with a nominal risk-free rate, $R_{t-1}$. These revenues are exploited in the purchase of retailer goods $C_t$ at an aggregate price $P_t$, payment taxes $T_t$, and invest their financial assets.

A.2 Capital Goods Producers

Capital goods produce are owned by households. They produce new capital goods using a technology that yields

$$1 - \frac{\eta_i}{2} \left( \frac{I_{t+i}}{I_{t+i-1}} - 1 \right)^2$$

capital goods for each unit of investment expenditures $I_t$, with $\eta_i \geq 0$ denoting the curvature of the investment adjustment cost. Capital goods are sold to entrepreneurs at currency price $P_t Q_t$. The real expected profits of the capital goods producer are then given by

$$E_t \left\{ \sum_{i=0}^{\infty} \frac{Q_{t+i}}{Q_t} \beta^i I_{t+i} \left[ Q_{t+i} \left( 1 - \frac{\eta_i}{2} \left( \frac{I_{t+i}}{I_{t+i-1}} - 1 \right)^2 \right) - 1 \right] \right\}$$

$Q_t$ denotes the marginal utility of real income of the household.

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3 We assume that both assets have the same maturity and therefore they are perfectly substitutable and earn the same interest rate.
A.3 Retailers

The retailers are indexed by $i$ and produce the varieties of the products consumed. Each retailer operates under monopolistic competition and is owned by households, with the demand for its product given by

$$Y_t(i) = \left( \frac{P_t(i)}{P_t} \right)^{-\epsilon} Y_t$$

where $\epsilon > 1$ is the elasticity of substitution between different varieties. Retailers use the labor force $l_t(i)$ of the households and rent capital services $K_{st}(i)$ at the rental rate $r_t^k$ from entrepreneurs. Hence, the production of the retailer firm $i$ is as follow:

$$Y_t(i) = (K_{st}(i))^\alpha (\exp(a_t)l_t(i))^{1-\alpha}$$

Where $a_t$ is transitory productivity shock.

We assume, like Rannenberg (2016), that retail firms have to pay fractions $-\psi L$ and $\psi K$, respectively—of their expenditures for labor and capital services in advance and borrow from banks to do so. We remember that the interest rate on these loans equals the risk-free rate $R_t$. The loans are paid back at the end of period $t$. Hence, the working capital loan of retailer $i$.

$L_{rt}(i)$ is given by: $L_{rt}(i) = \psi L \cdot w L l_t(i) + \psi K \cdot r_t k K_{st}(i)$.

Retailers are subject to nominal rigidities in the form of Calvo (1983) contracts which mean that only a fraction, $1 - \xi P$, is allowed to optimize their price in a given period. The firms that are not allowed to optimize their prices index them to past inflation at a rate $\gamma P$ and the steady-state inflation rate at rate $1 - \gamma P$.

A.4 Bankers

The financial intermediation is the risk-neutral and dies with a fixed probability $1 - \theta$ after receiving the interest income on the loans, they supply in the precedent period. If banker $q$ dies, he consumes his accumulated real net worth $N_{tb}(q)$ at the end of period $t$. Dying bankers are substituted by new ones who receive a transfer $N_{nb}$ from households, which under the calibration presented very small, as Badarau and Popescu (2014).

The model assumes that Banks derive income from offering loans to nonfinancial firms. Banker attributes two kinds of credits. The first kind is a “risky inter period loans”. The $L_{et}(q)$, to entrepreneurs who need to purchase their capital stock at the period $t + 1$. These credits are due at the starting of period $t + 1$. The second kind is “risk-free intraperiod working capital loans”, $L_{rt}(q)$, to retailers who used to pay for the labor and capital services dedicated to the production at the end of period $t$.

The financial friction is introduced in the model through the fact that, after collecting deposits, the banker can distract a fraction of assets collected from the household and declare bankruptcy, if the bank is not adequately profitable (the moral hazard problem). This implies that the ability of a bank to attract deposits and to extend loans to

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4 Gertler and Karadi (2011) assume that banks derive profit by buying equity stakes, which makes them owners.
entrepreneurs is positively related to its current net worth and its expected future wealth. Therefore, the intermediaries’ leverage ratio facing an endogenous constraint. This constraint held on bank capacity to offer credit is playing an amplification role similar to the financial accelerator in the Bernanke et al. (1999) model. This problem of moral hazard only concerns the management of inter period credit and friction in a banks-entrepreneurs relationship.

Specifically, a banker can deflect a part \( 0 \leq \lambda \leq 1 \) of loans to entrepreneurs and use it. In this case, the banker declares bankruptcy and households recuperate the residual assets. This signifies that households will only make deposits if the banker has no incentive to default, that is, if \( V_{t+1}^b(q) > \lambda L_t^c(q) \), where \( V_t^b(q) \) denotes the value of banker q’s expected final wealth

\[
V_t^b(q) = E_t \left\{ \sum_{i=0}^{\infty} (1 - \theta)^i \theta^i \left( \frac{1}{\prod_{j=0}^{i} R_{t+1+j}^r} \right) N_{t+1+i}^b(q) \right\}, \quad R_{t+1}^r = \frac{R_t}{\Pi_{t+1}}
\]

In the management of intra-period credits, there is no moral hazard problem between bankers and depositors, and also no friction in the bank–retailer relationship. Hence, the equilibrium credit rate equals to the deposit rate, indicating that banks do not attract profit in this management. The intra-period credits activity thus is not affected by \( N_t^b(q) \) and \( V_t^b(q) \), and therefore does not affect on lending to entrepreneurs.

To offer credit, the bank uses its own net worth (accumulated capital), \( N_t^b(q) \), and the nominal deposits collected from households \( B_t(q) \). Hence, \( P_t L_t^c(q) = P_t N_t^b(q) + B_t(q) \).

The bank net worth is given by:

\[
P_t N_t^b(q) = \left[ R_t^b P_{t-1} L_{t-1}^c(q) - R_{t-1} B_{t-1}(q) \right] \exp(e_t^\gamma) = P_{t-1} \left[ \left( R_t^b R_{t-1} \right) L_{t-1}^c(q) + R_{t-1} N_{t-1}^b(q) \right] \exp(e_t^\gamma)
\]

Where \( R_t^b \) is the net average return the bank wins on the interperiod loan supply in period \( t-1 \). \( e_t^\gamma \) is an exogenous capital shock. The model assumes that all banks choose the identical ratio between inter period loans (loans to entrepreneurs) and their net worth.

Therefore, \( L_t^c = \varnothing_i N_t^b \), where \( \varnothing_i \) is the endogenous bank leverage. The variability \( \varnothing_i \) is crucial for the results and it presents the main parameters for the total leverage, i.e. the ratio of total loans to bank net worth \( L_t / N_t^b \).

\( N_t^b \) is composed of the net worth of bank exist in the mark at the period \( t \), \( N_{et}^b \), and net worth of new bankers, \( N_n^b \).

\[
N_t^b = N_{et}^b + N_n^b
\]

\( N_{et}^b \) is given by \( N_{et}^b = \theta z_{t-1,t} N_{t-1}^b \).

\[
Z_{t-1,t} = \frac{\left( (R_t^b - R_{t-1}) \varnothing_{t-1} + R_{t-1} \right)}{\Pi_t} \exp(e_t^\gamma)
\]

Where \( Z_{t-1,t} \) is the growth rate of the real net worth of the bankers in period \( t-1 \) and who is already in activity in period t. The consumption of bankers is given by:

\[
C_t^b = (1 - \theta) z_{t-1,t} N_{t-1}^b
\]
In the equilibrium, we assume that $\overline{V}^b_t(q) = \lambda L^e_t(q)$, and thus $\lambda$ is calibrated so that it checks this incentive compatibility constraint. If we divide both sides of the incentive constraint by $N^b_t(q)$ we obtained $\lambda \overline{\varnothing}^b_t = \frac{V^b_t}{N^b_t}$ (remember that $L^e_t = \overline{\varnothing}^b_t N^b_t$).

Where $\frac{V^b_t}{N^b_t}$, measure the bank profitability since it presents the ratio of the anticipated value of being a banker to the net worth of the bank in the period $t$. this constraint can be expressed as

$$\overline{\varnothing}^b_t = \hat{L}^e_t - \hat{\bar{N}}^b_t$$

$$\overline{\varnothing}^b_t = E_t \left\{ \theta \beta^2 Z^2 \overline{\varnothing}^b_{t+1} + \overline{\varnothing}^b R^b \left( \hat{R}^b_{t+1} - R_t \right) \right\}$$

The equation shows that the Bank leverage positively related to the anticipated sum of profit margins on loans supply in period $t$ and after $\hat{R}^b_{t+1+i} - R_{t+i}$.

A.5 Entrepreneurs

At the end of period $t$, the risk-neutral entrepreneur $j$ buys capital $K^j_t$ for price $P_t Q_t$.

In period $t+1$, the entrepreneur rents part of his capital stock to retailers at a rental rate $P_t+1 r_k t+1$ and then sells the non-depreciated capital stock at price $P_{t+1} Q_{t+1}$. The average return to capital across entrepreneurs is given by

$$R^K_t = \Pi_{t+1} \frac{r^k_{t+1} + Q_{t+1}(1-\delta)}{Q_t}$$

The gross nominal return on capital is affected by an idiosyncratic shock, $\omega^j_{t+1}$, generating a posterior heterogeneity among entrepreneurs. It presents in a log-normal distribution with mean 1, and variance $\sigma^2$. Thus, the posterior assets return of the entrepreneur are $\omega^j_{t+1} R^K_t P_t Q_t$.

To finance investment, the entrepreneur uses his net worth, $P_t N^j_t$, and the credit, $P_t L^j_t$, borrowers from the bank at a gross nominal loan rate, $R^b_t$. Where $P_t L^j_t = P_t (Q_t K^j_t - N^j_t)$. Loan and interest are repaid in period $t+1$. Therefore, there exists a threshold value, $\sigma^j_{t+1}$, below which the return to the investment project is not sufficient to refund the bank loan. This threshold is defined such thus the posterior gross return on capital is equal to the loan borrowed by the bank: $\omega^j_{t+1} R^K_{t+1} K^j_t P_t Q_t = R^b_{t+1} P_t L^j_{t+1}$.

The presence of idiosyncratic risk gives rise to asymmetric information between the borrower and the bank regarding the outcome of the investment project. The bank proceeds to a costly state verification (Townsend 1979) only if the entrepreneur defaults, that is, when $\omega^j_{t+1} < \sigma^j_{t+1}$. In this case, the bank pays a fraction, $\mu$, to check “the true value” of the borrower and which is proportional to the posterior gross return, $\mu \omega^j_{t+1} R^K_{t+1} K^j_t P_t Q_t$. 

Like the bank’s program, the model supposes that after the realization of $\omega t + 1$ RK $t + 1$, entrepreneurs die with a fixed probability $1 - \gamma$. Dying entrepreneurs consume their equity $Vt$. This assumption ensures that entrepreneurs never become fully self-financing. The fraction $1 - \gamma$ of entrepreneurs who have died are replaced by new entrepreneurs in each period who receive a transfer $W_e$ from households, which under our calibration is very small.

Following Christiano et al. (2010a, b, c), any debt contract between the entrepreneur and the bank $(Ltj, RtL)$ has to yield an expected revenue to the bank such that its expected return on these loans equals $Et Rb t + 1$. Hence, the participation constraint of banks in the market for loans to entrepreneurs is given by

$$P_t L_t^j R_t = R_{t+1}^j P_t L_t^j \int_\omega f(\omega) d\omega + (1 - \mu) R_{t+1}^K P_t Q_t K_t^j \int_\omega (\omega f(\omega) d\omega). \tag{1.2}$$

This equation shows that in expectation level the entrepreneurial sector supports all costs related with bankruptcy via the loan rate. That is, it supports a very high-interest rate which covers also the bankruptcy costs of the bank.

Rannenberg demonstrates that all entrepreneurs choose the same leverage $\phi_t = (Qt K_t)/N_t$, implying that $\omega_t^j$ is the same across all firms as well\(^5\). Up to first order, these equations give rise to a relationship between $Et R^K_t + 1/Et R^b_t + 1$ as follow:

$$E_t R^K_{t+1} - E_t R^b_{t+1} = \chi' (\hat{K}_t + \hat{Q}_t - \hat{N}_t)$$

Where $\chi' \geq 0$. Higher entrepreneurial leverage increases the probability of bankruptcy and thus expected marginal bankruptcy costs, which requires an increase in the entrepreneurial quasi-profit margin, $E_t R^K_t / E_t R^b_{t+1}$.

Finally, the total entrepreneurial net worth at the end of period $t$ consists of that part of entrepreneurial equity $V_t$ not consumed by dying entrepreneurs and a transfer from households to entrepreneurs $W_e$.

$$N_t = \gamma V_t + W_e$$

Entrepreneurial equity and consumption are given by:

$$V_t = \left[ \int_\omega f(\omega) (\omega^j R^K_t L^j_t - R^K_{t-1} L^j_{t-1}) d\omega \right] \exp(\epsilon^N_t)$$

$$C^e_t = (1 - \gamma) V_t$$

Where $\epsilon^N_t$ denotes an exogenous i.i.d. shock to aggregate entrepreneurial net worth.

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\(^5\) Refer to Rannenberg (2016), Appendix A.4 for more details on the entrepreneur’s maximization program.
A.6 Monetary Policy

The central bank determines the risk-free (nominal) interest rate following the interest feedback rule of the form:

\[ R_t - 1 = (1 - \rho_i)[R - 1 + \psi_\pi (\log(\pi_t) - \log(\pi)) + \psi_y (\log(Y_t) - \log(\bar{Y}_t)) + \rho_i (R_{t-1} - 1) + \epsilon^i_t] \]

where, \( \epsilon^i_t \) denotes an i.i.d. monetary policy shock, where \( \bar{Y}_t \) denotes the natural (flexible price equilibrium) level of GDP. \( \rho_i \) measure the interest rate smoothing, \( \psi_\pi \) and \( \psi_y \) are the coefficient associated to the deviation of the inflation from its target and to the output gap, respectively. When studying the impulse response functions, we follow a standard calibration in the literature also used by Alimi et al. (2019) and set \( \rho_i = 0.3, \psi_\pi = 1.53, \) and \( \psi_y = 0.48. \)

A.7 Market Equilibrium

The resource constraint is given by:

\[ S_t = (1 - \xi^p) \left( \frac{\Pi_t}{\Pi_t^*} \right)^\epsilon + \xi^p \left( \frac{\Pi_t}{\Pi_{t-1}^*} \right)^\epsilon S_{t-1} \]

\[ C_t^p = C_t + C_t^e + C_t^b \]

\[ Y_t = S_t \left( I_t + C_t + \frac{R^k_t}{\Pi_t} Q_{t-1} K_{t-1} \mu \int_0^{\omega_t} \omega f(\omega) d\omega \right) \]

\[ Y_t = (K_{t-1})^\alpha (A_t I_t)^{1-\alpha} \]

\[ GDP_t = I_t + C_t + G_t \]

where \( G_t \) denotes government spending (For the moment, we assume that \( G_t \) is constant, \( G_t = G) \). \( S_t \) denotes the efficiency loss arising from price dispersion (it does not appear in the first-order approximation).

The law of motion of capital is given by

\[ K_t = (1 - \delta)K_{t-1} + I_t \left[ 1 - \frac{\eta_i}{2} \left( \frac{I_{t+i}}{I_{t+i-1}} - 1 \right)^2 \right] \]

while total loans \( L_t \) are given by: \( L_t = Le_t + Lr_t \).

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