The Effects of Macroprudential Policy on the Imperfect Banking Competition

Matheus Anthony de Melo*

Abstract

This paper studies the stabilization properties of time-varying capital requirements in an environment dominated by an oligopolistic banking sector that accumulates capital subject to a leverage adequacy cost. The results indicate that the macroprudential policy can stabilize fluctuations in Brazil's business and credit cycles by controlling the loan rate and, consequently, affecting the spread in the banking system. A welfare analysis shows that welfare gains from the introduction of macroprudential policy depend on the type of shock that hits the economy, and more banking competition can amplify the benefits of macroprudential policy. The results still highlight those time-varying capital requirements should not be a substitute for monetary policy but a helpful complement to deal with financial problems or adverse sectoral shocks.

1 Introduction

After the 2008 crisis, restrictions on loans, higher borrowing costs, and financial regulation, which directly affected the credit markets, translated into distortions in the entire economy. A series of papers on the bank's role, credit risk, and bank capital in transmitting technology and financial shocks to the real economy has emerged to understand this scenario.[1] In this context, the study of macroprudential policy and its relationship with monetary policy has gained higher importance. Macroprudential policies aim to reduce the probability of a collapse of the financial system, which would substantially impact the interest rate, exchange rate, and asset prices in general, affecting the economy widely. Besides, macroprudential policies can increase the financial system's resilience by reducing the economic impact of financial crises.

According to the de Supervisión Bancaria (2011), one of the main reasons for the 2008 financial crisis was the excessive leverage of the banking sector. This scenario,

*Ph.D. in Sao Paulo School of Economics-FGV, matheus.ant92@gmail.com

[1] Gerali et al. (2010) and Meh and Moran (2010) examine the role of banking capital in amplifying the effects of various shocks. Jermann and Quadrini (2012) and Christiano et al. (2014) highlight the effects of financial shocks on macroeconomic stability.

accompanied by a destruction of bank capital, made it difficult for the banking sector to absorb losses. Besides, the crisis was amplified by a procyclical process of banks deleveraging, and the negative effects of the financial system crises have spilled over onto the real economy. To deal with the crisis, the Basel Committee introduced some fundamental reforms (Basel III) to strengthen the banking sector's supervision, regulation, and risk management. The Basel Committee also suggests building a bank capital buffer that can absorb unexpected losses in periods of economic stress when the buffer must be released. This countercyclical capital buffer also offers the additional benefit of moderating credit growth in times of no financial stress, increasing banks' leverage cost.

Our study presents a framework to analyze the consequences of introducing a specific macroprudential policy, a time-varying capital requirement, on macroeconomic and financial stability. The macroprudential approach avoids excess lending to the private sector about the economy's size to guarantee financial stability. We also studied its interaction with monetary policy in a scenario with three distinct financial frictions. First, the credit flow is intermediated by a banking sector characterized by Cornout competition, in which the spread is determined endogenously. Second, banks accumulate capital subject to bank capital adequacy cost. Third, borrowers are subject to collateral constraints.

According to Angelini et al. (2014), some countries have already started to use countercyclical capital requirements, and the macroprudential authorities are following suit since the recently approved Basel III reform provides for a countercyclical capital buffer, along with many other instruments.[2] To see how macroprudential and monetary policies are related in an environment of imperfect banking competition, we consider an economy formed by households, entrepreneurs, and imperfectly competitive banks. The entrepreneurs are restricted financially and offer their assets as collateral to obtain bank loans. Entrepreneurs have constraints that limit their ability to borrow to an expected resale value of their assets. We also assume that savers do not lend directly to borrowers but place their money in deposits at banks responsible for the loans. A few large banks dominate the banking system with market power, whereas Cournot's competition predominates. Banks are also able to accumulate capital through retained earnings.

In this context, monetary policy assumes a standard Taylor rule. Besides, we adopted a macroprudential regulator and studied how macroprudential policy affects the welfare of banks, entrepreneurs, and households depending on the type of shock.[3] We adopted time-varying capital requirement as an instrument of macroprudential policy that can affect real and financial variables regardless of monetary policy. Credit supply to the real economy is limited by the availability of bank capital (Basel regulation). Our results show that macroprudential policy efficiently combats financial and collateral shocks since welfare gains are also possible for all agents, including banks. The macroprudential policy allows banks to suffer lower costs of deviation from the optimal leverage target and recover more quickly from financial shocks. Besides, the macroprudential policy also allows

[2] See de Supervisión Bancaria (2011).

[3] The macroprudential regulator can be the Central Bank that accumulates this function.

entrepreneurs to increase their investment levels given the lower cost of credit and avoid entrepreneurs deleveraging, which brings consequences to the real side of the economy.

We calibrate the model for Brazil as an exercise to verify if an interaction between the macroprudential and monetary policy can minimize fluctuations over the business cycle in the presence of four main adverse shocks: (i) productivity, (ii) collateral, (iii) financial, and (iv) investment shocks in the economy with a banking system dominated by few large banks, and entrepreneurs financially constrained. Our results show that macroprudential policy has a redistributive effect on welfare depending on the type of shock. Banks have reduced welfare to the detriment of households and entrepreneurs for productivity and investment shocks because the macroprudential policy prevents banks' higher capital accumulation. Our findings also show that banking competition can increase the efficiency of the macroprudential policy and contribute to welfare improvement for households and entrepreneurs. With higher banking competition, the imperfect banking competition channel cannot amplify the effect of adverse shocks, and combined with the macroprudential policy in the bank stress channel (the other channel amplifies shocks), the power of banks to readjust the spread is further reduced.

The paper is organized as follows. Sections 2 describe how our paper contributes to the existing macroprudential policy literature. Section 3 describes the model. Section 4 shows the possible policy regimes. Section 5 shows the calibration for the structural parameters of the model. Section 6 shows a dynamic analysis that verifies the effects of adverse shocks (productivity, collateral, financial, and investment) on the financial and real sides of the economy, given the interaction between macroprudential and monetary policies. Section 7 brings welfare gains to agents with the introduction of macroprudential policy. Section 8 shows how banking competition could reduce fluctuations of the main variables of the model. Section 9 presents the conclusions.

2 Theoretical Reference

The literature argues that macroprudential policy must guarantee the stable provision of financial intermediation services to the economy, avoiding the cycle of expansion and retraction in credit supply. Reinhart and Rogoff (2008) and Borio and Drehmann (2009) highlight evidence that abnormal credit expansions can lead to financial crises, while Kannan et al. (2011) shows the influence of credit expansion on house and asset price crashes.[4] Several recent articles have examined financial stability issues in more standardized macroeconomic models. The literature has tried to study capital requirements as a macroprudential policy in financial stabilization, besides its interaction with the monetary policy. Kannan et al. (2012) and Angeloni and Faia (2013) are the first to analyze this interaction, introducing capital ratios as a policy tool into a DSGE model. Kannan et al. (2012) show that strong monetary policy reactions to accelerating mechanisms

[4] Reinhart and Rogoff (2008) study crises in the USA, Finland, Japan, Norway, Spain, and Sweden while Borio and Drehmann (2009) focus on a larger series of countries.

that drive the growth of credit and housing prices can help macroeconomic stability. A macroprudential instrument designed specifically to absorb credit market cycles would also provide stabilization benefits when an economy faces shocks in the financial sector or demand for housing. Angeloni and Faia (2013) studies the role of banks in transmitting shocks, the effects of monetary policy when banks expose to runs, and the interaction between monetary policy and capital requirements. The best policy combination includes slightly countercyclical minimum capital and monetary policy response to asset prices or bank leverage.

A number of other articles such as N'Diaye (2009), Covas and Fujita (2009), Beau et al. (2012) and Lambertini et al. (2013) focus on various macroprudential instruments and address the effectiveness of the interaction between monetary and macroprudential policies. N'Diaye (2009)'s results suggest that binding countercyclical macroprudential regulations may help reduce output fluctuations and decrease the risk of financial instability. Countercyclical capital adequacy rules may allow monetary authorities to achieve the same output and inflation objectives but with minor adjustments in interest rates. This context would help contain fluctuations in asset prices, reduce the process of financial acceleration, and reduce the risks of financial instability.

In that same sense, Covas and Fujita (2009) quantifies the procyclical effects of bank capital requirements in a general equilibrium model where financing the production of capital goods is subject to an agency problem. The authors find that output fluctuation is smaller in economies that use capital requirements that vary over time.[5] Beau et al. (2012) shows how macroprudential policy interactions may affect the conduct and performance of monetary policy besides the potential conflicts, and discuss the constitution of the institutions responsible for macroprudential policy in the USA and Europe. The authors find that the macroprudential authority can combat the propagation of destabilizing shocks in asset prices and credit supply over the real economy. Lambertini et al. (2013) highlight potential gains from the interaction between monetary and macroprudential policies that lean against housing prices and credit cycles. In many of these articles, the extent to which macroprudential policies are effective depends on several factors, including how monetary policy handles.

Other articles such as Cecchetti and Kohler (2012), and Quint and Rabanal (2013) show that macroprudential policy can stabilize the economy beyond what can be achieved by monetary policy. However, this depends on the type of shock, the setup, or the parameter values. Besides, they highlight the risk of conflict between the two policies in the absence of coordination. Cecchetti and Kohler (2012) emphasize that the objectives of the macroprudential policy are to reduce the frequency and severity of financial crises. The authors study how capital adequacy requirements and interest rates can be substitutes in fulfilling the objective of stabilizing the economy. The authors show that these tools are substitutes for consolidating conventional monetary policy objectives. They also show

[5]This problem characterizes by the interaction between entrepreneurs' moral hazard and the provision of liquidity by banks as analyzed by Holmström and Tirole (1998).

that both can be used to meet financial stability objectives. Quint and Rabanal (2013) study the ideal combination of macroprudential and monetary policies in an estimated model for the euro area. The model includes real, nominal, and financial frictions. Therefore both monetary and macroprudential policy can play an important role. Introducing a macroprudential rule would reduce volatility, improve welfare, and partially replace the shortage of national monetary policies. The macroprudential policy would also increase savers' welfare, but its effects on borrowers depend on the economy's shock.

Our model is based in Angelini et al. (2014), but it has many modifications. Angelini et al. (2014) presents a framework to analyze the consequences of a specific type of macroprudential policy, capital requirements that vary over time, on macroeconomic stability. The authors also study the interaction of macroprudential and monetary policies to minimize cyclical fluctuations. Angelini et al. (2014) uses a dynamic stochastic general equilibrium (DSGE) model with a monopolistic banking system based on Gerali et al. (2010). The banking system is realistic enough to allow capital requirements to affect real and financial variables independently of monetary policy. Credit supply to the real economy is limited by the availability of bank capital (Basel agreements) accumulated from retained earnings. There are two cases of interaction between monetary and macroprudential policies: (i) cooperative, and the policy rules are implemented together to minimize a common loss function, and (ii) non-cooperative, each policy rule minimizes its loss function. Angelini et al. (2014) results suggest that when supply shocks influence economic dynamics, the use of capital requirements has a small effect on output volatility and inflation. However, for financial shocks, the macroprudential policy reduces output volatility independently of cooperation with monetary policy.

In our model, different than Angelini et al. (2014), few large banks dominate the banking system under Cournot competition. Banks accumulate a capital from retained earnings and use their capital with deposits to finance new loans to entrepreneurs. Banks pay a cost when they deviate from the optimal leverage target and can readjust the spread through imperfect banking competition and bank stress channels. The macroprudential policy acts on the bank stress channel, preventing banks from amplifying the effects of adverse shocks when they pass through this channel. Macroprudential policy efficiently reduces output fluctuations generated by financial and collateral shocks. For these shocks, banks can recover more quickly in the presence of capital requirements that vary over time. The macroprudential policy reduces spread fluctuations, which generates a lower cost of credit and a faster recovery of the entire economy.

3 Model

The model comprises six agents: households, entrepreneurs, capital producers, retailers, commercial banks, and the Central Bank.

3.1 Households

Households consume c and work l. Households are providers of homogeneous labor services that are sold to entrepreneurs. The entrepreneurs fix nominal wages w. The representative household maximizes the following utility function:

$$\max_{\{c_t,l_t\}} \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left[\ln(c_{t+s}) + \phi_l \ln(1 - l_{t+s})\right] \tag{1}$$

which depends on consumption c_{t+s}, labor supply l_{t+s}, and the relative utility weight of leisure time ϕ_l, with $\beta \in (0, 1)$ being the subjective discount factor. The household maximization problem is subject to the following budget constraint in real terms:

$$c_t + d_t = \frac{R^d_{t-1} d_{t-1}}{\pi_t} + w_t l_t + \Gamma^{CP}_t + \Gamma^R_t \tag{2}$$

where $\pi_t \equiv \frac{p_t}{p_{t-1}}$ denotes the inflation rate, d_t is the deposit of the households, R^d_t is the interest rate on the deposits, Γ^{CP}_t and Γ^R_t are lump-sum aggregate profits from capital producers and retailers sectors, respectively. The first-order conditions of this problem can be expressed as:

$$\lambda_t = \frac{1}{c_t} \tag{3}$$

$$\lambda_t w_t = \frac{\phi_l}{(1 - l_t)} \tag{4}$$

$$\lambda_t = \beta \mathbb{E}_t \left[\lambda_{t+1} \frac{R^d_t}{\pi_{t+1}}\right] \tag{5}$$

where the equation (5) is the intertemporal Euler equation can also be written as:

$$1 = \mathbb{E}_t \left[\Lambda_{t,t+1} \frac{R^d_t}{\pi_{t+1}}\right] \tag{6}$$

which $\Lambda_{t,t+1} = \beta \frac{\lambda_{t+1}}{\lambda_t} = \beta \frac{u'(c_{t+1})}{u'(c_t)} = \beta \frac{c_t}{c_{t+1}}$ is the stochastic discount factor in period t for real payoffs in period $t + 1$, with $u(c_t) = \ln(c_t)$.

3.2 Entrepreneurs

The utility of entrepreneurs depends on consumption c^E_t:

$$\mathbb{E}_t \sum_{s=0}^{\infty} (\beta^E)^s \ln\left(c^E_{t+s}\right) \tag{7}$$

where β^E is the discount factor. Entrepreneurs maximize their lifetime utility subject to the following budget constraint:

$$c_t^E + w_t l_t + q_t k_t + \frac{R_{t-1}^b b_{t-1}}{\pi_t} = \frac{y_t^w}{x_t} + q_t(1-\delta)k_{t-1} + b_t \tag{8}$$

where δ is the depreciation rate of physical capital, q_t is the price of physical capital, R_t^b is the interest rate on loans b_t and $\frac{1}{x_t}$ is the price of the wholesale good y_t^w produced in period t using Cobb-Douglas production technology with constant-returns-to-scale:

$$y_t^w = z_t k_{t-1}^{\alpha} l_t^{1-\alpha} \tag{9}$$

which productivity z_t follows an AR(1) process:

$$\ln(z_t) = \psi_z \ln(z_{t-1}) + \varepsilon_t^z \tag{10}$$

where $\psi_z \in (0,1)$ is the persistence of process z_t, and ε_t^z is a productivity shock with variance σ_z^2. Entrepreneurs are also subject to the borrowing constraint:

$$b_t \leq m_t^k \mathbb{E}_t \left[\frac{q_{t+1}(1-\delta)k_t \pi_{t+1}}{R_t^b} \right] \tag{11}$$

where m_t^k is the pledgeability ratio, and the term in brackets represents the value of the entrepreneurs' collateral given by the market value of the physical capital k_t. Assuming that physical capital k_t can be used as collateral assets, let $m_t^k \in (0,1)$ denote the fraction of physical capital collateral that banks can confiscate if entrepreneurs fail to repay their loans. The pledgeability ratio m_t^k is subject to the collateral shock and follows an AR(1) process:

$$\ln\left(m_t^k\right) = \psi_{m^k} \ln\left(m_{t-1}^k\right) + \varepsilon_t^{m^k} \tag{12}$$

where ψ_{m^k} indicate the persistence of process m_t^k, and $\varepsilon_t^{m^k}$ is a collateral shock with variance $\sigma_{m^k}^2$. The first-order conditions of this problem are:

$$\lambda_{1,t}^E = \frac{1}{c_t^E} \tag{13}$$

$$w_t = (1-\alpha)\frac{y_t^w}{x_t l_t} \tag{14}$$

$$\lambda_{2,t}^E = \lambda_{1,t}^E - \beta^E \mathbb{E}_t \left[\lambda_{1,t+1}^E \frac{R_t^b}{\pi_{t+1}} \right] \tag{15}$$

$$\lambda_{1,t}^E q_t = \beta^E \mathbb{E}_t \left[\lambda_{1,t+1}^E \left(\alpha \frac{y_{t+1}^w}{x_{t+1} k_t} + (1-\delta) q_{t+1} \right) \right] + \lambda_{2,t}^E \mathbb{E}_t \left[\frac{m_t^k (1-\delta) q_{t+1} \pi_{t+1}}{R_t^b} \right] \tag{16}$$

Combining the equations (13) and (15), we get the following expression in the steady-state:

$$\lambda_2^E = \frac{1}{c^E}\left(1 - \beta^E \frac{R^b}{\pi}\right) \tag{17}$$

To ensure that the borrowing constraint is always binding in the steady-state, λ_2^E must be positive, which implies $\beta^E < \beta$. The heterogeneity in the β and β^E guarantees that entrepreneurs are net borrowers in the steady-state.[6] The entrepreneur's net worth n_t in period t after the productivity shock has been realized and the output y_t^w produced is defined by:

$$n_t = \frac{y_t^w}{x_t} - w_t l_t + q_t(1-\delta)k_{t-1} - \frac{R_{t-1}^b b_{t-1}}{\pi_t} \tag{18}$$

where $q_t(1-\delta)k_{t-1}$ is the total value of the capital stock and $\frac{R_{t-1}^b b_{t-1}}{\pi_t}$ is the loan interest payment at the beginning of period t. Then, the c_t^E can be written in terms of n_t:

$$c_t^E + q_t k_t = n_t + b_t \tag{19}$$

which implies that the entrepreneurs finance consumption c_t^E and the purchase of new capital k_t through bank loans b_t and retained earnings n_t. Under the assumption of log utility, c_t^E is a fixed proportion of the accumulated profits n_t:

$$c_t^E = (1-\beta^E)n_t \tag{20}$$

Note that the binding borrowing constraint (11) determines the entrepreneur's loan demand, and it implies the inverse relation between the equilibrium loan rate R_t^b and loan quantity b_t. In the perfect banking competition scenario, loan rate R_t^b is given by the gross deposit rate R_t^d, thus b_t is determined. With imperfect banking competition, each bank determines the amount of b_t and consequently affects the R_t^b. In particular, for a given asset prices q_{t+1} and π_{t+1}, a higher loan rate R_t^b corresponds to a lower loan quantity b_t.

3.3 Capital Producers

The perfectly competitive capital producers buy non-depreciated capital from entrepreneurs and also buy final consumption good i_t from retail firms to produce new capital k_t at the end of period t:

$$k_t = i_t + (1-\delta)k_{t-1} \tag{21}$$

where i_t is also a gross investment. The activity of capital producers increases the physical capital stock k_t, which is then sold back to entrepreneurs with a price q_t at the end of the period. Following Christiano et al. (2005), assume that old capital can be converted into new capital at a one-to-one rate subject to a quadratic investment adjustment cost

[6] In the literature, its standard approach to assume $\beta^E < \beta$ to ensure that the borrowing constraint permanently binds in the steady-state and its neighborhood, as long as the size of shocks are sufficiently small (Iacoviello (2005), Gerali et al. (2010), Andrés and Arce (2012)).

$f\left(\frac{i_t}{i_{t-1}}\right) = \frac{\chi}{2}\left(\frac{i_t s_t^{qk}}{i_{t-1}} - 1\right)^2$. Besides, $\chi > 0$ reflects the magnitude of the adjustment cost, and s_t^{qk} is the total factor productivity of the investment i_t that follows an autoregressive AR(1):

$$\ln\left(s_t^{qk}\right) = \psi_{s^{qk}} \ln\left(s_{t-1}^{qk}\right) + \varepsilon_t^{qk} \tag{22}$$

where $\psi_{s^{qk}}$ measures the degree of persistence of s_t^{qk} and ε_t^{qk} is a investment productivity shock with variance $\sigma^2_{s^{qk}}$. The capital producers' optimization problem can be written as:

$$\begin{aligned} \max_{\{i_t, k_t\}} \quad & \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda_{t,t+s} \left[q_t k_t - q_t(1-\delta)k_{t-1} - i_t - \frac{\chi}{2}\left(\frac{i_t s_t^{qk}}{i_{t-1}} - 1\right)^2 i_t \right] \\ \text{s.t.} \quad & k_t = (1-\delta)k_{t-1} + i_t \end{aligned} \tag{23}$$

where $\Lambda_{t,t+s} \equiv \beta^s \frac{u'(c_{t+s})}{u'(c_t)}$ is the stochastic discount factor since the households own capital producers. The capital producer's problem returns the following relation to the capital price q_t taking the first-order condition concerning i_t:

$$q_t = 1 + \frac{\chi}{2}\left(\frac{i_t s_t^{qk}}{i_{t-1}} - 1\right)^2 + \chi\left(\frac{i_t s_t^{qk}}{i_{t-1}} - 1\right)\left(\frac{i_t}{i_{t-1}}\right) s_t^{qk} \tag{24}$$

$$-\chi \mathbb{E}_t \left\{ \Lambda_{t,t+1} \left(\frac{i_{t+1} s_{t+1}^{qk}}{i_t} - 1\right)\left(\frac{i_{t+1}}{i_t}\right)^2 s_{t+1}^{qk} \right\} \tag{25}$$

All profits Γ_t^{CP} made outside the steady-state ($q \neq 1$) by capital producers sector return to households where $\Gamma_t^{CP} = (q_t - 1)i_t - \frac{\chi}{2}\left(\frac{i_t s_t^{qk}}{i_{t-1}} - 1\right)^2 i_t$.

3.4 Retailers

The retailers are assumed to be monopolistically competitive. Retailers buy wholesale good $y_t^w(i)$ from entrepreneurs at wholesale price $p_t^w(i)$ and differentiate it at no cost. Each retailer i then sells its unique variety $y_t(i)$ at nominal price $p_t(i)$, applying a markup $x_t(i) = \frac{p_t(i)}{p_t^w(i)}$ on the wholesale price. The output of the final consumption good y_t is a constant elasticity of substitution (CES) composite of all the different varieties produced by the retailers (using the Dixit and Stiglitz (1977) framework):

$$y_t = \left[\int_0^1 y_t(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}} \tag{26}$$

where $\epsilon > 1$ is the elasticity of intertemporal substitution between different varieties. Retailers' prices are sticky and indexed to a combination of past and steady-state inflation. Then, retailers must choose $\{p_t(i)\}_{t=0}^{\infty}$ to maximize profits given by:

$$\Gamma^R = \mathbb{E}_t \sum_{t=0}^{\infty} \Lambda_{t,t+s} \left[p_t(i)y_t(i) - p_t^w(i)y_t(i) - \frac{\kappa_\pi}{2}\left(\frac{p_t(i)}{p_{t-1}(i)} - \pi_{t-1}^{\iota_p}\overline{\pi}^{1-\iota_p}\right)^2 p_t y_t \right] \tag{27}$$

subject to a downward sloping demand coming from consumers' maximization of a consumption aggregator:

$$y_t(i) = y_t \left(\frac{p_t(i)}{p_t}\right)^{-\epsilon} \tag{28}$$

where κ_π is a quadratic adjustment cost for change prices beyond what indexation determines. In symmetrical equilibrium, $p_t(i) = p_t$, the first-order conditions imply at Phillips curve, given by:

$$\frac{\epsilon_t^y}{x_t} - \kappa_\pi \left(\pi_t - \pi_{t-1}^{\iota_p}\overline{\pi}^{1-\iota_p}\right)\pi_t + \beta\mathbb{E}_t\left[\Lambda_{t,t+1}\kappa_\pi\left(\pi_{t+1} - \pi_t^{\iota_p}\overline{\pi}^{1-\iota_p}\right)\pi_{t+1}^2\frac{y_{t+1}}{y_t}\right] = \epsilon_t^y - 1 \tag{29}$$

where $\Lambda_{t,t+s} = \beta^s \frac{u'(c_{t+s})}{u'(c_t)}$ is the stochastic discount factor since households own retail firms, and $x_t = \frac{p_t(i)}{p_t^w(i)} = mc_t(i)$ is the markup of the final good price.

3.5 Banks

The Cournot banking sector is used to characterize oligopolistic competition and capture banks' market power once the banking sector tends to be dominated by a few prominent players that accumulate capital.[7] Assume there are N banks in the economy, indexed by j. Banks have market power in conducting their intermediation activity, allowing them to adjust loan rates in response to adverse shocks. Commercial banks play an essential role in our model, as they act as intermediaries for all financial transactions between agents in the economy and obey the following balance-sheet identity:

$$b_t(j) = d_t(j) + k_t^B(j) \tag{30}$$

where loans b are equal to deposits d plus bank capital k^B.[8] Banks aim to keep the capital-to-loans ratio $\frac{k^B}{b}$ close to an optimal target τ_t^B, which we interpret as a capital requirement imposed by the regulatory authority.[9] We introduced a time-varying capital requirement ratio τ_t^B, which will be the main instrument of macroprudential policy:

$$\Omega_t(j) = \frac{\kappa_{k^B}}{2}\left(\frac{k_t^B(j)}{b_t(j)} - \tau_t^B\right)^2 k_t^B(j) \tag{31}$$

where κ_{k^B} is the magnitude of the cost Ω that banks pay if they deviate from the leverage target τ_t^B.[10] Thus, the bank capital in period t is accumulated from the retained earnings Γ_t^B discounted by the payment of dividends div_t^B plus the bank capital of the previous

[7]Bank capital can be thought of as bank assets, as Gerali et al. (2010).

[8]The two sources of finance are perfect substitutes for the banks' balance.

[9]The optimal target τ_t^B can also be considered as a minimum requirement that the bank maintains for precautionary reasons.

[10]The capital requirement τ^B incorporates in the model the accelerator mechanism described by Adrian and Shin (2010), which played an essential role in the 2008 crisis.

period k_{t-1}^B:

$$k_t^B(j) = (1-\delta^B)\frac{k_{t-1}^B(j)}{s_t^{k^B}} + \Gamma_t^B(j) - div_t^B(j) \tag{32}$$

where δ^B is the bank operation cost, and the retainer earnings Γ_t^B can be written as:

$$\Gamma_t^B(j) = \frac{1}{\pi_t}\left[R_{t-1}^b\left(b_{t-1}(j) + \sum_{m\neq j} b_{t-1}(m)\right)b_{t-1}(j) - R_{t-1}^d d_{t-1}(j) - \Omega_{t-1}^B(j)\right] \tag{33}$$

which dependence of the loan rate R^b on loans b means that each bank j has specific control over the equilibrium gross loan interest rate by changing its quantity of $b_t(j)$ given the other amount of $b_t(m)$ granted by banks $m \neq j$ in the banking system with Cournot structure. The bank capital accumulation (32) is subject to a unexpected financial shock $s_t^{k^B}$ that follows an autoregressive AR(1):

$$\ln\left(s_t^{k^B}\right) = \psi_{s^{k^B}} \ln\left(s_{t-1}^{k^B}\right) + \varepsilon_t^{k^B} \tag{34}$$

where $\varepsilon_t^{k^B}$ is the financial shock with variance $\sigma_{k^B}^2$. In the otimization bank's problem, each bank j maximizes the sum of the present discounted value of future dividends (35) subject to bank capital accumulation law (32) and $b(j), div(j) \geq 0$:

$$\max_{\{b_t(j), k_t^B(j), div_t^B(j)\}} \mathbb{E}_t \sum_{s=0}^{\infty} \Lambda_{t,t+s}[\ln\left(div_{t+s}^B(j)\right)] \tag{35}$$

where $\Lambda_{t,t+s} = \beta^s \frac{u'(c_{t+s})}{u'(c_t)}$ is the stochastic discount factor, since households own the banks. Solving the banks' problem maximization concerning $b(j)$, we found the following expression:

$$\mathbb{E}_t\Lambda_{t,t+1}\left\{\frac{\lambda_{t+1}^B(j)}{\pi_{t+1}}\left[\frac{\partial\Omega_t^B(j)}{\partial b_t(j)} - \left(\frac{\partial R_t^b}{\partial b_t(j)}b_t(j) + R_t^b - R_t^d\right)\right]\right\} = 0 \tag{36}$$

In a Cournot equilibrium, the total optimal loan quantity is $b_t = b_t(j) + \sum_{m\neq j} b_t(m)$ and the total optimal bank capital is $k_t^B = k_t^B(j) + \sum_{m\neq j} k_t^B(m)$. Assuming banks are identical, then $b(j) = \frac{b_t}{N}$, $k_t^B(j) = \frac{k_t^B}{N}$, and $\frac{\partial R_t^b}{\partial b_t(j)} = \frac{\partial R_t^b}{\partial b_t}\frac{\partial b_t}{\partial b_t(j)} = \frac{\partial R_t^b}{\partial b_t}$ in Cournot equilibrium, the first-order condition (36) can be written as:

$$\mathbb{E}_t\Lambda_{t,t+1}\left\{\frac{\lambda_{t+1}^B}{\pi_{t+1}}\left[\frac{\partial\Omega_t^B}{\partial b_t} - \left(\frac{\partial R_t^b}{\partial b_t}\frac{b_t}{N} + R_t^b - R_t^d\right)\right]\right\} = 0 \tag{37}$$

The loan rate directly affects market loan demand b_t because an increase in R_t^b reduces the entrepreneurs' borrowing capacity. Furthermore, the loan rate also has an indirect effect on loans taken by borrowers, influencing the entrepreneur's demand for physical capital.[11] When bank j chooses $b_t(j)$ to maximize dividends, it needs to consider how entrepreneurs would respond by changing their demand for physical capital $\frac{\partial k_t}{\partial R_t^b}$ that

[11] It can be seen by the equation (16).

affects the level of investments in the economy. The entrepreneurs' demand for physical capital decreases in the loan rate because $\frac{\partial k_t}{\partial R_t^b} < 0$ and the interest rate elasticity of capital demand $PEK_t \equiv -\frac{\partial k_t}{\partial R_t^b}\frac{R_t^b}{k_t}$ monotonically decreases in the expected marginal product of capital:

$$PEK_t = \frac{1}{1-\alpha}\left(\frac{m_t^k \mathbb{E}_t\left[\frac{q_{t+1}(1-\delta)\pi_{t+1}}{R_t^b}\right]}{\mathbb{E}_t\left[\Lambda_{t,t+1}^E MPK_{t+1}\right]}\right) \tag{38}$$

where $MPK_{t+1} \equiv \frac{\alpha z_{t+1}(k_t)^{\alpha-1}(l_{t+1})^{1-\alpha}}{x_{t+1}}$ is the marginal product of capital in real terms. The entrepreneur's loan demand elasticity PED_t captures their dependency on the capital demand elasticity PEK_t, given by:

$$PED_t \equiv -\frac{\partial b_t}{\partial R_t^b}\frac{R_t^b}{b_t} = 1 + PEK > 0 \tag{39}$$

Solving the first order condition (37), it is possible to find the following expression for the loan interest rate R_t^b, with $\Lambda_{t,t+1} > 0$ and $\pi_{t+1} \equiv \frac{p_{t+1}}{p_t} > 0$:

$$R_t^b = \frac{R_t^d - \kappa_{k^B}\left(\frac{k_t^B}{b_t} - \tau_t^B\right)\left(\frac{k_t^B}{b_t}\right)^2}{\left(1 - PED_t^{-1}\frac{1}{N}\right)} \tag{40}$$

where N is the number of banks and κ_{k^B} is the bank's capitalization cost. From equation (40), the R_t^b decreases in the number of banks N (more banking competition) and in the elastic PED_t, entrepreneurs respond quickly to increased loan interest rate and reduce the amount of loans b_t demanded, forcing the banks to charge a lower R_t^b. Modeling the leverage level of banks (and their capital accumulation) allows us to introduce shocks that originate on the credit supply side and, thus, study their effects on setting loan rates subject to capital requirements and its propagation in the real economy. In particular, we can check the impact of a weakening in the balance sheet position of the Cournot banking sector, arising from an exogenous shock that destroys banking capital.

3.6 Equilibrium

Equilibrium was imposed on deposit and loan markets, and the aggregate resource constraint is:

$$c_t + c_t^E + i_t + div_t^B + \frac{\kappa_\pi}{2}(\pi_t - \overline{\pi})^2 y_t + \frac{\chi}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 i_t + \frac{\kappa_{k^B}}{2}\left(\frac{k_t^B}{b_t} - \tau_t^B\right)^2 k_t^B = y_t \tag{41}$$

The new capital supplied by capital producers equals entrepreneurs' capital demand, and the labor supplied by households equals entrepreneurs' labor demand. The Cournot equilibrium of banking sector can be written as $b_t^B = \sum_{j=1}^N b_t(j)$, $d_t^B = \sum_{j=1}^N d_t(j)$ and

$k_t^B = \sum_{j=1}^{N} k_t^B(j)$, where the supply of loans from the banking sector b_t^B equals market loan demand b_t, demand for deposits from the banking sector d_t^B equals the supply of deposits from households d_t, and the banking system capital k_t^B is equal to the sum of the N banks' capital. From equation (30), the total loan supply b_t^B equals the total deposit holding in the banking system plus the total capital accumulated k_t^B in the banking sector, $b_t^B = d_t^B + k_t^B$.

4 Policy Regimes

Two types of policy interventions are possible. First, monetary policy has real effects due to sticky prices. Second, we assume that macroprudential authority can affect the spread by imposing additional capital requirements or provisions when credit growth is above its steady-state value. In our model, monetary policy is kept fixed over time. We will see the effects of introducing the macroprudential policy in an imperfect banking competition environment where banks can accumulate capital subject to adequacy costs and capital requirements that vary over time.

4.1 Monetary Policy

We assume that the Central Bank instrument can be modeled via the Taylor rule with the following specification:

$$R_t = (1-\rho_r)\overline{R} + (1-\rho_r)[\phi_\pi(\pi_t - \overline{\pi}) + \phi_y(y_t - \overline{y})] + \rho_r R_{t-1} \tag{42}$$

where ϕ_π and ϕ_y measure, respectively, the response to inflation and output deviations from its targets, and ρ_r is the persistence in the interest rate adjustment.

4.2 Macroprudential Policy

In line with Angelini et al. (2014), we assume that macroprudential authorities react to abnormal credit behavior since one of the objectives of macroprudential policy is to guarantee the financial system's resilience. We take time-varying capital requirements as the macroprudential instrument for two main reasons. First, banking capital has occupied the debate on regulatory reform, and the Basel III package has recently introduced a countercyclical capital requirement. Second, systemic financial crises directly or indirectly affect banking capital and credit supply. We assume that the macroprudential authority defines a time-varying capital requirement rule such as:

$$\tau_t^B = (1-\rho_{\tau^B})\overline{\tau}^B + (1-\rho_{\tau^B})\left[\chi_{\tau^B}\left(\frac{b_t}{y_t} - \frac{\overline{b}}{\overline{y}}\right)\right] + \rho_{\tau^B}\tau_{t-1}^B \tag{43}$$

where $\overline{\tau}^B$ is the steady-state value of τ_t^B. In the baseline specification of equation (43), we assume that the macroprudential authority adjusts capital requirements only in response to movements in the loans-to-output ratio.[12] As the macroprudential instrument affects lending rates, policymakers can directly offset fluctuations in spread caused by adverse shocks.

5 Calibration

The parameters calibrated in the model are adjusted to represent the Brazilian economy. The parameter calibration not found to Brazil is calibrated according to the strategy of Gerali et al. (2010), Angelini et al. (2014) and Li (2019). The calibration information is summarized in Table 1. Subjective discount factors are chosen as 0.989 for saving households and 0.97 for borrowing entrepreneurs, following De Castro et al. (2015) and Gerali et al. (2010). The weight of leisure-time ϕ_l in the household's utility function is 1.8. In the production sector, the depreciation rate δ for physical capital is chosen to be 0.015 and the capital share α is 0.44, according to De Castro et al. (2015). The elasticity of substitution between retail goods ϵ is set to 6, following Li (2019), to generate a 20% final good price markup, a value frequently used in the literature.

We estimate a value of 5.02 for the investment adjustment cost χ to Brazil from 2000 to 2019. Other parameters are estimated for the same period. The price adjustment cost κ_π equal to 86.35 and prices indexation ι_p equal to 0.73 to the Phillips curve. We define a number of banks N equal to 5 to represent the five largest Brazilian banks. The cost of managing the bank capital δ^B is 0.09, and the optimal leverage target τ^B is 0.16 (in the absence of macroprudential policy), following Ferreira et al. (2015). We estimated a value of 22.19 for the banks' capitalization cost κ_{k^B} for Brazil from 2000 to 2019.

[12] According to the cited elements of the Basel III regulation.

Table 1: Calibrated parameters

Parameters	Value	Description
Households		
β	0.989	Subjective discount factor
ϕ_l	1.8	Relative utility weight on leisure time
Entrepreneurs		
β^E	0.97	Subjective discount factor
α	0.44	Physical capital share
δ	0.015	Depreciation rate for physical capital
Capital producers		
χ	5.02	Investment adjustment cost
Retailers		
ϵ	6	Elasticity of substitution between retail goods
κ_π	86.35	Prices adjustment cost
ι_p	0.73	Indexation prices
Banks		
N	5	Number of banks
δ^B	0.09	Cost of managing the position of bank capital
$\overline{\tau}^B$	0.16	Target for the capital-to-loans ratio
κ_{k^B}	22.19	Bank capital adjustment cost
Taylor rule		
ρ_r	0.62	Persistence of the interest rate
ϕ_π	1.56	Inflation feedback parameter
ϕ_y	0.33	Output feedback parameter
Macroprudential policy		
χ_{τ^B}	0.5	Loans-to-output feedback parameter
ρ_{τ^B}	0.9	Persistence of the capital requirements
AR coefficients		
ψ_z	0.919	Productivity
ψ_k	0.391	Collateral
ψ_{qk}	0.404	Investment
ψ_{k^B}	0.903	Financial
Shocks: standard deviations		
σ_z	0.01	Productivity
σ_k	0.01	Collateral
σ_{qk}	0.01	Investment
σ_{k^B}	0.01	Financial

About the monetary policy parameters, we estimate the inflation and output response parameters as $\phi_\pi = 1.56$ and $\phi_y = 0.33$, and the parameter that measures the monetary policy persistence, $\rho_r = 0.62$. The persistence parameter of macroprudential policy and feedback parameter of loans-to-output ratio are calibrated as Angelini et al. (2014) with values $\rho_{\tau^B} = 0.9$ and $\chi_{\tau^B} = 0.5$, respectively. The positive coefficient for χ_{τ^B} means the macroprudential policy is countercyclical, i.e., the capital requirements are increased when there is an expansion of credit in the economy. We use Brazil's estimated values for the shock's persistence parameters. We consider four adverse shocks: productivity, collateral, financial, and investment. However, we use the smallest standard deviation for the shocks, in line with Angelini et al. (2014), to see the impact of macroprudential policy on the agent's welfare gains and the fluctuations of the main variables of the model.

6 Interaction between Monetary and Macroprudential Policies

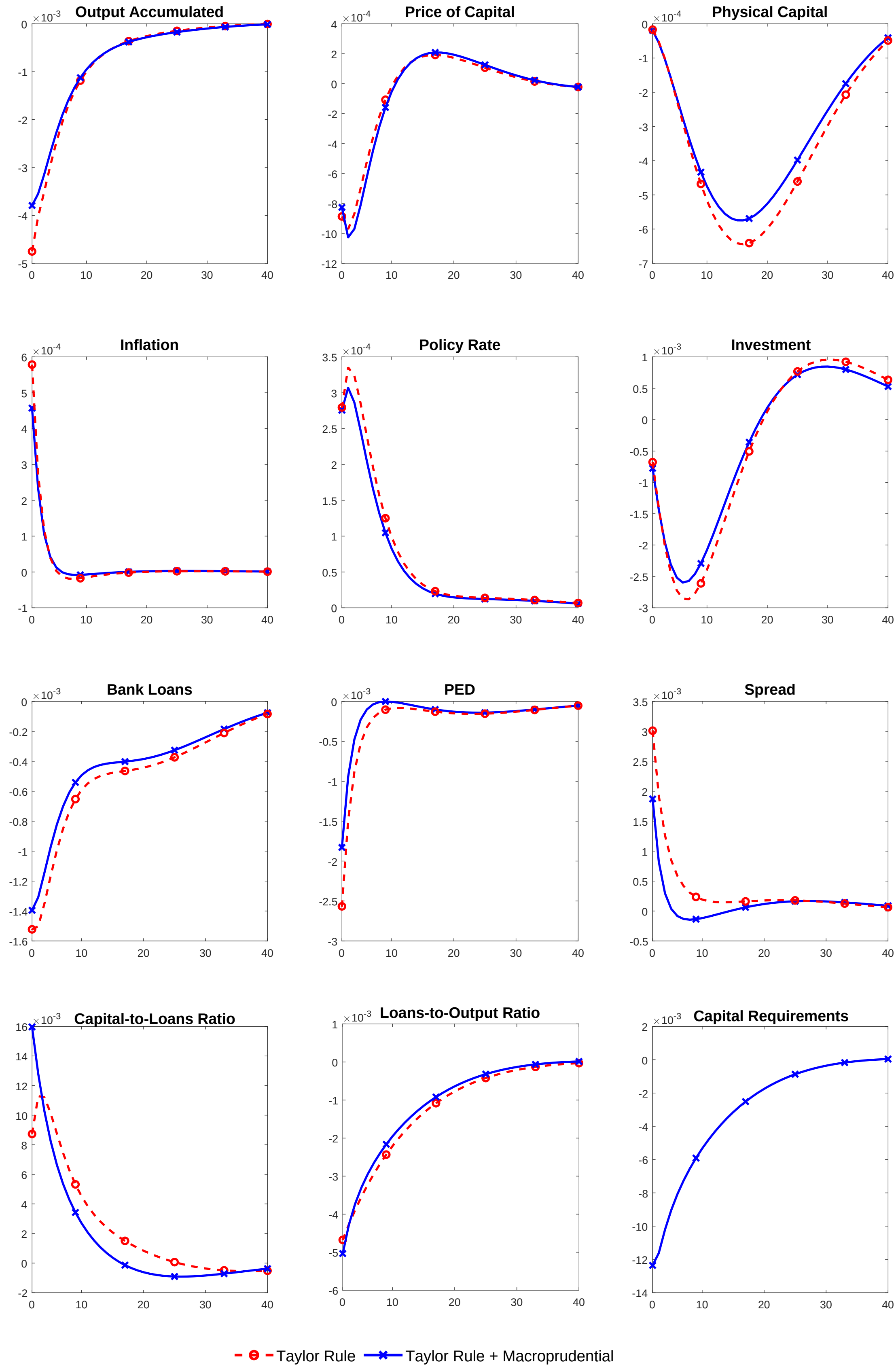
In this section, we analyze the effects of adverse shocks on the macroeconomic variables of the model. Two scenarios are examined. First, a baseline scenario with only the monetary policy modeled under the standard form of a Taylor rule. Second is the alternative scenario in which the macroprudential policy is active. We also verified the importance of the macroprudential policy to mitigate spread fluctuations and, consequently, reduce the impact on the accumulated output.

6.1 Productivity Shock

Figure 1 shows the impulse responses to an adverse productivity shock z for loans, inflation, spread, and other main variables. The scenario with only monetary policy amplifies the effects of the negative shock z for output y in the initial quarters. Productivity z falls at the beginning of period one and drives down the expected marginal product of capital (MPK). The fall in MPK reduces entrepreneurs' demand for physical capital and causes a drop in their price q. The reduction in the collateral value of the entrepreneurs makes them more financially constrained with inelastic demand for loans. Under Cournot's competition, the banks respond to the more inelastic loan demand by reducing their loans to achieve a higher loan rate, leading to a rise in the spread.

A higher spread allows banks to accumulate more capital, increasing the $\frac{k^B}{b}$ for both policy scenarios. However, the reduction of loans made by banks leads to a fall in the loans-to-output ratio, causing an action by the macroprudential authority that reduces the capital requirements τ^B. The movement of τ^B in the opposite direction of the $\frac{k^B}{b}$ movement reduces the effect of productivity shock when it passes by the bank stress channel. Then, the spread increase is more significant when there is only a monetary policy about the scenario with the active macroprudential policy.

Figure 1: Impulse responses to a negative productivity shock



Note: Impulse response functions given the negative productivity shock, from baseline (TR) model and dynamic capital requirements (MP) model.

The differential responses of the output and other main variables under the two policy scenarios can be explained by the difference in spread fluctuation when the capital requirements vary over time. The lower cost of loans with active macroprudential policy impacts the accumulation of physical capital k made by entrepreneurs and the level of investments. The fall in k is higher in the scenario with only monetary policy. The recovery of the entrepreneurs' level of k begins about 20 quarters after the initial shock in the scenario with macroprudential policy. It coincides with the period when the spread returns to the initial equilibrium and has its fluctuation eliminated. The fall in output in the scenario where macroprudential policy is active is smaller than the only monetary policy scenario.

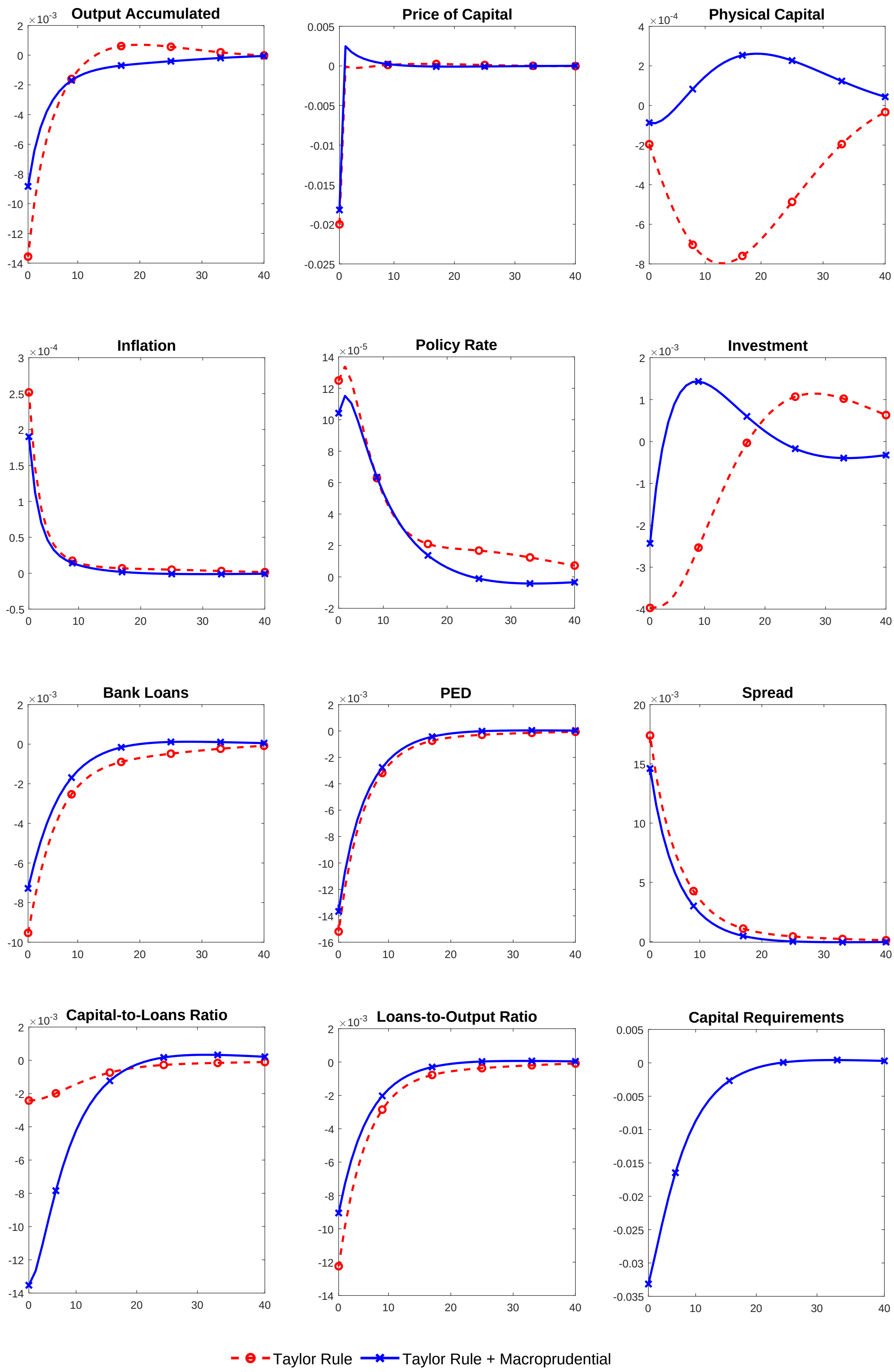
6.2 Collateral Shock

Figure 2 shows the effects of a negative collateral shock m^k that reduces the guarantees entrepreneurs can give banks to get loans.[13] The adverse collateral shock affects the elasticity of demand for loans (PED) from entrepreneurs, making them financially constrained. Banks can reduce the number of loans b offered to achieve a higher loan rate due to inelastic loan demand and entrepreneurs' dependence on credit. However, even setting a higher loan rate, the adverse shock that destroys the entrepreneurs' collateral prevents banks from increasing their capital accumulation k^B, which directly reduces the capital-to-loans ratio $\frac{k^B}{b}$. The fall in $\frac{k^B}{b}$ would generate a high amplifying effect on the spread if the capital requirements τ^B were fixed over time. However, the movement made by banks organized under Cournot competition reduces the loans-to-output $\frac{b}{y}$ ratio, and the macroprudential authority reacts by lowering the capital requirements (43) of the banking system. This interference reduces the amplifying effect of the spread in the bank stress channel, and the economy is better in the presence of macroprudential policy.

The investment shows a rapid recovery compared to the scenario with only monetary policy, taking about five quarters to return to initial equilibrium. With only monetary policy, a return to initial equilibrium occurs about 20 quarters after the shock. The rapid recovery of entrepreneurs makes the fall in physical capital last only for a few periods with macroprudential policy active. After the negative collateral shock, it is possible to observe a quick return of k to the initial equilibrium in the presence of macroprudential policy.

[13] The negative collateral shock m^k affects the borrowing constraint of entrepreneurs, reducing their capacity to borrow.

Figure 2: Impulse responses to a negative collateral shock



Note: Impulse response functions given the negative collateral shock, from baseline (TR) model and dynamic capital requirements (MP) model.

In contrast, the fall in physical capital lasts around 15 quarters with only monetary policy, and full recovery is achieved only after 40 quarters. Therefore, the quick recovery of investment made by entrepreneurs impacts the accumulated output in the economy, preventing the decline of output equal to the scenario in which only monetary policy. The output fall with macroprudential policy active is smaller than in the scenario with only monetary policy.

6.3 Financial Shock

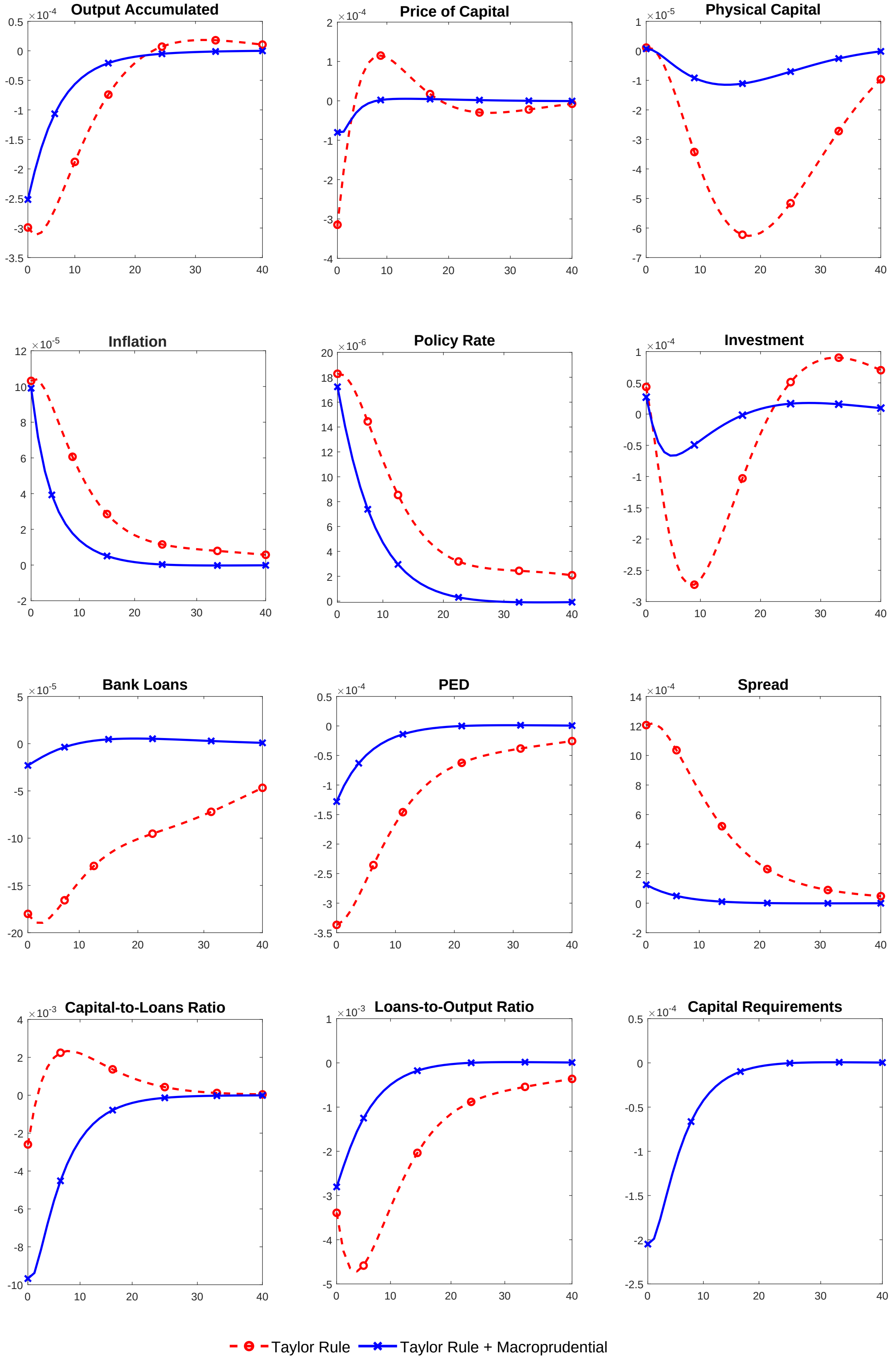
Figure 3 shows the effects of a bank capital loss resulting from an unexpected shock that destroys bank capital k^B. It is possible to observe that the macroprudential policy is more efficient in reducing the spread amplifying effect for this type of shock because it acts on the bank stress channel. A sudden drop in bank capital (32) reduces the capital-to-loans ratio $\frac{k^B}{b}$ and increase the loan rate in equation (40). The increase in the loan rate is a bank's mechanism to recover their losses in the oligopolistic banking sector and directly increases the spread. The capital requirement parameter ($\chi_{\tau^B} = 0.5$) is chosen in the model that τ^B reacts countercyclically to the loans-to-output ratio, and has a high degree of inertia ($\rho_{\tau^B} = 0.9$).

Comparing both policy scenarios reveals that monetary policy alone is insufficient to stabilize the economy for this shock. When time-varying capital requirements are available, spread fluctuation is significantly lower. The reduction in the loans-to-output rate $\frac{b}{y}$ due to the fall of loans b affects the capital requirements (43), reducing them. This way, the gap between the capital-to-loans ratio $\frac{k^B}{b}$ and the capital requirements τ^B is reduced. With the smaller increase in the spread, entrepreneurs are less financially constrained, and the economy's investment level fall is mitigated when the macroprudential policy is active. The lower cost of credit reduces the fall in the physical capital k, and k recovery occurs about 15 quarters after the initial quarter compared to the scenario with only monetary policy. This lower impact on the spread is transmitted to the output drop, smaller in the scenario with active macroprudential policy.

6.4 Investment Shock

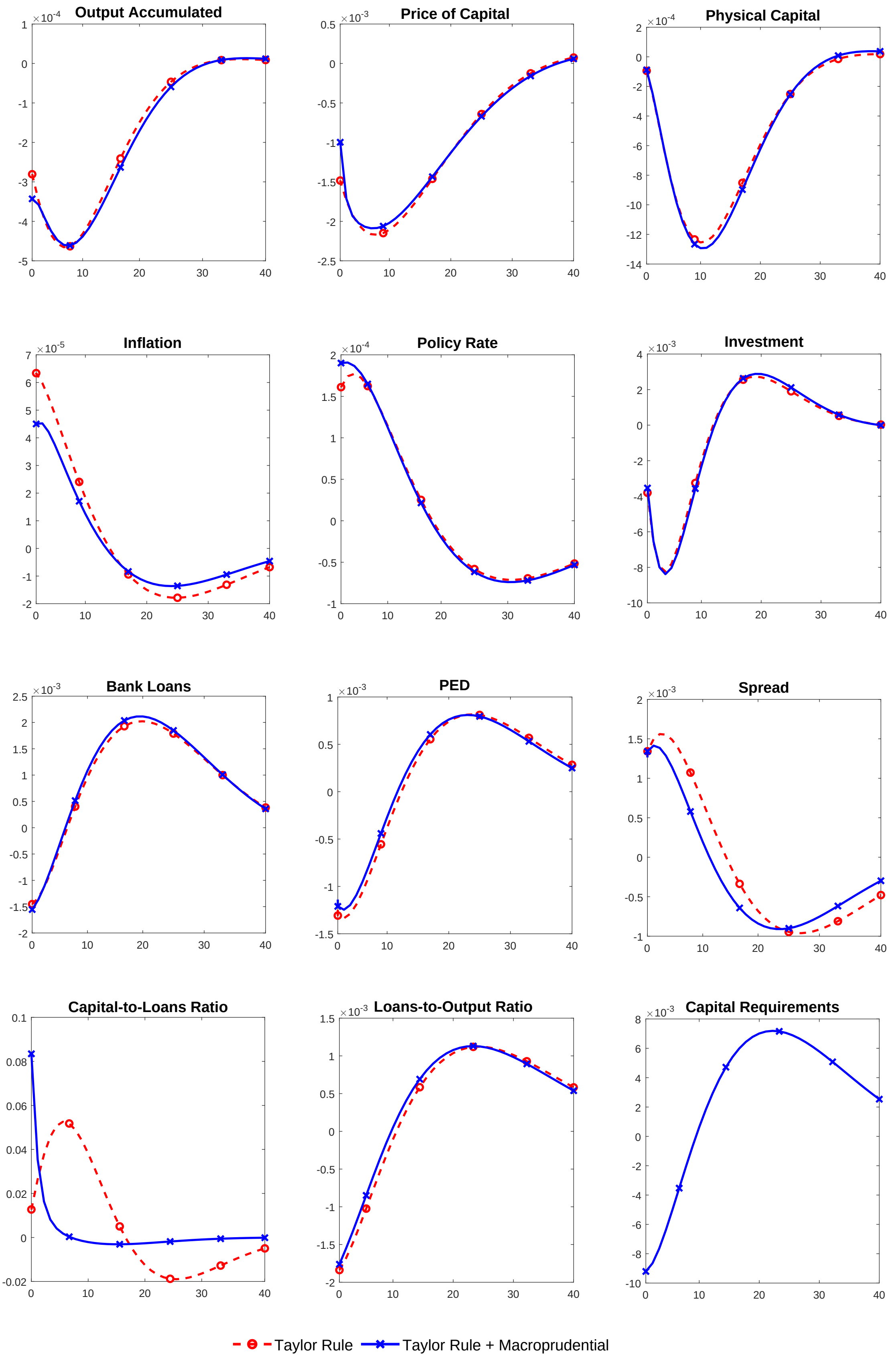
Figure 4 shows the effects resulting from a negative investment shock which increases the cost of transforming old physical capital into new capital for the production of wholesale goods. The investment shock reduces the price q of collateral that entrepreneurs

Figure 3: Impulse responses to a negative financial shock



Note: Impulse response functions given the negative financial shock, from baseline (TR) model and dynamic capital requirements (MP) model.

Figure 4: Impulse responses to a negative investment shock



Note: Impulse response functions given the negative investment shock, from baseline (TR) model and dynamic capital requirements (MP) model.

can give the bank to obtain loans and makes them more financially constrained (inelastic PED). However, the investment shock impact on the spread is not mitigated by the presence of macroprudential policy at instant zero. The trajectories of the spread start to deviate only after some quarters. Figure 4 shows that macroprudential policy does not have higher efficiency in minimizing output, investment, and physical capital fluctuations than the monetary policy.

The movement of banks to reduce loans b and, consequently, increase the spread leads to a fall in the loans-to-output ratio $\frac{b}{y}$ that reduces the capital requirements by macroprudential authority. The banks' capital-to-loans ratio increase occurs immediately after the negative investment shock, showing a fast recovery of bank capital. The movements in the opposite direction of $\frac{k^B}{b}$ and τ^b reduce the spread amplifying effect when the macroprudential policy is active. After ten quarters, the initial recovery of investment and physical capital influences accumulated output recovery. The total output recovery occurs about 30 quarters after the investment shock in both policy scenarios.

7 Welfare Analysis

The focus of this section is to verify if the introduction of macroprudential policy can improve the welfare of economic agents given an established monetary policy, using the second-order approximation of the equilibrium. We establish a grid to which macroprudential policy can vary. To assess the efficiency of different policies, we numerically consider the welfare derived in two scenarios. First is the baseline scenario with only monetary policy in the form of the standard Taylor rule (TR). The second is an alternative scenario with the monetary and macroprudential policies (MP).

Monetary policy is kept fixed over time. We want to study if the introduction of countercyclical macroprudential policy improves the agents' welfare after four adverse shocks in a Cournot banking competition environment: (i) productivity, (ii) collateral, (iii) financial, and (iv) investment. The economy has three main agents: households, entrepreneurs, and banks. We also verify the effects of increasing the macroprudential policy response to the loans-to-output ratio, and increased banking competition.

The welfare measure is the unconditional expectation of the average utility of the households, entrepreneurs, and banks. Thus, the welfare is evaluated separately for households W_t^H, entrepreneurs W_t^E and banks W_t^B, according to the equations:[14]

$$W_t^H \equiv \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left[\ln(c_{t+s}) - \phi_l \ln(1 - l_{t+s})\right] \tag{44}$$

$$W_t^E \equiv \mathbb{E}_t \sum_{s=0}^{\infty} (\beta^E)^s \left[\ln\left(c_{t+s}^E\right)\right] \tag{45}$$

$$W_t^B \equiv \mathbb{E}_t \sum_{s=0}^{\infty} \beta^s \left[\ln\left(div_{t+s}^B\right)\right] \tag{46}$$

which $\mathbb{E}$ denotes the unconditional expectations operator. The policy rules in the model are designed to be implementable and simple because the rules are functions of observable macroeconomic indicators.[15] In our model, macroprudential policy is simple because it is a function of observable macroeconomic variables (output y and loans b) and implementable because the policy coefficients $(\rho_{\tau^B}, \chi_{\tau^B})$ are restricted to an interval that guarantees a unique bounded approximate second-order solution.

According to Ferreira et al. (2015), there is higher uncertainty about about the macroprudential policy parameter, then we restrict the reaction of capital requirements to the loans-to-output ratio to the range $\chi_{\tau^B} \in [0, 5]$. A smaller range than authors that vary χ_{τ^B} on the range $[0, 10]$. Our range for χ_{τ^B} is partitioned with grids of size 0.1. We assume, as Angelini et al. (2014), that $\chi_{\tau^B} = 0$ implies no macroprudential policy. In our baseline analysis, we consider the value of $\chi_{\tau^B} = 0.5$ for the macroprudential policy. We also analyze how an increase in banking competition can improve welfare, varying the number of banks N in the range $[5, 30]$.

We present welfare gains in terms of consumption equivalents. We assess the welfare when only monetary policy is active and compare it with the welfare obtained when the macroprudential policy works together with monetary policy. Our concern is to calculate the welfare benefits of introducing a macroprudential policy. The consumption equivalent is an understandable measure that allows accessing the macroprudential policy's gains (or losses) and defines the maximum fraction of consumption (λ) that agents would be willing to resign in an economy with only monetary policy (TR) to enter the economy where macroprudential policy is active (MP).[16] Formally, λ must satisfy the following conditions for households (H), entrepreneurs (E), and banks (B), respectively:

$$\lambda^H = \exp\left[(1-\beta)(W^{H,MP} - W^{H,TR})\right] - 1 \tag{47}$$

$$\lambda^E = \exp\left[(1-\beta^E)(W^{E,MP} - W^{E,TR})\right] - 1 \tag{48}$$

$$\lambda^B = \exp\left[(1-\beta)(W^{B,MP} - W^{B,TR})\right] - 1 \tag{49}$$

[14]As discussed in Rubio and Carrasco-Gallego (2013) and Rubio and Carrasco-Gallego (2014).

[15]Schmitt-Grohé and Uribe (2007) define a policy as simple when the rules are defined in terms of a small number of macroeconomic indicators and being implementable when there is the uniqueness of the equilibrium of rational expectations.

[16]Otherwise, the amount of consumption the agents would need to be indifferent between remaining in the economy TR and entering the economy MP.

where $W^{i,MP}$, $i = \{H, E, B\}$, is the welfare obtained by the agents with the macroprudential policy active, and $W^{i,TR}$ is the welfare when there is no macroprudential policy.[17]

7.1 Negative Productivity Shock

Table 2 shows the welfare gains of the households, entrepreneurs, and oligopolistic banks obtained by the introduction of the macroprudential policy, keeping the baseline calibration for the policies parameters when a negative productivity shock hits the economy. The entrepreneur's welfare gain due to capital requirements that vary over time as a macroprudential instrument is a consequence of the lower cost of credit. Entrepreneurs are borrowers in the economy. They are affected by the bank stress channel when adverse shocks cause fluctuation of the capital-to-loans ratio and increase the loan rate, even when these shocks arise in the IBC channel. In this way, a fall in capital requirements reduces the difference $(\frac{k^B}{b} - \tau_t^B)$ that increases the loan rate after an adverse productivity shock, decreasing the cost of credit and pushing the economy toward a low-inflation and high-output equilibrium about to scenario with only monetary policy, as shown in the Figure 1.

Table 2: Welfare gains with baseline parameters - negative productivity shock

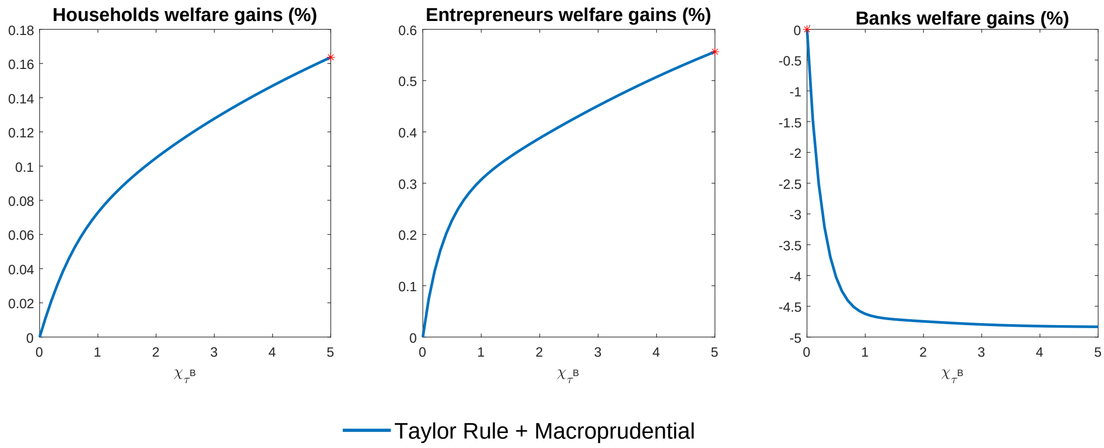
	TR		MP	Welfare gains $(\lambda)^*$		
	ϕ_π	ϕ_y	χ_τ^B	W^H	W^E	W^B
Monetary Policy + Macroprudential	1.56	0.33	0.5	0.0457	0.2277	-0.4030

* Welfare gains compared with the baseline policy regime (only TR).

Entrepreneurs can leverage their level of investment with a lower credit cost, which has a direct positive impact on the level of accumulated output y of the economy and, consequently, on their consumption c^E and welfare W^E with a gain of 0.22%. The macroprudential policy also can increase the welfare gains of households since the growth in accumulated output resulting from larger investment activity by entrepreneurs tends to bring the economy to equilibrium with higher aggregate consumption and lower inflation, which has a direct impact on the real earnings of households that can thus smooth their consumption over time. In contrast, the macroprudential policy reduces the welfare gains of banks. The productivity shock amplifying effect is reduced because the bank stress channel impacts the increase of the loan rate less. With the decrease in the loan rate R^b and lower spread, oligopolistic banks have lower capital accumulation k^B and, consequently, lower dividends div^B. Table 2 shows that macroprudential policy reduces banks' welfare gain at -0.40% to baseline calibration.

[17]The welfare gains derivation can be seen in the Appendix A.

Figure 5: Welfare gains with $\chi_{\tau^B} \in [0, 5]$ - negative productivity shock



Note: Welfare gains from introducing the macroprudential rule, given monetary policy (different values of the feedback parameter for capital-to-loans ratio in capital requirements).

Figure 5 shows the scenario in which the macroprudential policy is active, and we allow χ_{τ^B} to vary in the interval $[0, 5]$. If $\chi_{\tau^B} = 0$, there is no macroprudential policy. The monetary policy parameters are defined according to the baseline calibration in $\phi_\pi = 1.56$ and $\phi_y = 0.33$. The higher χ_{τ^B} values represent an increase of the welfare gain for the households and entrepreneurs and a loss of welfare for banks. Entrepreneurs' welfare gains are larger than for households, given an increase in χ_{τ^B}. Higher intervention by the macroprudential authority, regulating τ^B after a negative productivity shock that hits the economy, reduces the ability of banks under Cournot competition to amplify the effects of shocks to the spread when the bank stress channel transmits the shock. Figure 1 shows that the spread and accumulated output fluctuations are smaller with macroprudential policy active.[18]

7.2 Negative Collateral Shock

This section studies the effects on agents' welfare given a reduction in the entrepreneur's guarantees to bank loans. Table 3 reports the agents' welfare gains with the macroprudential policy's introduction. The gains are higher for banks about households and entrepreneurs. Banks show an improvement in welfare W^B by introducing capital requirements that vary over time. The macroprudential policy helps reduce the costs of deviation from the optimal target in a scenario where banks cannot accumulate capital. The adverse collateral shock makes entrepreneurs financially constrained, motivating banks under Cournot competition to reduce the number of loans to obtain a higher loan rate. However, even charging a higher loan rate, the demand for loans decreases and directly impacts the fall in the capital-to-loans ratio through the fall in k^B, as seen in Figure 2. The reduction in the amount of bank loans causes the fall of the loans-to-output ratio,

[18]Impulse responses are measured in percentage changes from steady-state values, and the magnitude of the shocks is scaled as one standard deviation for each type of shock.

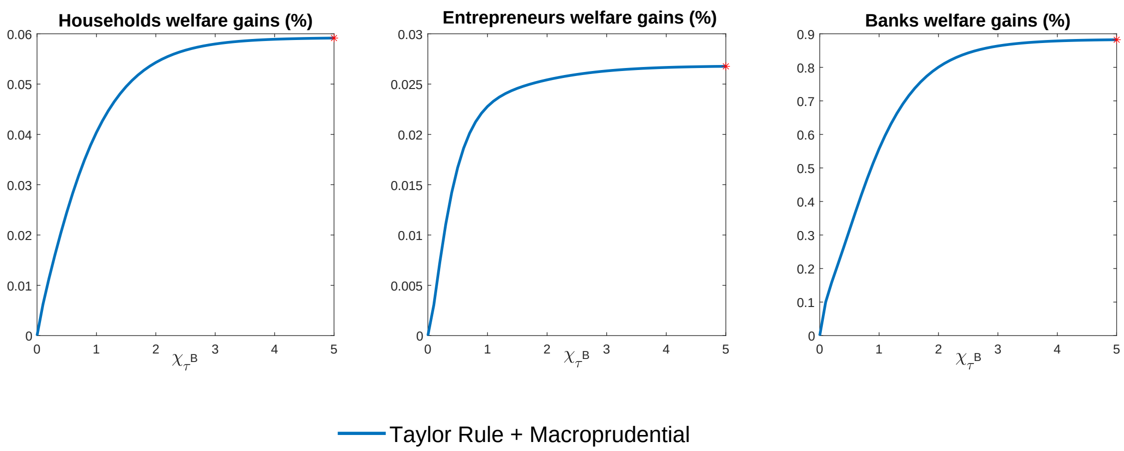
and the macroprudential authority interferes by reducing optimal capital requirements, generating a welfare gain for banks equal to 0.31%.

Table 3: Welfare gains with baseline parameters - negative collateral shock

	TR		MP	Welfare gains (λ)*		
	ϕ_π	ϕ_y	χ^B_τ	W^H	W^E	W^B
Monetary Policy + Macroprudential	1.56	0.33	0.5	0.0247	0.0170	0.3143

* Welfare gains compared with the baseline policy regime (only TR).

Figure 6: Welfare gains with $\chi_{\tau^B} \in [0, 5]$ - negative collateral shock



Note: Welfare gains from introducing the macroprudential rule, given monetary policy (different values of the feedback parameter for capital-to-loans ratio in capital requirements).

Introducing a macroprudential policy also generates welfare gains for entrepreneurs because of the low credit costs. This gain equals 0.01% if we maintain the baseline calibration for the monetary policy and introduce the macroprudential policy with $\chi_{\tau^B} = 0.5$. Entrepreneurs' welfare gains are lower concerning the other scenarios shocks. Figure 6 shows that an entrepreneur's gains can be higher if we increase the value for χ_{τ^B}. The recovery of economic activity after adverse collateral shock involves the recovery of investments made by entrepreneurs, which can help recover the accumulated output more quickly.

7.3 Negative Financial Shock

In this section, we analyze the effects of an unexpected financial shock on the welfare of the main agents of the model. Figure 7 shows that all agents benefit from the introduction of macroprudential policy, especially the banks that have reduced costs of deviating from the optimal leverage target. When a financial shock destroys the capital accumulated by banks, there is an immediate fall in the capital-to-loans ratio that generates costs (31) of deviation from the optimal target. If the macroprudential policy is active, capital requirements can vary over time and reduce the difference $\left(\frac{k^B}{b} - \tau^B_t\right)$ that increases the cost after the negative financial shock. The target reduction allows banks to recover the capital loss suffered more quickly and not need to charge a high loan rate. With the lower cost of credit, entrepreneurs can increase the level of investments, which mitigates the fall in the accumulated output about the scenario with only monetary policy. The macroprudential policy with a high response to the deviations of loans-to-output ratio (χ_{τ^B}) leads to a higher welfare gain for all agents, as can be seen from Figure 7.

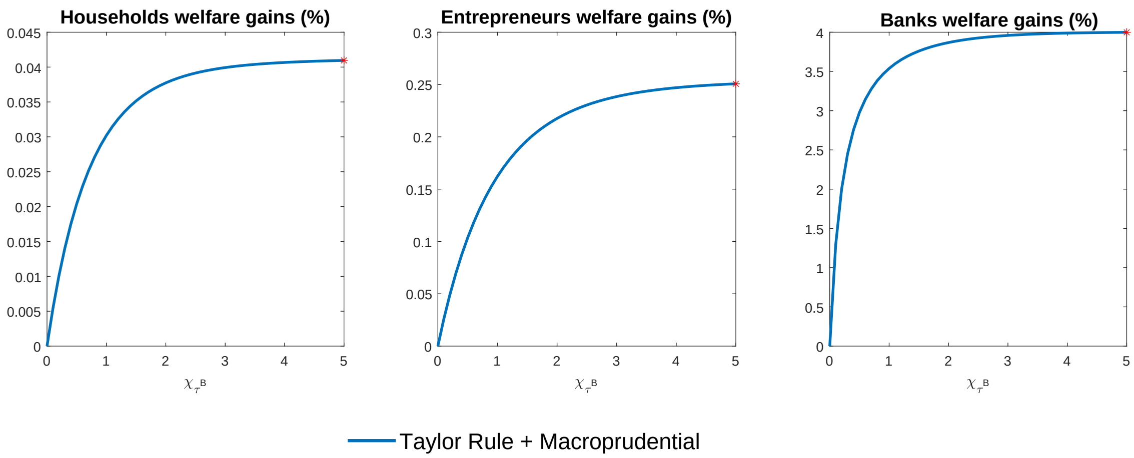
Table 4: Welfare gains with baseline parameters - negative financial shock

	TR		MP	Welfare gains (λ)*		
	ϕ_π	ϕ_y	χ_τ^B	W^H	W^E	W^B
Monetary Policy + Macroprudential	1.56	0.33	0.5	0.0204	0.1035	0.2977

* Welfare gains compared with the baseline policy regime (only TR).

The positive effect of macroprudential policy on bank welfare is not seen in negative shocks where banks accumulate more capital, such as productivity and investment shocks. For these shocks, the macroprudential policy reduces the bank spread and the accumulation of bank capital, resulting in lower levels of dividends and lower welfare for banks. In the case of an adverse financial shock, macroprudential policy positively affects banks' welfare, reducing shock effects. The welfare gain about to the scenario with only monetary policy is 0.29% if we consider an adverse financial shock with a standard deviation of 0.01 and macroprudential policy calibrated with $\chi_{\tau^B} = 0.5$. The macroprudential policy also has a beneficial effect on households due to stabilizing the output fluctuation about the scenario with only monetary policy, allowing lower inflation rates and higher real gains for households.

Figure 7: Welfare gains with $\chi_{\tau^B} \in [0, 5]$ - negative financial shock



Note: Welfare gains from introducing the macroprudential rule, given monetary policy (different values of the feedback parameter for capital-to-loans ratio in capital requirements).

7.4 Negative Investment Shock

This section looks at the adverse shock effects that increase the cost of transforming old capital into new capital to produce a wholesale good. It is a shock that reduces the price of capital and makes entrepreneurs more financially constrained, creating incentives for the Cournot banking system to increase the loan rate by reducing loans. Figure 4 shows that banks can accumulate more capital with this shock. The macroprudential policy inhibits the amplifying effect on the loan rate generated by the bank stress channel, making the difference $(\frac{k^B}{b} - \tau_t^B)$ smaller given the negative investment shock. The macroprudential policy increases the welfare of households and entrepreneurs, who experience less fluctuation in the accumulated output. However, it is worse for banks that experience a fall in the spread, and the lower accumulation of capital k^B decreases the dividends generated. Banks have a welfare loss of -0.40% with the introduction of macroprudential policy, given a negative investment shock.

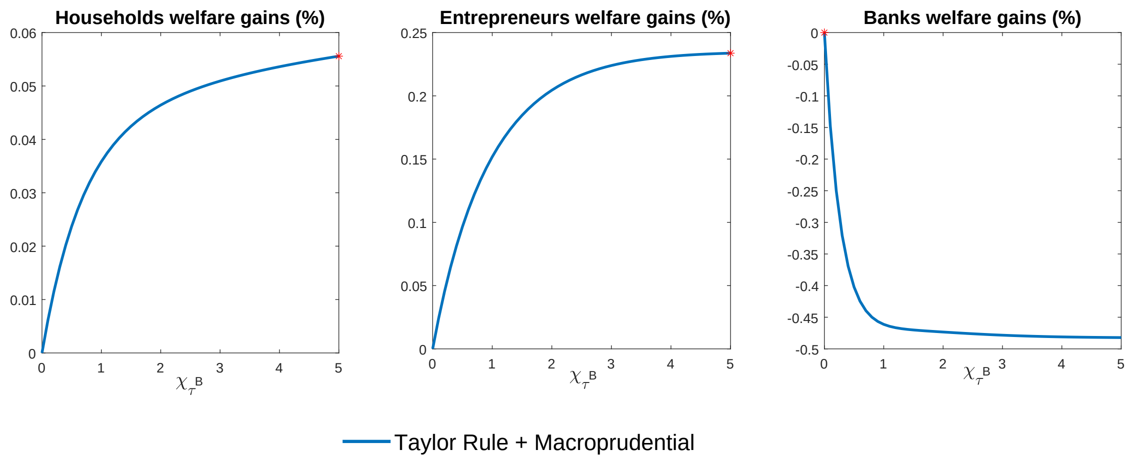
Table 5: Welfare gains with baseline parameters - negative investment shock

	TR		MP	Welfare gains $(\lambda)^*$		
	ϕ_π	ϕ_y	χ_τ^B	W^H	W^E	W^B
Monetary Policy + Macroprudential	1.56	0.33	0.5	0.0237	0.0966	-0.4022

* Welfare gains compared with the baseline policy regime (only TR).

Figure 20 shows that increasing the macroprudential policy feedback parameter χ_{τ^B} in the range $[0, 5]$ further reduces the welfare gains of banks, which is not seen for households and entrepreneurs who benefit from the intervention of the macroprudential authority. Welfare gains can reach the value of 0.05% for households and 0.23% for entrepreneurs if we allow χ_τ^B equal to the maximum value in the given range. In contrast, the χ_{τ^B} increase implies a higher welfare loss for banks, reaching -0.48% when $\chi_\tau^B = 5$.

Figure 8: Welfare gains with $\chi_{\tau^B} \in [0, 5]$ - negative investment shock



Note: Welfare gains from introducing the macroprudential rule, given monetary policy (different values of the feedback parameter for capital-to-loans ratio in capital requirements).

7.5 Increasing Banking Competition

Table 6 shows the effects of increased banking competition on the agents' welfare gains when the macroprudential policy is active. There are two scenarios: (i) the baseline scenario with only monetary policy, and (ii) the alternative scenario with macroprudential policy active. Monetary policy feedback parameters are kept in $\phi_\pi = 1.56$ and $\phi_y = 0.33$, while the macroprudential policy feedback parameter assumes a value $\chi_{\tau^B} = 0.5$. The baseline scenario also considers $N = 5$, referring to the five largest Brazilian banks.

Table 6: Welfare gains with more banking competition (MP active)

	Productivity Shock						
	TR		MP	Banks	Welfare gains (%)*		
	ϕ_π	ϕ_y	χ_τ^B	N	W^H	W^E	W^B
Monetary + Macroprudential	1.56	0.33	0.5	15	5.3888	0.3385	-1.2063
Monetary + Macroprudential	1.56	0.33	0.5	30	6.7703	0.4246	-1.6318
	Collateral Shock						
	TR		MP	Banks	Welfare gains (%)*		
	ϕ_π	ϕ_y	χ_τ^B	N	W^H	W^E	W^B
Monetary + Macroprudential	1.56	0.33	0.5	15	5.7793	0.4098	-1.1528
Monetary + Macroprudential	1.56	0.33	0.5	30	7.4231	0.5530	-1.5447
	Financial Shock						
	TR		MP	Banks	Welfare gains (%)*		
	ϕ_π	ϕ_y	χ_τ^B	N	W^H	W^E	W^B
Monetary + Macroprudential	1.56	0.33	0.5	15	5.3809	0.3407	-1.4385
Monetary + Macroprudential	1.56	0.33	0.5	30	6.7571	0.4283	-1.8525
	Investment Shock						
	TR		MP	Banks	Welfare gains (%)*		
	ϕ_π	ϕ_y	χ_τ^B	N	W^H	W^E	W^B
Monetary + Macroprudential	1.56	0.33	0.5	15	5.5828	0.3393	-1.4247
Monetary + Macroprudential	1.56	0.33	0.5	30	7.0895	0.4259	-1.8351

* Welfare gains compared with the alternative policy regime formed by monetary and macroprudential policies with $N = 5$.

The welfare gains generated by introducing the macroprudential policy to the households and entrepreneurs are amplified in the presence of more banking competition, as seen in Figure 9. If new banks' entry barriers are removed in the presence of productivity shock, allowing more competition until $N = 15$, a welfare gain equals 5.38% to households and 0.33% to entrepreneurs about the scenario with $N = 5$. If we further increase bank competition to $N = 30$, the welfare gain about the scenario with $N = 5$ will be 6.77% for households and 0.42% for entrepreneurs (Table 6). In contrast, in the presence of z shock, banks lose welfare with increased competition and macroprudential policy active because they will accumulate less capital due to the lower spread, consequently having lower dividends. The macroprudential authority can intervene when the loan-to-output ratio falls, reducing capital requirements τ^B. Banks lose the power to amplify the spread through the bank stress channel. In this way, banks lose the power of their two channels and, consequently, have lower welfare gains. A similar scenario is seen for the investment shock, in which banks are also unable to charge a higher spread with the introduction of macroprudential policy. Consequently, banks have a higher welfare loss compared to the only monetary policy scenario.

Table 7: Welfare gains with more banking competition (only TR)

	Productivity Shock						
	TR		MP	Banks	Welfare gains (%)*		
	ϕ_π	ϕ_y	χ_τ^B	N	W^H	W^E	W^B
Only Monetary Policy	1.56	0.33	0	15	1.5843	0.1560	-1.1542
Only Monetary Policy	1.56	0.33	0	30	1.9052	0.1915	-1.5305
	Collateral Shock						
	TR		MP	Banks	Welfare gains (%)*		
	ϕ_π	ϕ_y	χ_τ^B	N	W^H	W^E	W^B
Only Monetary Policy	1.56	0.33	0	15	1.2229	0.1841	-1.1095
Only Monetary Policy	1.56	0.33	0	30	1.2230	0.2378	-1.6456
	Financial Shock						
	TR		MP	Banks	Welfare gains (%)*		
	ϕ_π	ϕ_y	χ_τ^B	N	W^H	W^E	W^B
Only Monetary Policy	1.56	0.33	0	15	1.5803	0.1555	-1.7639
Only Monetary Policy	1.56	0.33	0	30	1.8957	0.1906	-2.7095
	Investment Shock						
	TR		MP	Banks	Welfare gains (%)*		
	ϕ_π	ϕ_y	χ_τ^B	N	W^H	W^E	W^B
Only Monetary Policy	1.56	0.33	0	15	1.5793	0.1709	-1.3945
Only Monetary Policy	1.56	0.33	0	30	1.8969	0.2155	1.8057

* Welfare gains compared with the baseline policy regime formed by only monetary policy with $N = 5$.

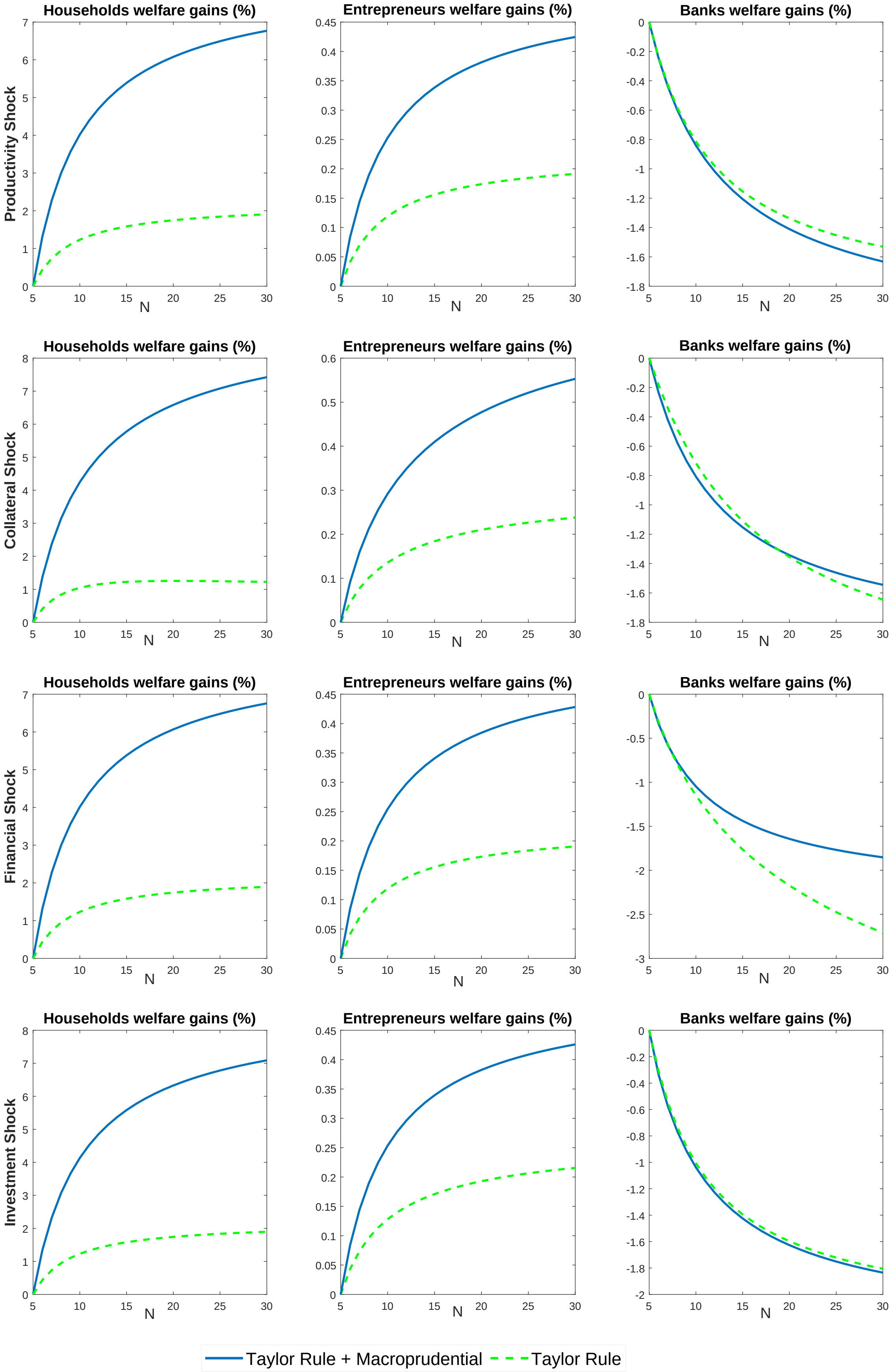
Figure 9 shows an opposite effect on the banks' welfare gains when we increase banking competition in the presence of financial shocks. Higher banking competition reduces the power of banks to readjust the loan rate by reducing loans when the economy suffers adverse shocks that have the IBC channel as the main transmission channel. In this way, banks can accumulate less capital and pay lower dividends, reducing their welfare gains. However, the introduction of macroprudential policy contributes to reducing the costs that punish banks for deviating from the optimal level of leverage when an unexpected financial shock reduces the banks' accumulated capital. More bank competition implies that banks have less profit and less capital, which can worsen their ability to face financial shocks given banks' capitalization costs. In this scenario, the macroprudential policy becomes important for the financial recovery of banks. Table 6 shows that banks have a welfare loss of -1.43% when the number of banks increases to $N = 15$, and a loss equal to -1.85%

when $N = 30$ (scenario with MP active). In the scenario with only monetary policy, the welfare loss is -1.76% when $N = 5$ increases to $N = 15$, and equals -2.70% with $N = 30$, respectively.

Macroprudential policy performs similarly on the bank's welfare for the adverse collateral shock because there is a bank capital loss. However, it is less effective in minimizing the decline in banks' welfare gain given more competition, as seen in Figure 9. The low efficiency of the macroprudential policy occurs because collateral shock affects the IBC channel by PED, and the macroprudential policy acts on the bank stress channel. Table 6 shows that banks have a welfare loss of -1.15% when the number of banks increases to $N = 15$, and a welfare loss equal to -1.54% when $N = 30$.

In the scenario with only monetary policy, introducing new banks also increases the welfare gains of households and entrepreneurs. Equation (40) shows that increasing the number of banks reduces the adverse effect of shocks that arise in the IBC channel and, consequently, reduces banks' loan rates in imperfect competition. Due to the lower cost of loans, entrepreneurs can increase the number of investments in the economy, increasing output y and directly impacting the welfare of the households and entrepreneurs. However, these welfare gains are smaller than the scenario with the macroprudential policy active. In the presence of productivity shock, increasing the banking competition from $N = 5$ to $N = 15$ implies a welfare gain of 1.58% for households and 0.15% for entrepreneurs. With more banking competition up to $N = 30$, welfare gain increased to 1.90% for households and 0.19% for entrepreneurs (Table 7). More banking competition improves W^H and W^E for collateral and investment shocks. However, monetary policy alone is insufficient to stabilize the decline in banks' welfare W^B given the occurrence of financial shocks.

Figure 9: Welfare gains with $N \in [5, 30]$



Note: Welfare gains from introducing the macroprudential rule, given monetary policy (different values of the number of banks).

8 Banking Competition and the Effect of Stabilization Policies

This section analyzes the effects of banking competition on the accumulated output and spread fluctuations. We explore three possible scenarios in the presence of all adverse shocks: (i) when the banking system is imperfectly competitive ($N = 5$), (ii) when barriers to entry are reduced ($N = 15$), (iii) and the closest scenario to perfect competition ($N = 30$). The idea is to verify how the efficiency of monetary and macroprudential policies in minimizing fluctuations in economic cycles is affected by different levels of banking competition. We again consider two scenarios, baseline with only monetary policy and alternative with macroprudential policy active.

The impact on the spread is reduced by increasing the number of banks for all shocks. Figure 10 shows that more banking competition can further reduce the spread fluctuations when the macroprudential policy is active. Fluctuations are smaller because the two bank channels that amplify the shocks are constrained: the number of banks N limits the power of the IBC channel, and the power of the bank stress channel is limited by capital requirements τ^B that vary over time. The negative productivity shock in the production function (9) reduces entrepreneurs' demand for k and causes a fall in the price of physical capital q. The fall in q reduces entrepreneurs' borrowing capacity (11) and makes them more financially constrained. The result is a more inelastic PED, and for the scenario with $N = 5$, the negative effect of the z shock on the PED increases the spread. This impact on the spread is reduced by increasing the number of banks to $N = 15$ and $N = 30$, respectively. Figure 11 shows that the drop in output, given a negative shock z, is mitigated by more banks due to the lower cost of borrowing for entrepreneurial activity, and the presence of macroprudential policy further reduce the drop in y.

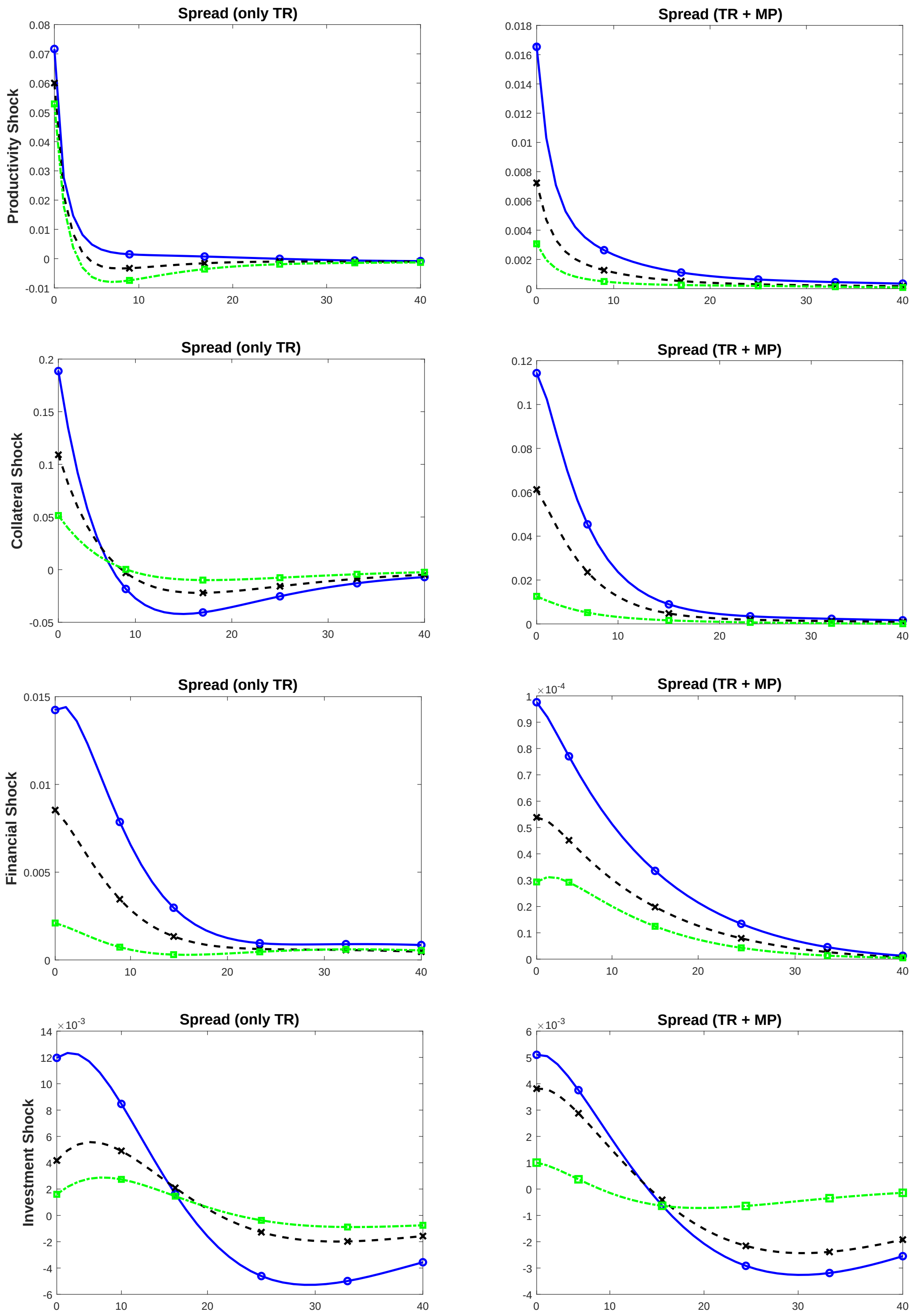
The negative collateral shock destroys the guarantees entrepreneurs provide to banks to obtain loans and makes them more financially constrained. Banks in imperfect competition take advantage of the inelastic PED and reduce the number of loans to get a high loan rate, directly affecting the spread. The increased cost of credit that finances entrepreneurial activity impacts physical capital and labor investments, causing a fall in accumulated output. More banking competition reduces banks' power to charge a high loan rate even if entrepreneurs are financially constrained. In this way, for collateral shock, the introduction of the macroprudential policy combined with a large number of banks ($N = 30$) keeps the output deviation close to the original steady-state as seen in Figure 11.

Figure 11 shows that the financial shock effects are amplified when the banking system presents a low number of banks ($N = 5$) and the absence of macroprudential policy. An adverse financial shock that hits banks moves the capital-to-loans rate below the initial optimal leverage ratio. This $\frac{k^B}{b}$ movement increases the punitive costs of deviating from the optimal leverage target, and banks can pass their financial loss to the entrepreneurs.

The loan rate increases borrowing costs, leading to a slowdown in the level of investments and accumulated output. The existence of capital requirements that vary over time allows the macroprudential authority to reduce the banking system's costs. In this way, the bank stress channel has less influence on the cost of credit and economic activity, allowing for smaller fluctuations in spread and output.

Lastly, the negative investment shock affects capital producers. It increases the cost of transforming old capital into new capital used to create wholesale goods y^w, causing a fall in the output. The lower price q makes entrepreneurs more financially constrained. The banks in imperfect banking competition take advantage of the financial constraints of entrepreneurs and increase the spread. The increase in the number of banks from $N = 5$ to $N = 30$ allows the spread deviation from the initial steady-state to be smaller. Figure 11 shows that the introduction of macroprudential policy does not have much influence in reducing the fluctuation of accumulated output about the scenario with only monetary policy in the initial quarters. However, in the presence of a high number of banks ($N = 30$), the accumulated output y recovers more quickly in the presence of macroprudential policy for the adverse investment shock.

Figure 10: Impulse response to spread given different number of banks

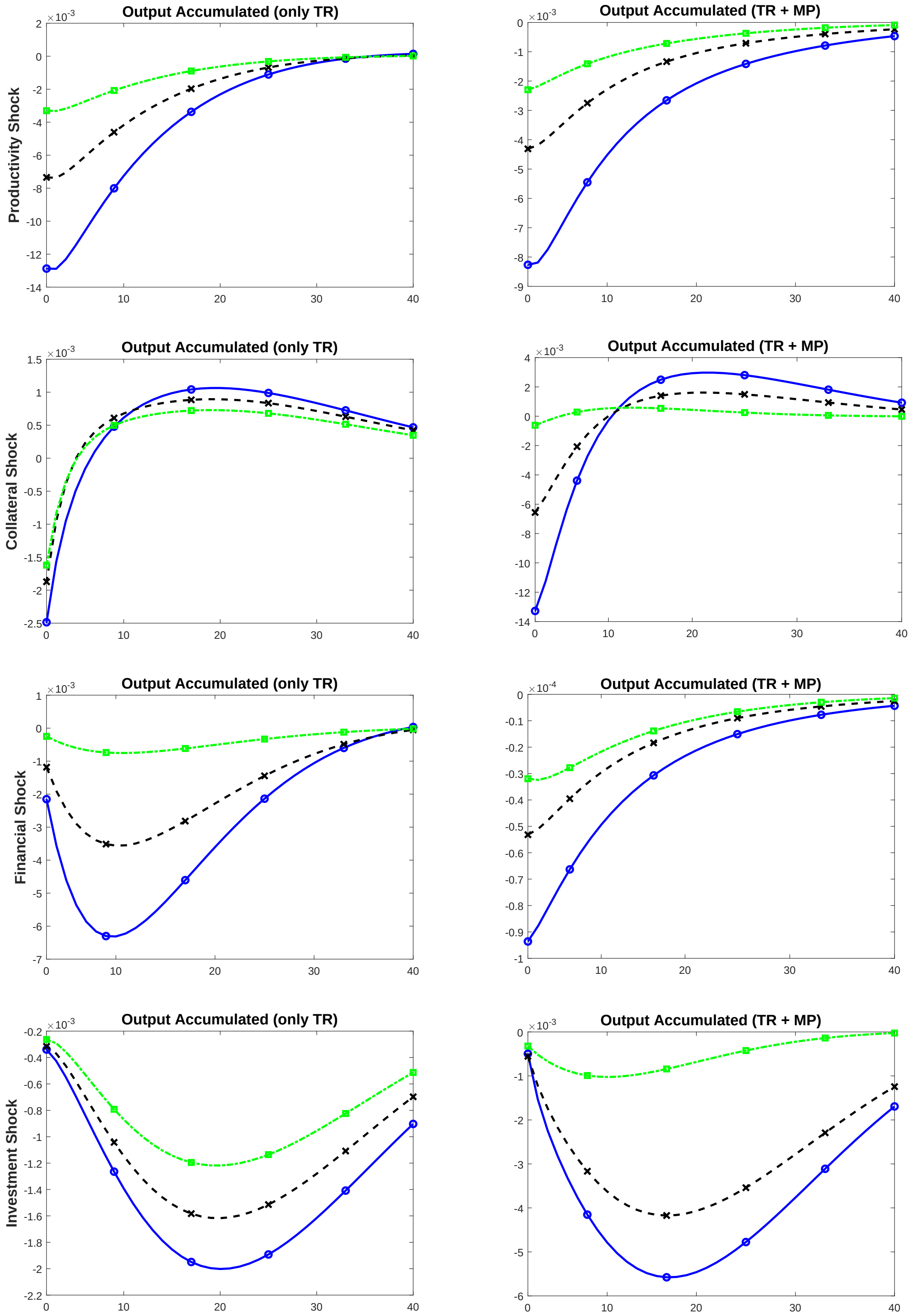


(a) Only monetary policy (b) Macroprudential policy active

N = 5 N = 15 N = 30

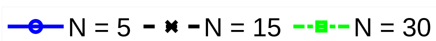
Note: The horizontal axis shows quarters after a negative shock at the beginning of period one. The vertical axis shows the percentage deviation from the steady-state for the spread. We consider two scenarios, baseline with only monetary policy (only TR), and alternative with macroprudential policy active (TR + MP).

Figure 11: Impulse response to output given different number of banks



(a) Only monetary policy

(b) Macroprudential policy active



Note: The horizontal axis shows quarters after a negatives shocks at the beginning of period one. The vertical axis shows the percentage deviation from the steady-state for the output. We consider two scenarios, baseline with only monetary policy (only TR), and alternative with macroprudential policy active (TR + MP).

9 Conclusions

Our paper examines the stabilization properties of macroprudential policy in an environment dominated by an oligopolistic banking system. The results indicate that a countercyclical macroprudential policy can stabilize Brazil's business cycle fluctuations by controlling the loan rate and, consequently, affecting the spread. Besides, a welfare analysis shows the macroprudential policy yields additional welfare gains over the scenario with only monetary policy for households and entrepreneurs. The macroprudential policy reduces bank stress channel impact on the cost of credit, and entrepreneurs can restore their productive activity, stabilizing the fall in accumulated output generated by adverse shocks that hit the economy.

Our findings also show that the oligopolistic banking system recovers more quickly from unexpected capital losses in an environment with an active macroprudential policy. For financial shocks that reduce banks' capital and increase the punitive costs of deviating from the optimal leverage target, the macroprudential policy reduces these costs, allowing banks to recover financially without charging a higher spread. However, the macroprudential policy produces negative banks' welfare gains for productivity and investment shocks because it prevents banks have a higher spread and accumulating more capital. Our results show that the effectiveness of macroprudential policy in controlling the spread can be amplified in the presence of more banking competition.

The 2008 global financial crisis clarified that new instruments are needed to deal with an environment where financial shocks can increase business cycle fluctuations. The results found in this paper show that the macroprudential policy should not be treated as a substitute for monetary policy but as a helpful complement to deal with financial problems or adverse sectoral shocks, and improve welfare. Macroprudential policy is a better tool for financial stabilization than monetary policy, as the macroprudential policy operates in the supply of credit, an important driver of macroeconomic dynamic.

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Appendices

A Welfare Gains

The unconditional welfare means W_0, defined as follows:

$$W_0 = \mathbb{E} \sum_{t=0}^{\infty} \beta^t [U(c_t, l_t)] \tag{50}$$

where $U(c_t, l_t)$ is the utility function depending on consumption c_t and hours of labor l_t. Schmitt-Grohé and Uribe (2007) and Benigno and Woodford (2012) explained that different policies are associated with different stochastic steady-state. Therefore, we neglect the transitional dynamics that lead to the stochastic steady-state when using the unconditional welfare mean. It is also helpful to quantify the welfare differences between the macroprudential policy and the baseline policy rule (only monetary policy). As a welfare measure, the unconditional expectation utilities of households, entrepreneurs, and banks in period zero are calculated:

$$\mathbb{E}_0 W^H = \mathbb{E}_0 \sum_{s=0}^{\infty} \beta \left[\ln(c_{t+s}) - \phi_l \ln(1 - l_{t+s})\right] \tag{51}$$

$$\mathbb{E}_0 W^E = \mathbb{E}_0 \sum_{s=0}^{\infty} \beta^E \left[\ln\left(c^E_{t+s}\right)\right] \tag{52}$$

$$\mathbb{E}_0 W^B = \mathbb{E}_0 \sum_{s=0}^{\infty} \beta \left[\ln\left(div^B_{t+s}\right)\right] \tag{53}$$

Usually, the desirability of a policy regime is evaluated by computing the compensating fraction of steady-state consumption (λ) that would be necessary to equate the level of welfare in a baseline scenario (TR) to the level of welfare under the alternative regime (MP). In this way, λ satisfies the following equation:

$$\mathbb{E}_t \sum_{s=0}^{\infty} \beta^s U\left((1+\lambda) c^{TR}_{t+s}, l^{TR}_{t+s}\right) = W^{MP}_t \tag{54}$$

where $\{c^{TR}_t, l^{TR}_t\}_{t=0}^{\infty}$ denote consumption and labor in the baseline scenario, and W^{MP}_t is the welfare under the macroprudential rule. It holds:

$$\mathbb{E}_t \left\{ \sum_{s=0}^{\infty} \beta^s \left[U\left((1+\lambda) c^{TR}_{t+s}, l^{TR}_{t+s}\right) - U\left(c^{TR}_{t+s}, l^{TR}_{t+s}\right)\right] \right\} = W^{MP}_t - W^{TR}_t \tag{55}$$

where W_t^{TR} is welfare in the baseline scenario, rewriting the terms for the paper's log-utility function of households, we have:

$$\begin{aligned}
\mathbb{E}_t\left\{\sum_{s=0}^{\infty}\beta^s\left[\ln\left((1+\lambda)c_{t+s}\right)-\phi_l\ln(1-l_{t+s})-\ln(c_{t+s})+\phi_l\ln(1-l_{t+s})\right]\right\} &= W_t^{MP,H}-W_t^{TR,H}\\
\mathbb{E}_t\left\{\sum_{s=0}^{\infty}\beta^s\left[\ln\left((1+\lambda)c_{t+s}\right)-\ln(c_{t+s})\right]\right\} &= W_t^{MP,H}-W_t^{TR,H}\\
\frac{1}{1-\beta}\left\{\ln(1+\lambda)+\ln(c_{t+s})-\ln(c_{t+s})\right\} &= W_t^{MP,H}-W_t^{TR,H}
\end{aligned} \tag{56}$$

Then,

$$\begin{aligned}
\ln(1+\lambda) &= (1-\beta)\left(W_t^{MP,H}-W_t^{TR,H}\right)\\
1+\lambda &= \exp\left[(1-\beta)\left(W_t^{MP,H}-W_t^{TR,H}\right)\right]\\
\lambda &= \exp\left[(1-\beta)\left(W_t^{MP,H}-W_t^{TR,H}\right)\right]-1
\end{aligned} \tag{57}$$

The same reasoning for entrepreneurs:

$$\begin{aligned}
\mathbb{E}_t\left\{\sum_{s=0}^{\infty}(\beta^E)^s\left[\ln\left((1+\lambda)c^E_{t+s}\right)-\ln\left(c^E_{t+s}\right)\right]\right\} &= W_t^{MP,E}-W_t^{TR,E}\\
\frac{1}{1-\beta^E}\left\{\ln(1+\lambda)+\ln\left(c^E_{t+s}\right)-\ln\left(c^E_{t+s}\right)\right\} &= W_t^{MP,E}-W_t^{TR,E}\\
\ln(1+\lambda) &= (1-\beta^E)\left(W_t^{MP,E}-W_t^{TR,E}\right)\\
1+\lambda &= \exp\left[(1-\beta^E)\left(W_t^{MP,E}-W_t^{TR,E}\right)\right]\\
\lambda &= \exp\left[(1-\beta^E)\left(W_t^{MP,E}-W_t^{TR,E}\right)\right]-1
\end{aligned} \tag{58}$$

Lastly, we can write welfare gains for banks:

$$\begin{aligned}
\mathbb{E}_t\left\{\sum_{s=0}^{\infty}\beta^s\left[\ln\left((1+\lambda)div^B_{t+s}\right)-\ln\left(div^B_{t+s}\right)\right]\right\} &= W_t^{MP,B}-W_t^{TR,B}\\
\frac{1}{1-\beta}\left\{\ln(1+\lambda)+\ln\left(div^B_{t+s}\right)-\ln\left(div^B_{t+s}\right)\right\} &= W_t^{MP,B}-W_t^{TR,B}\\
\ln(1+\lambda) &= (1-\beta)\left(W_t^{MP,B}-W_t^{TR,B}\right)\\
1+\lambda &= \exp\left[(1-\beta)\left(W_t^{MP,B}-W_t^{TR,B}\right)\right]\\
\lambda &= \exp\left[(1-\beta)\left(W_t^{MP,B}-W_t^{TR,B}\right)\right]-1
\end{aligned} \tag{59}$$