Monetary Policy and Banking System Functionality: A Regional Approach

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Abstract

Monetary policy mechanisms have long been studied, with increasing interest in their effects on various dimensions of inequality, including subnational regions. While most studies focus on general impacts on regional income and prices, very few have dedicated themselves to analyzing the effects on the inner functioning of the banking system. This study investigates the regional effects of monetary policy on banking functionality and funding, evaluating how banks in diverse municipalities respond to fluctuations in their assets and liabilities. The present study innovates by constructing an annual database spanning 2000-2016 (pre-COVID) and evaluating the impact of monetary and macroprudential policies on local banking performance at the municipality-bank level using crossed multilevel models and, secondarily, spatial panels as a robustness check. Results indicate the significant impact of these variables on local funding and functionality, with institutional and regional aspects influencing this causal relationship. Changes in monetary policy have a greater impact on banking functionality in less developed regions, ultimately hindering investment and development prospects in these areas.

KEYWORDS: Monetary policy; financial system; functionality; regions
JEL CLASSIFICATION: E52; G21; R12

Resumo

Mecanismos de política monetária são estudados há muito tempo, com crescente interesse em seus efeitos sobre diversas dimensões de desigualdade, incluindo as regionais. Enquanto a maioria destes estudos se concentra nos impactos gerais sobre a renda e os preços regionais, poucos se dedicaram a analisar os efeitos sobre o funcionamento do sistema bancário em diferentes municípios. Este estudo investiga os efeitos regionais da política monetária sobre a funcionalidade e funding bancários, avaliando como os bancos em diferentes municípios ajustam seus ativos e passivos. A presente pesquisa inova ao construir uma base de dados anual, de 2000 a 2016 (pré-covid), e ao avaliar o impacto de políticas monetárias e macroprudenciais na funcionalidade bancária local, no nível de município-banco, utilizando modelos cruzados e, secundariamente, painéis espaciais como verificação de robustez. Os resultados indicam o impacto significativo dessas variáveis sobre a funcionalidade e funding locais, com aspectos institucionais e regionais influenciando essa relação causal. Mudanças na política monetária têm um impacto maior sobre a função bancária em regiões menos desenvolvidas, dificultando, assim, as perspectivas de investimento e desenvolvimento nessas áreas.

PALAVRAS-CHAVE: Política monetária; sistema financeiro; funcionalidade; regiões
CLASSIFICAÇÃO JEL: E52; G21; R12

ÁREA ANPEC 2: Macroeconomia, Economia Monetária e Finanças

1. Introduction

Prior to the 2008 financial crisis, most central banks' monetary policies were conventionally based on targeting inflation, which effectively plunged inflation to historically low levels. However, the crisis revealed the limits of this approach. When interest rates were quickly cut to zero, traditional tools became limited by the zero lower bound. In response, central banks adopted unconventional policies, including quantitative easing (the purchase of government bonds to add liquidity), credit easing (the purchase of private sector assets), forward guidance (influencing expectations about future interest rates), and interest payments on reserves. These strategies addressed new concerns, including preventing deflation, maintaining demand when traditional policies failed, and ensuring financial stability by directly addressing stressed markets and spreads (Campante et al., 2021).

The effectiveness of these unconventional policies has been studied over the past decade. Some scholars have been studying how to incorporate the financial sector into standard economic models to account for post-crisis developments, demonstrating that finance can both initiate shocks and amplify disturbances, thereby altering the way monetary policy operates. This broader view enables analysis of how central banks can respond not only to traditional macroeconomic fluctuations but also to crises rooted in financial instability. The urgency of these issues reemerged with the Covid-19 crisis, when central banks worldwide once again lowered rates to the zero bound and launched massive liquidity programs, this time with broad participation from emerging economies. The experience highlighted the close connection between monetary policy, finance, and stability in modern macroeconomics.

While the growing interest in understanding the mechanisms of the financial system is welcome, there remains a lack of studies on how it operates at the subnational (firm or regional) level. Most specifically, few studies have examined how transmission channels, when institutional and regional differences are considered, affect liquidity, risk, and inflation. National policies often have uneven effects across regions due to structural and economic differences, underscoring the importance of understanding the regional impacts of monetary policy (Drechsler et al., 2017). Variations in industrial mark-ups, financial development, market concentration, labor market flexibility, and exposure to interest-rate-sensitive sectors can yield different policy outcomes. This spatial asymmetry can increase regional inequalities, undermining objectives of fairness and cohesive growth.

Awareness of the financial sector regional dynamics improves coordination among monetary, fiscal, and regional development policies. Identifying where targeted fiscal transfers, credit guarantees, or investment incentives are necessary to mitigate adverse local policy effects. Indeed, recognizing regional disparities also enhances the legitimacy of central banks. Advances in empirical research now enable a rigorous assessment of these regional impacts, making studies and research on the topic vital for informing national macroeconomic strategy.

The present study analyzes the impact of changes in national short-term interest rates on variables related to credit operations and medium- to long-term deposits (time deposits) at different levels of aggregation across banking branches and municipalities. The main objective is to analyze the effects of monetary policies at the subnational level, with a specific focus on banks' branches and regions. A Bayesian crossed model and a spatial panel model were implemented on banking data collected from municipalities' consolidated balance sheets. The use of Bayesian crossed models for this analysis of monetary policy efficiency is, to the best of our knowledge, novel. Besides this introduction, the remainder of this chapter is organized into literature review, methodology, results, and final remarks.

2. Financial systems' functionality and regional impacts of monetary policy

Economic activity unfolds through a dynamic circuit in which finance, investment, savings, and funding are interdependent stages of the same process. Expenditures precede both savings and taxation, and the Keynesian multiplier ensures that the initial act of financing generates income in excess of the original outlay. The injection of credit into the economic system activates the multiplier mechanism, expanding output and employment through successive rounds of expenditure (Barbosa, Alencar, & Diniz, 2016). Firms

initiate investment by obtaining bank loans, transforming borrowed funds into productive capital and future cash flows. These flows, once distributed as wages and profits, generate savings that return to the financial system, providing the resources required to fund long-term assets and maintain a balance between the maturities of assets and liabilities. The financial system fulfills its developmental function when it supports investment while preserving liquidity and maturity coherence within its operations.

The effectiveness of this finance–funding circuit depends on financial institutions' capacity to sustain credit creation without generating instability. In well-developed systems, the transformation of finance into funding occurs smoothly, allowing investment cycles to proceed without liquidity shortages or excessive fragility. However, in economies or regions with incomplete financial structures, the circuit is often interrupted between the investment and funding stages, constraining productive activity and increasing dependence on external financing. Functionality, in this sense, implies not only the availability of credit but also the institutional mechanisms that ensure its continuity and efficient allocation to productive uses (Studart, 1993, 1995).

Regional disparities in financial development generate asymmetric responses to monetary and credit policies. Peripheral regions, with lower income levels, limited savings, and scarce access to credit markets, are more vulnerable to restrictive conditions, while central regions, endowed with diversified investment sources and mature financial systems, maintain greater resilience and capacity to absorb shocks (Cavalcante, 2018). The coherence of the finance–investment–saving–funding circuit thus determines how effectively financial flows support growth, with a functional financial system ensuring that short-term finance evolves into long-term funding, sustaining both investment and stability. Empirical evidence supports these structural asymmetries. Cavalcante et al. (2004), using data from the Brazilian Central Bank, demonstrate that wealthier regions display lower liquidity preferences for public and bank assets, while poorer regions exhibit higher liquidity preferences, reflecting greater limited confidence and fewer investment opportunities. Crocco et al. (2010) show that banking activity in Brazil is spatially concentrated: areas with higher credit volumes tend to cluster, surrounded by regions with lower lending activity. In a complementary analysis, Crocco et al. (2011) find evidence consistent with credit rationing: the regional credit gap, defined as the regional difference between actual and potential credit-to-GDP ratios, narrows with larger deposit bases in more developed regions but responds nonlinearly to population size. Similarly, Nogueira et al. (2009), applying principal component and cluster analyses, find evidence supporting that bank branches in wealthier Brazilian states, particularly in the South and Southeast, lend substantially more than those in poorer regions, evidencing a center–periphery divide in credit distribution and financial functionality.

In its own turn, monetary policy influences the real economy through a network of interconnected transmission channels that operate simultaneously. Conventional rates move primarily through changes in interest rates, expectations, exchange rates, and bank-funding margins, with spillovers to valuations, balance sheets, and risk appetite. At or near the lower bound, non-standard measures such as targeted refinancing operations, asset purchases, and negative rates recalibrate money creation, funding costs, capital constraints, and risk-taking. The net macroeconomic effect depends on how these channels align with prevailing financial conditions, the health of banks and borrowers, and collateral valuations, as well as the openness of the economy, as factors that determine how powerfully monetary policy translates into output and inflation.

The regional transmission of monetary policy operates through complex interactions between financial structures, credit markets, and asset dynamics that vary substantially across territories. Financial intermediaries' balance-sheet positions play a decisive role in shaping how policy impulses propagate spatially. Dow and Montagnoli (2007) postulate that there are three channels through which monetary policy is transmitted from the central bank to the regions. Those three channels are banking lending channels (intra-regional differences between banks and also more funds available in core regions), borrowing channels (related to the borrower, with core regions being characterized by possessing wealthier clients than peripheral regions), and expectations/confidence channels (peripheral regions are riskier and have higher levels of uncertainty than core regions).

As argued by Bernanke and Gertler (1995) and later by Kashyap and Stein (2000), the credit channel magnifies regional asymmetries, since differences in bank capitalization, liquidity, and access to funding determine the degree of pass-through from policy rates to credit availability. In regions with deeper credit markets and more diversified financial networks, monetary shocks are absorbed with relative stability. Conversely, areas characterized by shallow financial systems or limited interbank connectivity experience delayed and amplified effects, as lending constraints bind more tightly during contractionary phases. Empirical analyses by Ciccarelli and Rebucci (2006) and Peersman and Smets (2005) confirm that variations in financial intermediation and industrial specialization remain central determinants of the heterogeneous transmission of monetary policy across the Euro area.

These asymmetries are further reinforced by mechanisms described in the financial accelerator framework. Building on Bernanke et al. (1996), Azevedo et al. (2025) emphasize that the interplay between borrower net worth, collateral valuation, and lender risk perception can generate region-specific amplification cycles. Monetary tightening reduces asset prices and collateral values, lowering firms' and households' borrowing capacity, thereby constraining investment and spending. Regions heavily dependent on collateralized credit, especially those with high leverage ratios or weak asset markets, are thus more exposed to procyclical credit contractions. In contrast, more diversified regions, where firms rely on internal financing or stable credit lines, display smaller output fluctuations in response to the same policy shock. These nonlinearities suggest that financial structure, rather than monetary stance alone, dictates the depth and persistence of regional cycles.

Empirical investigations support these theoretical mechanisms. Carlino and DeFina (1998) identified systematic regional differences in the responsiveness of output and employment to monetary shocks across U.S. states, attributing them to industrial composition and the degree of banking concentration. Arnold and Vrugt (2002) studied the impact of monetary policy on combinations of sectors and regions in the Netherlands using a VAR for the period between 1973 and 1993. They find evidence of different regional effects of monetary policy across regions, and that these impacts are also correlated with the sector composition of each region's economic activities. Similarly, Fratzscher et al. (2016) show that financial integration and institutional design shape the extent to which monetary policy promotes convergence or divergence among European regions. The persistence of such disparities implies that even within integrated monetary unions, transmission remains geographically fragmented.

Fraser et al. (2014) analyzed the impact of interest rates, commodity prices, among others, on variables related to GDP in Australia. By deploying Structural Vector Auto-Regressive (SVAR) on data from 1986 to 2008, the authors find regional differences in the effect of monetary policy on economic variables, with poorer states being the most affected. Pizzuto (2020) analyzes the evidence for differences in the impact of monetary policy across US regions by deploying a narrative approach to unexpected monetary policy changes (usually represented by unexpected changes in the FED funds rate) alongside a spatialized approach using a spatial weight matrix. The author concludes that there is evidence for the interest rate and housing market channels. In contrast, there is no evidence of a credit channel in the heterogeneous effects of monetary policy on American regions.

Bertanha and Haddad (2006) employed a spatial VAR study that examined the impacts of monetary policy on employment from 1995 to 2005 in Brazil. The authors employed three weight matrices (trade-weighted, queen, and no spatial weights) and found that spatial effects tend to concentrate the impact of monetary policy in Brazil. In contrast, using a non-spatial weight matrix tends to disperse the effect of monetary policy on employment, resulting in a thinner spatial impact. More recently, Dutra et al. (2017) employed VAR to analyze the impact of monetary policy on liquidity preference and credit provision (a proxy for uncertainty) by Brazilian regions between January 2003 and December 2012. Their conclusions align with the referenced literature: less developed regions are more susceptible to shocks from monetary policy. Carvalho et al. (2020), in turn, analyze the impact of monetary policy on credit for the Brazilian Southeast region. Using data from 2002 to 2012 and dynamic panel methods, the authors find that a monetary policy tightening affects credit differently across regions, depending on whether they are in the center or the periphery. In that way, credit in peripheral regions is more negatively affected by changes in the interest

rate than in central regions. Analogously, an interest rate reduction also positively affects the credit more in those peripheral regions than in central regions.

More recent research extends the analysis to asset-price and housing-market channels, highlighting their growing importance in regional monetary dynamics. Iacoviello and Minetti (2008) demonstrate that fluctuations in housing wealth and household leverage mediate the strength of monetary transmission across local economies, while Tagkalakis, et al. (2019) find that differences in banking concentration and property market exposure explain variations in regional inequality following monetary shocks. These findings point to the increasing role of housing and asset markets in shaping spatially uneven policy outcomes. Together, this body of evidence underscores that aggregate indicators cannot fully capture the regional effects of monetary policy. Understanding them requires a multidimensional approach that integrates macro-financial linkages, spatial structures, and institutional heterogeneity to explain why a uniform monetary stance produces diverse outcomes across regions.

In this context, this study seeks to understand how Brazilian monetary policy affects the funding and bank functionality at the regional level. Assuming the finance-investment-savings-funding circuit and the monetary policy transmission channels, it is expected that a change in monetary policy will diversely affect banks across regions. Thus, a monetary policy tightening would reduce credit availability and economic activity, thereby reducing funding options as income, the deposit base, and savings fall. Higher interest rates also raise lending rates and funding costs, making it more difficult for banks to manage their assets and liabilities. Finally, a tighter monetary policy affects expectations of economic growth and future prospects, thereby reducing investment.

According to the literature, one should expect banks in peripheral regions to be the most affected, as they deal with worse local economic prospects and a higher liquidity preference than those in central regions. This expectation stems from the analysis of the channels of monetary policy at work in response to a change in interest rates. In that way, an increase in interest rates implies a reduction in the credit available in the economy and the functionality of the banking system, since banks now tend to lend at higher rates, and the economic activity may fall, inducing fund shortages. At the same time, asset prices tend to fall, reducing profit prospects. Hence, this change in interest rates also reduces deposits and increases funding costs, especially long-term ones. In terms of regional responses, developed regions tend to rely on a more diverse set of funding options than less developed regions, which makes them less affected by contractionary monetary policy.

From this perspective, this study uses two methods to analyze the regional impact of monetary policy on local banking performance: cross-sectional models and spatial panel methods. With the regional effects of monetary policy appropriately discussed, the following section presents data and methodology.

3. Methodology

3.1. Data sources and Variables

The analysis relies on two dependent variables derived from the Brazilian Central Bank's ESTBAN[1] database, both designed to capture funding and functionality of bank branches at the municipal level. The first is the ratio of time deposits to total deposits, which indicates the degree to which a bank can manage its short- and long-term liabilities, thereby mitigating finance–funding mismatches. The second is the ratio of time deposits to loans, which serves as a proxy for a branch's ability to balance the maturity of its long-term assets and liabilities, reflecting its capacity to sustain credit operations. Together, these indicators reveal how banks effectively balance liquidity and maturity transformation, key aspects of financial functionality at the local scale.

In short, higher values of the time deposits-total deposits ratio denote greater capacity to manage deposit maturities and, consequently, stronger liquidity management. Conversely, the time deposits–loans ratio

[1] ESTBAN consist of consolidated banking statistics released monthly by the Brazilian Central Bank. They are released in two levels of analysis, which are the bank-municipal level, which we use in this work, and the bank branch-municipal level.

measures how branches sustain credit expansion while maintaining stable funding structures. The empirical model assesses the sensitivity of these two measures to changes in the SELIC rate (the Central Bank's policy rate), anticipating a negative relationship. Regional differences in this relationship are then explored, reflecting structural heterogeneity across Brazilian regions.

To capture additional dimensions of monetary policy, the model includes the reserve requirement computed per branch and a dummy variable for capital requirement tightening. Control variables include the SELIC rate, average municipal formal-sector wages, time (in years since 2000), and categorical variables indicating whether the branch is publicly owned, located in a state capital, or not one of the top five banks in Brazil by asset size. These variables collectively enable a comprehensive assessment of how monetary policy and institutional factors influence funding and functionality conditions within the Brazilian banking system. The following. Table 1 explains the variables and their sources.

Table 1. Variables and their sources

Variables	Description	Source
Funding	Time Deposits/Total Deposits (log)	Author's elaboration from ESTBAN (Brazilian Central Bank)
Functionality	Time Deposits/ Loans (log)	Author's elaboration from ESTBAN (Brazilian Central Bank)
$Year_{ij(kl)}$	Year (2000-2019), recoded to start from 0	Author' elaboration
$Wages_{..(il)}$	Mean of formal workforce wages in each municipality	Author's elaboration from RAIS, Ministry of Labor
Adapted RR	Reserve requirements proxy[2]	Author's elaboration from the Brazilian Central Bank
$Capital_Requirements_{..(..)}$	Capital requirements change for banks. This dummy assumes the value of 1 for tightening and 0 otherwise.	Alam et al. (2019)
$SELIC_{..(..)}$	National short-term interest rates	Brazilian Central Bank
$NTOP5_{..(..)}$	Dummy for whether or not a bank institution does not belong to the TOP 5 institutions, according to their assets, as in 2019.	Author's elaboration, based on Valor Econômico's rank.
State Capitals	Dummy for whether a municipality is a state capital or not	IBGE (2020)
$Public_{..(..)}$	Dummy for whether a bank institution is at least partially government-owned or not.	Brazilian Central Bank (2020)

Note: Author's elaboration.

3.2. Descriptive Statistics

In this section, we describe the data used in this analysis. It consists of 76653 observations, divided into five regions: North (3451), Northeast (15963), Midwest (7157), Southeast (30923), and South (19159). We display the means and standard deviations of all dependent and independent variables in Table 2.

Table 2. Descriptive Statistics

Variable	Northern	Northeast	Southeast	Southern	Midwest
Time Deposits/Total Deposits (Funding)	0.171 (0.186)	0.155 (0.170)	0.242 (0.209)	0.205 (0.212)	0.226 (0.192)
Time Deposits/Loans[3] (Functionality)	49.727 (5176.451)	0.932 (6.218)	3.944 (364.899)	1.245 (27.159)	0.894 (5.324)
Wages	1747.060 (753.537)	1486.120 (649.184)	1818.493 (802.998)	1728.226 (684.127)	1747.328 (876.308)

[2] It was calculated by the following quotient: (Total Deposits-Savings)/mean(Reserves), where mean(Reserves) is an average of the account 113 from ESTBAN across the branches that belong to the same bank.

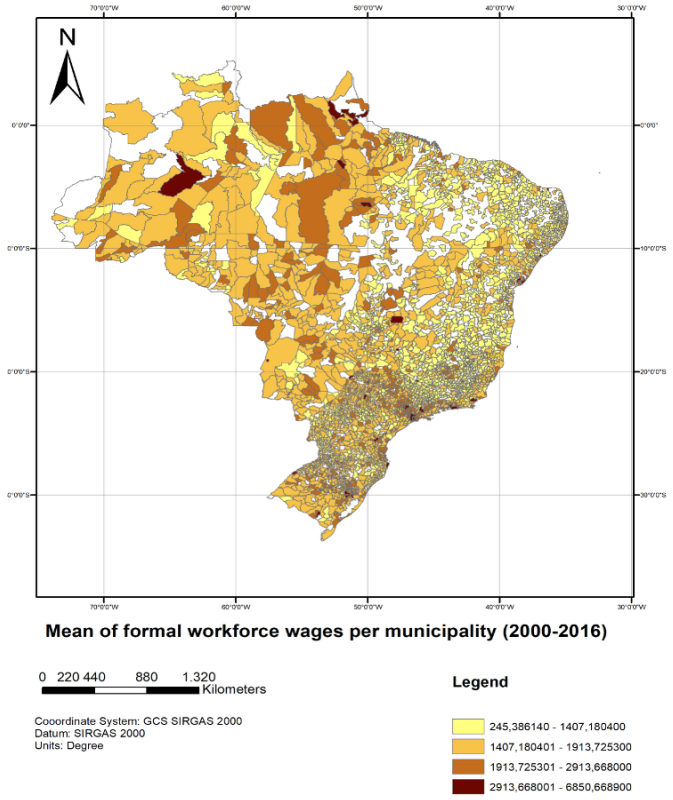
[3] Loans and discounted debts account in the ESTBAN data.

N-Top5	0	0.038	0.021	0.005	0.012
		(0.192)	(0.143)	(0.073)	(0.108)
Capitals	0.118	0.037	0.029	0.019	0.045
	(0.323)	(0.189)	(0.169)	(0.135)	(0.208)
Public	0.669	0.781	0.608	0.682	0.499
	(0.470)	(0.414)	(0.488)	(0.466)	(0.490)

Note: Author's elaboration.

The following figures display the spatial distribution of the two dependent variables and the formal workforce wages. The three variables are averaged over all municipalities for all years. Figure 1 displays the map of formal workforce wages for all municipalities in the sample. The figure shows that higher wages tend to be concentrated in the South and Southeast, as expected, given their higher population and economic concentration.

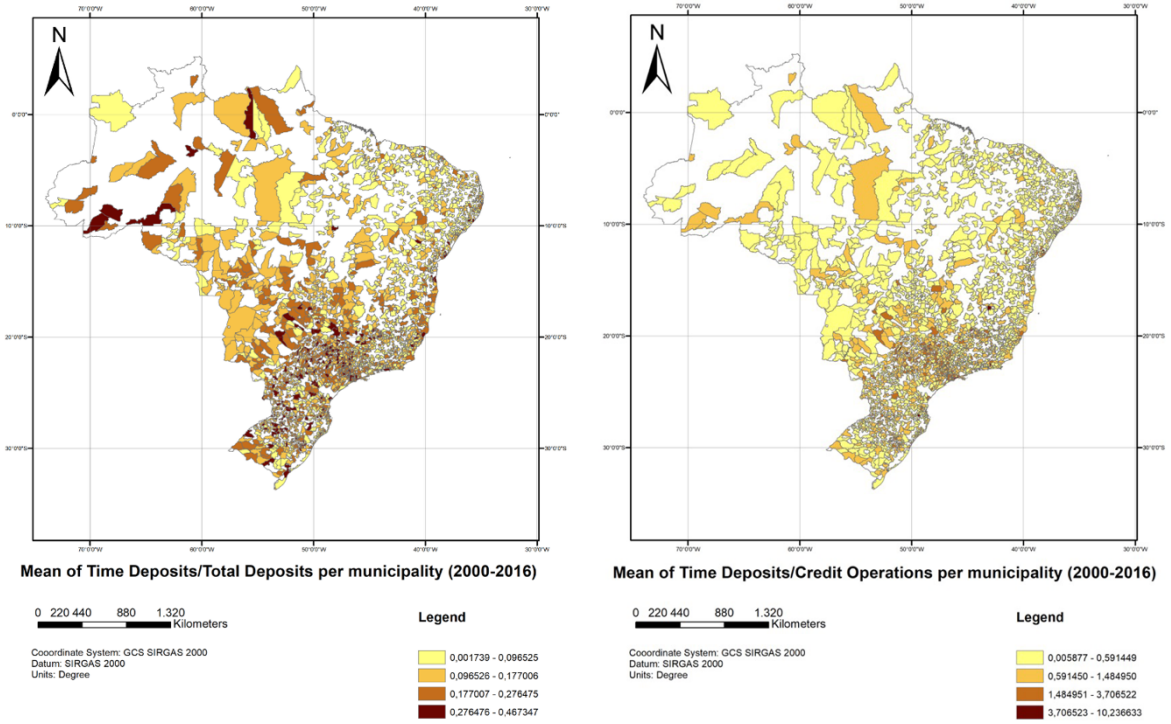
Figure 1. Mean of formal workforce wages per municipality (2000-2019)



Note: Author's elaboration from RAIS data.

Figure 2 displays funding and functionality across municipalities. The figure shows that bank branches in municipalities in developed regions (Southeast and South) have higher funding ratios than those in less developed regions. Moreover, banking functionality is also highly concentrated in the southeast portion of the country.

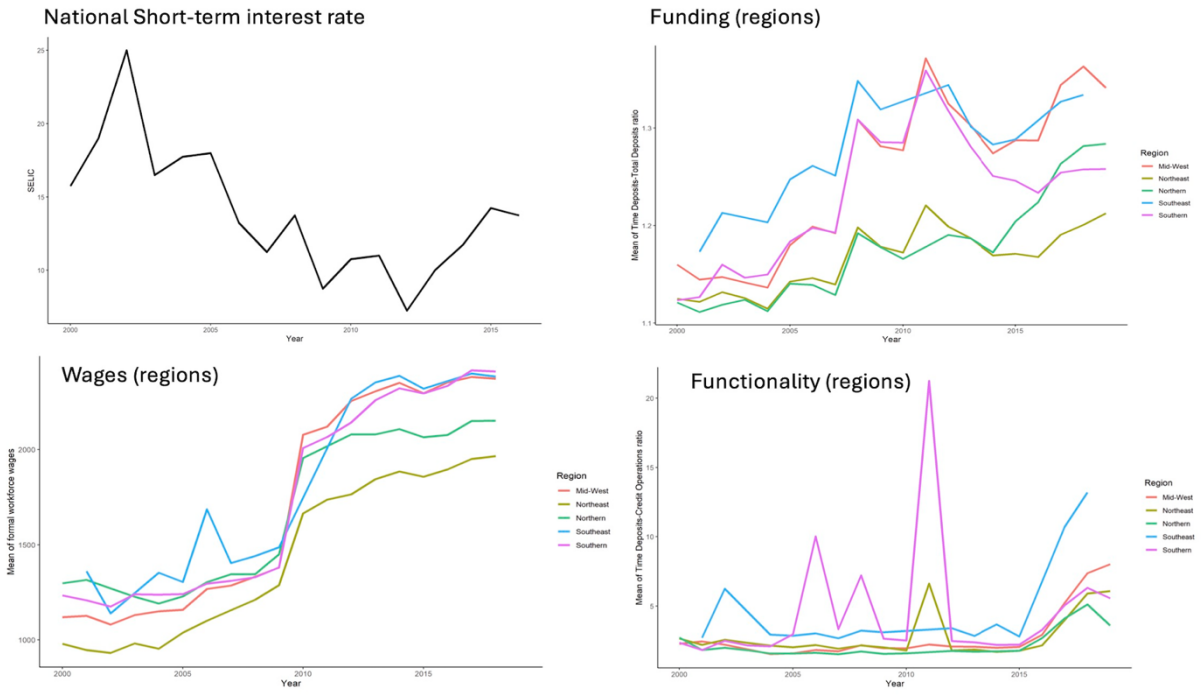
Figure 2. Banks Branches' Funding and Functionality ratio per municipality (2000-2016)



Note: Author elaboration from ESTBAN data.

Figure 3 displays four graphs: the first (top left) is the SELIC interest rate for 2000-2016. It is evident that national interest rates decreased during the period, reflecting the worldwide decline in interest rates before and after the 2007 financial crisis. From 2013 onwards, the Brazilian Central Bank began raising rates following an increase in inflation. In terms of wages (Bottom left), one can see that average wages increased across all regions, with the South and Southeast regions showing the largest increases.

Figure 3. Evolution of SELIC, wages, Time Deposits/Total Deposits, and Time Deposits/Loans per year and region



Note: Author's elaboration.

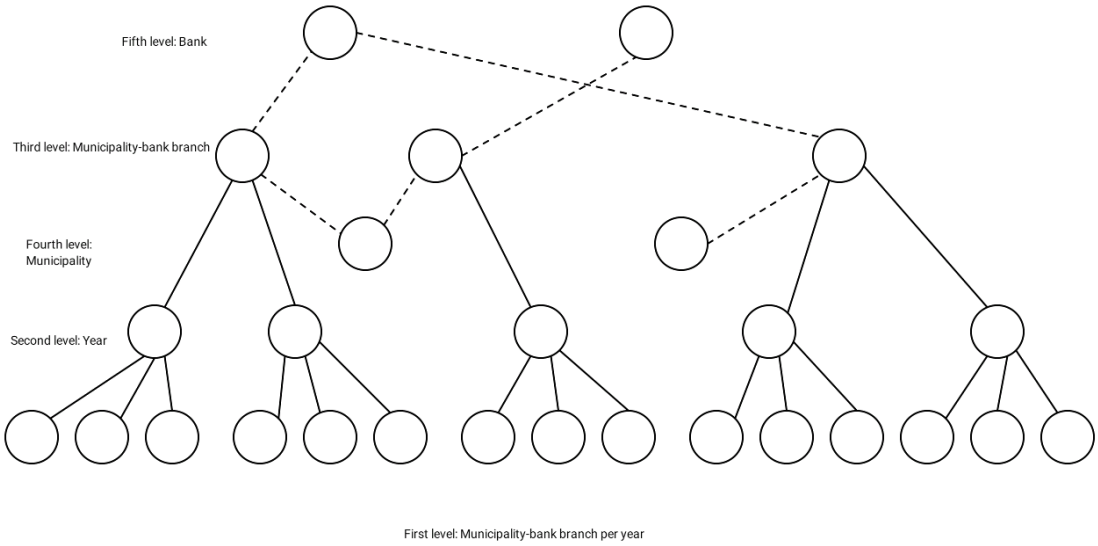
Figure 3 also displays the evolution of average funding (Time Deposits/Total Deposits ratio) per year and region (top right). Funding also improved through the years analyzed. Finally, at the bottom right, we display a graph of the average banks' functionality (Time Deposits/Credit Operations ratio) per year and region. Funding and functionality indicators show a striking difference between the Southeast, South, and Midwest regions and the North and Northeast, with the former showing banks with greater capacity to manage finance and funding.

3.3. Methodology: Bayesian crossed models

Bayesian crossed models are a generalization of hierarchical mixed models. In the latter models, data are usually nested within levels. Crossed models, in turn, do not require nested data; rather, they assume crossed data, i.e., lower levels belong to categories at each level that are not necessarily nested within each other. For instance, a purely hierarchical structure of banking data could be seen as branches nested within each correspondent bank. The novelty of this study is to make this nesting requirement more flexible by also considering the municipalities where each branch is located. In that way, a bank branch belongs to bank *i* and it is located inside municipality *j*. Logically, neither all banks *i* are located in municipality *j*, nor all *j* include banks *i*. That crossed design motivates the analysis as crossed models allow us to consider both the banking and the spatial characteristics of banks' activities. Alternatively, hierarchical models are more restrictive as they require choosing between analyzing the bank or the spatial structure. In this way, the generality[4] of the crossed models is more significant than that of hierarchical models, allowing us to capture the similarities and differences among banks and municipalities in the dependent variables.

Figure 4 synthesizes the crossed and nested character of the Brazilian Central Bank ESTBAN data, with the continuous line indicating a nesting structure among the levels. In contrast, the dotted line indicates a crossing nature among the levels.

Figure 4. Diagram of Crossed Design of the banking system



Source: Author's elaboration.

The first level comprises the municipality-bank combination in a single year. The second level, which nests the first one, consists of the years. The third level consists of each pair of municipality banks in the analysis. The fourth level consists of all municipalities in the analysis that are at the third level. The fifth level, crossed with the fourth level, consists of the banking institutions, which also nest the third level.

[4] A simple fixed-effect model may also be used for the data at hand. However, the fixed-effects model could not provide an answer regarding the relevance of the spatial (municipal) and the institutional levels at accounting for the error term in our modelling. In that way, the crossed model, contrary to the fixed-effects model, allows for a simple and effective way to analyze the source of the error term, explaining whether it comes from spatial characteristics of the municipalities where an observation is located or if it comes from a bank institutional aspect.

Crossed models may possess complex, numerous structures of fixed and random effects and variance components. The present study estimates these models using Restricted Maximum Likelihood (REML), as implemented in the lme4 package in R (Bates et al., 2015). REML is the standard frequentist approach for mixed-effects models: unlike ordinary maximum likelihood, it accounts for the degrees of freedom consumed by fixed effects when estimating variance components, yielding unbiased estimates of the random-effect structure. This property is particularly important in the present context, where the crossed design generates multiple variance components at the bank, municipality, municipality-bank pair, and year levels simultaneously. In the present case, the equation estimated is Equation (1).

$$Y_{ijk(lm)} \sim N(XB, \Omega)$$

$$\begin{aligned} Y_{ijk(lm)} = \beta_{0.jk(lm)} + \beta_1 * \text{SELIC}_{\ldots\ldots} + \beta_2 * \text{Capitalrequirements}_{\ldots\ldots} + \beta_3 \\ * \text{AdaptedReserveRequirements}_{\ldots k(\ldots)} + \beta_4 * \text{Ntop5}_{\ldots(l.)} + \beta_5 * \text{public}_{\ldots(l.)} + \beta_6 \\ * \text{statecapitals}_{\ldots(.m)} + \beta_7 * \text{wages}_{\ldots(.m)} \end{aligned} \quad (1)$$

$$\beta_{0ijk(lm)} = \beta_0 + u_{0,bank} + u_{0,municipality} + u_{0,bank-municipality} + u_{0,year} + e_{0ijk(lm)}$$

Where $Y_{ijk(lm)}$ is the dependent variable (linear) $SELIC$ (the short-term national interest rate), $Capitalrequirements$ is the dummy for capital requirements tightening in a given year, $AdaptedReserveRequirements_{\ldots k(\ldots)}$ is the adapted reserve requirements, $Ntop5_{\ldots(l.)}$ is a dummy for whether a bank is a TOP 5 bank, $public_{\ldots(l.)}$ is a dummy for whether a bank is public or not, $statecapitals_{\ldots(.m)}$ is a dummy for whether the municipality of a bank's branch is a state capital or not, and $wages_{\ldots(.m)}$ is the municipal average of the formal workforce wages. The index ijk(lm) indicates that the lower three levels (ijk) are nested within the two crossed levels (lm), banking institution and municipality, with i corresponding to each observation, j corresponding to the year, k corresponding to each pair of municipality-branch present in the data, l corresponding to banks, and m corresponding to the municipalities.

In the REML framework, inference on fixed effects is conducted through t-statistics and confidence intervals, with degrees of freedom approximated via the Satterthwaite method to account for the unbalanced crossed structure of the data. Each fixed-effect coefficient measures the expected change in the dependent variable associated with a one-unit change in the corresponding predictor, holding all other variables constant. Variance components decompose the residual variance across the levels of the crossed structure (bank, municipality, municipality–bank pair, year, and observation), allowing us to quantify how much of the unexplained variation in banking outcomes originates from institutional characteristics versus local economic conditions. This decomposition is one of the key analytical contributions of the crossed model relative to a standard fixed-effects specification, which cannot separately identify these two sources of heterogeneity.

3.4. Spatial panel models

Spatial econometrics methods can also account for the spatial and institutional structures of banks' branches, complementing the crossed multilevel model by explicitly modeling spatial dependence among municipalities. One critical difference between the two approaches lies in how they handle the error term: while the crossed multilevel model treats residual variance hierarchically, the spatial panel model (Equation 2) accounts for deterministic spatial regularities in the dependent variable and the error structure.

$$\begin{aligned} Y_{ijklm} = \beta_0 + \beta_1 * SELIC_{\ldots\ldots} + \beta_2 * Capitalrequirements + \beta_3 \\ * AdaptedReserveRequirements_{\ldots k\ldots} + \beta_4 * Ntop5_{\ldots l.} + \beta_5 * public_{\ldots l.} + \beta_6 \\ * state\ capitals + \beta_7 * wages_{\ldots\ldots m} + \beta_8 * W * Y_{ijklm} + e_{0ijklm} \\ \epsilon_{0ijklm} = \theta * W * \epsilon_{0ijklm} + u_t \end{aligned} \quad (2)$$

When compared to the crossed multilevel model, the spatial panel introduces two additional terms: W*Y (the spatially lagged dependent variable) and θ, the auto-regressive term of the error[5]. W is the spatial weight matrix. In this work, given the non-contiguity of the data, we opt to use an 8-nearest-neighbor weight matrix, following Crocco *et al.* (2010). One advantage of spatial panel modeling is that it allows for some spatial determinism to be considered in the model. In this way, this study considers the possible impact of the dependent variable values of 8 neighbors on the current value of our dependent variable for a bank in a given municipality. The non-contiguity of the data also explains the use of a neighbor spatial weight matrix; that is, the model's observations do not occupy a single polygon. In that way, distance-based spatial matrices, such as neighbor spatial weight matrices, are more commonly used.

The spatial model is estimated using the Generalized Moments Combo (GM-Combo) method, as implemented in the spreg module of PySAL (Anselin et al., 2013). GM-Combo belongs to the class of Generalized Method of Moments (GMM) estimators developed by Kelejian and Prucha (1998, 2010) for SARAR models, that is, models with both a spatially lagged dependent variable and spatially autocorrelated errors. In this approach, the spatially lagged dependent variable $W \cdot Y$ is instrumented with spatial lags of the exogenous regressors ($W \cdot X$ and $W^2 \cdot X$), while the spatial autoregressive parameter in the error term is estimated simultaneously via moment conditions. This two-step strategy yields consistent and asymptotically efficient estimates under broad conditions, including heteroskedastic and non-normal errors, making GM-Combo more robust than Maximum Likelihood estimation in settings where the distributional assumptions of ML may not hold (Arraiz et al., 2010; Drukker et al., 2013). The fixed-effect coefficients, and in particular the SELIC coefficient of primary interest, are consistent and directly comparable across both the GM-Combo and crossed multilevel model approaches.

Spatial econometric analysis requires careful interpretation of coefficients, as neighboring observations influence one another through spatial dependence. As Elhorst (2014) notes, values of the dependent variable, independent variables, and even the error term in neighboring locations can affect local outcomes. Consequently, a change in one observation may trigger effects that propagate through the spatial network, forming an infinite but convergent series of interactions. To correctly interpret results, it is necessary to decompose these interactions into direct, indirect, and total effects. The direct effect measures how a change in an explanatory variable influences the dependent variable in the exact location, while the indirect (spillover) effect captures its influence on neighboring observations through spatial links. The total effect combines both, reflecting the system's overall impact. Additionally, the sign and magnitude of spatially lagged terms, whether in the dependent variable or the error structure, provide insight into spatial patterns such as concentration or dispersion of the phenomenon under study.

4. Results

In this section, results from both crossed multilevel models and spatial models are presented. Table 3 shows results for funding (the log of the ratio of time deposits to total deposits) for each Brazilian macro region.

[5] The spatially lagged dependent variable and the spatially lagged error term might assume the same sign or the opposite sign. In the former case, the observable and non-observable characteristics of an observation's neighbors affect said observation in the same way, while in the latter case the opposite occurs, that is, the neighbors' observable characteristics affect an observation in a different manner from its non-observable characteristics. In the present estimation, the Lambda coefficient (spatial autoregression in the error term) is consistently positive across all regions, confirming positive spatial autocorrelation in the residuals. The Rho coefficient (spatially lagged dependent variable) is positive in most regions under GM-Combo. As discussed in Section 3.4, the sign of Rho is sensitive to the identification strategy of the estimator; under GM-Combo, the spatially lagged dependent variable is instrumented with spatial lags of the exogenous regressors, which may yield different parameter estimates than a full-system approach. This does not affect the consistency of the fixed-effect coefficients.

Table 3. Monetary policy impacts on funding for Brazilian regions – Crossed Model (REML)

Fixed Effects	South	North	Northeast	Southeast	Midwest
Year	**0.043*** **	**0.026*** **	**0.028** **	0.003	**0.063*** **
	(0.011)	**(0.011)**	**(0.011)**	(0.018)	**(0.014)**
SELIC	**-0.036** **	**-0.026** **	**-0.026** **	**-0.040** *	**-0.033** **
	(0.018)	**(0.013)**	**(0.013)**	**(0.021)**	**(0.015)**
Capital Req. Tightening	0.016	-0.065	0.005	0.052	-0.066
	(0.135)	(0.099)	(0.101)	(0.163)	(0.118)
Reserve Req.	-0.006	-0.007	-0.004	0.007	**-0.131*** **
	(0.005)	(0.029)	(0.015)	(0.006)	**(0.020)**
Non-Top5	0.204	-0.888	-0.211	-2.168	**-2.484*** **
	(0.940)	(0.779)	(0.727)	(1.820)	**(0.581)**
Public	-0.168	-0.781	-0.889	-0.276	-0.480
	(0.943)	(0.734)	(0.728)	(2.318)	(0.562)
Capital	**0.944*** **	**1.053*** **	**1.752*** **	**0.677*** **	**1.267*** **
	(0.244)	**(0.196)**	**(0.224)**	**(0.239)**	**(0.252)**
Wages	**0.090*** **	**0.091** **	**0.080*** **	**0.176*** **	0.045
	(0.015)	**(0.036)**	**(0.020)**	**(0.024)**	(0.035)
Constant	**-2.053** **	**-2.186*** **	**-2.508*** **	**-1.431**	**-2.289*** **
	(0.977)	**(0.638)**	**(0.690)**	**(1.527)**	**(0.513)**
Variance Components					
Bank Institutions	1.859	0.890	1.042	2.541	0.728
Municipality	0.413	0.330	0.581	0.338	0.328
Municipality-Bank	0.543	0.629	0.599	0.697	0.464
Year	0.234	0.161	0.173	0.282	0.199
Level 1	0.898	0.964	1.000	0.975	0.804
Sample					
Observations	36,691	5,199	21,981	26,179	6,369
Banks	51	6	9	11	8
Municipalities	865	122	650	602	174
Municipality-Banks	1,979	276	1,167	1,384	336
Years	17	17	17	17	17

Note: Standard deviations are reported inside the parentheses. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Wages and Reserve Requirements are standardized (z-score).

Results indicate that increases in the SELIC, the national short-term interest rate, negatively impacts funding across all regions. This coefficient assumes values in the (-0.4, -0.26) interval. This means that a 1 p.p. reduction in interest rates increases funding prospects by around 2.5-4%, with a lower effect for the poorest regions (Northern and Northeast), as expected. During the period of our analysis, the national interest rate declined, with two effects. First, as economic activity and income increase, so do bank deposits. Bond prices become more attractive, leading to a greater proportion of time deposits than other, more liquid deposits. Secondly, a reduction in interest rates increases the availability of credit in the economy, thereby incentivizing funding and increasing interbank competition for time deposits.

Regarding other variables in the model, wages and the dummy for state capitals are noteworthy. The dummy for state capital cities showed positive values across all regions, with higher values in the less developed regions. This indicates that bank branches in state capitals have greater funding capacity than branches in other municipalities, due to higher banking concentration and greater economic activity and deposit base. Higher coefficient values appear for capitals in less developed regions, which might indicate a higher regional concentration of banking branches in these regions. Wages were also significant, except for the

Midwest, with the highest value in the Southeast, which may reflect economic activity concentration in the region. Nonetheless, results for wages reflect the role of income growth in expanding time deposit bases, consistent with the finance–funding circuit dynamics discussed in Section 2. Thus, assuming the results from such a model, one would expect that bank branches in less developed regions would be more restricted in funding, as investment and savings in the circuit are prominent.

Also, by analyzing the effects on the variance component in the model, it is possible to conclude that regional differences in bank branches at the highest hierarchical level have a greater influence on changes in funding than lower-level categories, such as municipalities. Furthermore, results indicate that branches in the Southeast region have the greatest influence, suggesting that interest changes might have a comparatively smaller impact on banks' branches in other regions. Overall, Differences among bank institutions account for 79.8% of total variance in funding in the Southeast, 72.2% in the South, 35.2% in the North, 38.6% in the Northeast, and 34.5% in the Midwest. Comparatively, variance among municipalities accounts for only 1.4%, 3.6%, 4.8%, 12.0%, and 7.0%, respectively. The dominance of the institutional dimension over the municipal dimension is consistent across all regions, reinforcing the view that banking heterogeneity is primarily driven by differences among banks rather than by differences in the localities where they operate.

Table 4 presents the crossed multilevel model for banking functionality (the ratio of time deposits to loans).

Table 4. Monetary policy impacts on banking functionality for Brazilian regions, Crossed Model (REML)

Fixed Effects	**South**	**North**	**Northeast**	**Southeast**	**Midwest**
Year	**0.030****	0.021	-0.008	-0.014	**0.092*****
	(0.014)	(0.016)	(0.012)	(0.014)	**(0.021)**
SELIC	**-0.035****	-0.022	-0.022	**-0.031****	-0.035
	(0.016)	(0.019)	(0.014)	**(0.016)**	(0.024)
Capital Req.	-0.136	-0.193	-0.153	-0.097	-0.182
	(0.123)	(0.145)	(0.107)	(0.121)	(0.185)
Reserve Req.	-0.003	0.001	**0.029***	0.002	**-0.111*****
	(0.005)	(0.033)	**(0.017)**	(0.007)	**(0.023)**
Non-Top5	-0.523	-1.269	-0.634	-2.255	**-2.318****
	(1.203)	(0.774)	(0.866)	(1.903)	**(0.900)**
Public	-0.038	-0.879	-1.274	0.007	-0.469
	(1.206)	(0.729)	(0.868)	(2.415)	(0.880)
Capital	**1.329*****	**1.150*****	**1.778*****	**0.700*****	**1.805*****
	(0.277)	**(0.200)**	**(0.235)**	**(0.263)**	**(0.320)**
Wages	**0.112*****	**0.117*****	**0.092*****	**0.198*****	-0.024
	(0.017)	**(0.041)**	**(0.022)**	**(0.027)**	(0.041)
Constant	-0.765	-0.913	-0.653	-0.289	**-1.782****
	(1.213)	(0.691)	(0.810)	(1.559)	**(0.803)**
Variance Components					
Bank	2.384	0.878	1.241	2.645	1.163
Municipality	0.471	0.224	0.574	0.360	0.428
Municipality-Bank	0.610	0.801	0.743	0.800	0.586
Year	0.212	0.243	0.183	0.207	0.318
Level 1	0.995	1.083	1.140	1.103	0.921
Sample					
Observations	36,691	5,199	21,981	26,179	6,369

Banks	51	6	9	11	8
Municipalities	865	122	650	602	174
Municipality-Banks	1,979	276	1,167	1,384	336
Years	17	17	17	17	17

Note: Standard deviations are reported inside the parentheses. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. Wages and Reserve Requirements are standardized (z-score).

According to Table 4, results indicate that interest rates are a significant explanatory factor in the South and Southeast regions, suggesting that an increase in national interest rates decreases banking functionality by about 3% in these regions. Thus, reducing interest rates implies a proportionally greater increase in loans in those regions than in deposits. This is consistent with the theoretical approach discussed in section 2, which holds that monetary tightening reduces economic activity and funding options, impairing the finance-funding circuit, particularly in less developed regions. The North, Northeast, and Midwest coefficients are negative in sign but do not reach the significance level, reflecting the smaller sample sizes and greater institutional heterogeneity in those regions. Results also indicate that the dummies for state capitals were positive and significant across all regions, suggesting that a bank branch located in a state capital contributes relatively more to the banking system's functionality. The wages coefficient is positive and significant for all regions, indicating a positive impact of wages on time deposits and credit.

The public bank dummy does not reach statistical significance at conventional levels in the crossed multilevel model, likely reflecting the limited within-group variation of this institutional dummy across the crossed structure. Nonetheless, the descriptive evidence in Table A1 shows that public bank branches exhibit substantially lower functionality ratios than private banks in all regions, with the gap most pronounced in the Northeast (−70.7%) and North (−64.6%). These patterns are consistent with a different role for public banks: extending credit beyond what their time-deposit base would otherwise allow. This is captured descriptively but only partially identified through the fixed-effect coefficient.

In terms of variance decomposition, banks' branches are once again the most important category to explain differences in banking functionality. For the South, Southeast, North, Northeast, and Midwest regions, differences among institutions explain 77.7%, 77.5%, 28.6%, 41.0%, and 47.8% of the variance in functionality, respectively. Banks' branches in the Southeast and South regions explain the most variance, while the opposite occurs in the less developed regions, where the nested structure in the model (banks-municipalities) also contributes to variance explanation. Such results indicate that, apart from the share of variance not explained (residual), the pair banks-municipality in less developed areas can explain some of the variance, suggesting that policy transmission might be at work in banks in some places, possibly in important nodes of the banking regional network. However, in general, from Tables 3 and 4, differences originating from the branches are, on average, more important than those originating from the municipalities, with the Southeast region showing a greater weight of the error explained (when compared to other regions) than the municipalities.

Table 5 presents results for monetary policy impacts on funding from the spatial panel data model. The spatial panel model does not include public bank and non-top5 dummies, as these are collinear with the individual fixed effects in the panel specification. Results are analyzed together with total effects for each independent variable, which are presented in Appendix B.

Table 5. Monetary policy impacts on funding for Brazilian regions, Spatial Panel Model

Coefficients	South	North	Northeast	Southeast	Midwest
Year	**0.056*** **	**0.049*** **	**0.032*** **	**0.037*** **	**0.062*** **
	(0.002)	(0.005)	(0.003)	(0.003)	(0.004)
SELIC	**-0.035*** **	**-0.023*** **	**-0.025*** **	**-0.034*** **	**-0.030*** **
	(0.001)	(0.004)	(0.002)	(0.002)	(0.003)
Capital req. tightening	0.018	**-0.063** **	0.002	**0.049*** **	**-0.072*** **
	(0.011)	(0.032)	(0.017)	(0.015)	(0.025)
Reserve req. adapted	-0.003	-0.021	**0.042** **	0.008	**-0.142*** **
	(0.005)	(0.035)	(0.018)	(0.006)	(0.024)
Wages	**-0.073*** **	**0.087*** **	**0.042** **	**-0.044** **	**0.069** **
	(0.013)	(0.033)	(0.018)	(0.017)	(0.028)
W × Funding	**0.145*** **	-0.098	**0.124*** **	**0.248*** **	**0.111** **
	(0.025)	(0.094)	(0.047)	(0.037)	(0.046)
Lambda (W×error)	**0.2007**	**0.3846**	**0.1192**	**0.1551**	**0.2158**
Rho (W×Y)	**0.1454**	**-0.0978**	**0.1240**	**0.2479**	**0.1106**

*Note: Standard errors in parentheses. * p<0.1; ** p<0.05; *** p<0.01. Estimation: GM-Combo via PySAL/spreg (Python). 8-nearest-neighbor spatial weight matrix (Funding). Wages and reserve requirements standardized (z-score). Public and Non-Top5 omitted due to collinearity with individual fixed effects.*

Results indicate that coefficients for the short-term interest rate are significant and negative across all regions, meaning that a 1 p.p. decrease in the interest rate increases funding in the regions, with effects ranging from 2.3% in the North to 3.4% in the South. This confirms the robustness of the main finding in this study to the inclusion of spatial dependence in the model. Capital requirement tightening shows a significant negative effect in the North and Midwest and a positive effect in the Southeast, a result that warrants caution in interpretation, as the capital requirements dummy captures the timing of regulatory changes that may coincide with other aggregate shocks.

The dummy for public banks indicates a negative total effect for regions, except for the North and Midwest. This might indicate that regions with a higher share of public banks in the banking network are less sensitive to policy changes than those with a higher share of private banks. This would reflect a more prominent policy role for public banks. The wages' coefficient is significant across all regions, though it has a different sign in the Southeast, where it is negative. This mixed pattern is counterintuitive: an increase in income is supposed to favor savings and funding. An increase in wages (and economic activity overall) may boost demand deposits if liquidity preference rises, thereby negatively affecting banks' funding, a mechanism consistent with this study's perspectives on portfolio behavior in more developed regional economies. However, one should expect regional income flows to favor more developed regions, implying that growth in less developed regions would generate better funding prospects in more developed regions and their financial markets, a feature not captured by the model. Polarization forces might induce flows between regions in response to liquidity changes, potentially affecting funding. One should also note, in that regard, that the spatially lagged dependent variable is significant in all regions, but with diverse signs. While such a result indicates that neighboring municipalities in developed regions exhibit funding regional concentration, the opposite might occur in less developed regions. The Lambda coefficient is also positive across all regions, confirming the presence of positive spatial autocorrelation in the error term[6].

Table 6 presents results on the monetary impacts on bank branches' functionality from the spatial panel model. The SELIC coefficient remains negative and significant across all regions, corroborating our previous results. SELIC coefficients range from −0.021 in the North and Northeast to −0.034 in the South, consistent with the pattern observed for funding: the South exhibits the largest point estimate, while the North and Northeast show the smallest, reflecting the structural differences in financial development and monetary policy sensitivity across Brazilian regions.

[6] The sign and magnitude of these spatial parameters depend on the estimator's identification strategy and should be interpreted according to the GM-Combo methodology.

Table 6. Monetary policy impacts on functionality for Brazilian regions – Spatial Model

	South	North	Northeast	Southeast	Midwest
Year	**0.051*** **	**0.021*** **	−0.001	**0.014*** **	**0.081*** **
	(0.002)	**(0.006)**	(0.003)	**(0.003)**	**(0.005)**
SELIC	**-0.034*** **	**-0.021*** **	**-0.021*** **	**-0.027*** **	**-0.033*** **
	(0.002)	**(0.005)**	**(0.002)**	**(0.002)**	**(0.004)**
Capital req. tightening	**-0.118*** **	**-0.182*** **	**-0.148*** **	**-0.087*** **	**-0.187*** **
	(0.012)	**(0.036)**	**(0.019)**	**(0.017)**	**(0.029)**
Reserve Req.	-0.001	**-0.063**	**0.045** **	0.002	**-0.179*** **
	(0.005)	**(0.040)**	**(0.020)**	(0.007)	**(0.028)**
Wages	**-0.076*** **	**0.157*** **	**0.036***	0.020	**0.078** **
	(0.014)	**(0.037)**	**(0.021)**	(0.019)	**(0.033)**
W*functionality	**0.095*** **	0.002	**0.362*** **	0.093	**0.139*** **
	(0.034)	(0.127)	**(0.118)**	(0.079)	**(0.043)**
Lambda (W*error)	**0.2407**	**0.3062**	**-0.1371**	**0.2781**	**0.1864**
Sample					
N (obs)	37,601	5,244	22,173	26,296	6,384

Note: Standard errors in parentheses. * p<0.1; ** p<0.05; *** p<0.01. Estimation: GM-Combo via PySAL/spreg (Python). 8-nearest-neighbor spatial weight matrix (Functionality). Wages and reserve requirements standardized (z-score). Public and Non-Top5 omitted due to collinearity with individual fixed effects.

Capital requirement tightening is negative and significant across all five regions (ranging from −0.087 in the Southeast to −0.187 in the Midwest), consistent with macroprudential policy having a contractionary effect on credit activity beyond what the interest rate channel alone captures. The wages coefficient is negative for the South and positive for the North, Northeast, and Midwest, mirroring the mixed pattern observed in the funding equation and suggesting that the relationship between income and long-term deposit formation is also conditioned by regional financial structures and liquidity preferences, but in opposite directions. Instead of favoring flows to developed regions, income growth may be broadening the local deposit base, which in turn favors banks' local loans and increases functionality, a matter that should be further investigated.

The spatially lagged dependent variable is positive and significant in the South, Northeast, and Midwest, indicating positive spatial clustering of functionality. The Northeast exhibits the largest Rho coefficient, suggesting that spatial spillovers in credit activity are most pronounced there. This pattern is consistent with the concentration of banking activity in a small number of urban centers in the region, surrounded by municipalities with lower levels of financial development. The Lambda coefficient (spatial autocorrelation in the error term) is positive across most regions, confirming that unobserved local factors generating residual correlation are not purely idiosyncratic but spatially structured.

5. Final Remarks

This study analyzed the impact of changes in the Brazilian short-term interest rate (SELIC) on bank-level financing and funding within a municipality. The objective was to shed some light on the policy effects on the inner workings of the banking system. By employing both cross-sectional and spatial panel models, this study found a strong, negative relationship between the national short-term interest rate and banking funding and functionality at the bank level within a municipality. This result is consistent with the theoretical framework of the finance–investment–saving–funding circuit (Studart, 1995): monetary tightening raises the cost of credit and compresses banks' capacity to transform short-term finance into long-term funding. The SELIC rate emerges as a systematic and pervasive constraint on local banking

performance across all regions of Brazil. The Southeast and Southern regions showed significantly greater resilience to contractionary monetary policy compared to the Northern, Northeast, and Midwest regions. These asymmetries are consistent with the center–periphery dynamics described by Cavalcante (2018) and Crocco et al. (2010, 2011): peripheral regions, characterized by shallower financial systems, stronger liquidity preferences, and greater reliance on public credit, are more exposed to the contractionary effects of rising interest rates.

Moreover, the source of variance in the dependent variables, quotients of time deposits, total deposits, and credit operations, differed among the regions. Regarding *funding* (time deposits to total deposits), institutional characteristics at the bank level account for at least 34.5% of the variance in the error term in the Midwest and up to 79.8% in the Southeast. Municipal characteristics, in turn, account for a maximum of 12.0% of the error variance, corresponding to the Northeast region. This confirms that differences among banks' institutions, rather than among municipalities, are the primary driver of heterogeneity in funding behavior. Regarding the *functionality* ratio (time deposits to credit operations), institutional reality remains the dominant source of variance across all regions, with results similar to those for funding. This comparison shows that, even across different regions, the institutional reality is, on average, far more able to explain the heterogeneity in our model than municipal characteristics, a finding that persists across both the crossed multilevel and the spatial panel specifications.

Institutional factors played a more prominent role in the more developed South and Southeast, whereas municipal factors were more relevant in the Midwest and Northeast. This comparison indicates that, across regions, institutional factors are at least four times more influential than municipal factors in explaining variance. In contrast, the differences between minimum and maximum variance contributions are more pronounced for functionality than for funding. This is consistent with results indicating that, pending further investigation, public bank branches extended proportionally more credit relative to their time deposit base, particularly in the North (−64.6%) and Northeast (−70.7%), which may partially cushion the restrictive effects of monetary tightening in the less developed regions, and underscores the countercyclical role of state-owned financial institutions in Brazil's regional credit landscape.

Future research should explore other macroeconomic, institutional, and local variables to further clarify a bank's loan profile across different areas, especially in less developed regions, where results indicate a higher residual explanation for error variance. In particular, studies could explore the role of monetary policy expectations and forward guidance in shaping regional credit dynamics, as well as the differential response of public and private banks to macroprudential instruments such as reserve and capital requirements, variables whose regional effects remain only partially identified in the present analysis.

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Appendix

Table B1- Total effects of each variable for the spatial panel models for Log(Time Deposits/Total Deposits)

	South	North	Northeast	Southeast	Mid-West

Year	0.0513***	0.033***	0.058***	0.063***	0.056
	(0.003)	(0.005)	(0.003)	(0.002)	(0.004)
SELIC	-0.047***	-0.029***	-0.039***	-0.039***	-0.031***
	(0.002)	(0.004)	(0.002)	(0.002)	(0.003)
Reserve requirements adapted	1.42e-10*	7.58e-10	-9.07e-11	-1.72e-11***	-1.41e-10
	(8.03e-11)	(4.68e-10)	(1.36e-10)	(4.72e-12)	(1.24e-10)
Non-top 5	-0.335	-	0.033	0.192	-1.854***
	(0.319)		(0.152)	(0.229)	(0.321)
Public	-0.555***	-0.048	-0.178**	-0.550***	-0.235***
	(0.045)	(0.103)	(0.073)	(0.043)	(0.068)
Capital	0.533***	0.661***	0.940***	0.733***	0.426**
	(0.181)	(0.159)	(0.149)	(0.195)	(0.180)
Wages	-0.0001***	0.00008**	7.64e-07	-0.0001***	0.00005*
	(0.00002)	(0.00004)	(0.00002)	(0.00001)	(0.00003)

Note: p-value: *0.1; ** 0.05; *** 0.01. The standard deviations are reported inside parentheses.

Table B2- Total effects of each variable for the spatial panel models for Log(Time Deposits/Credit)

	South	**North**	**Northeast**	**Southeast**	**Mid-West**
Year	0.015***	-0.008	0.007**	0.039***	0.041***
	(0.003)	(0.006)	(0.003)	(0.002)	(0.005)
SELIC	-0.028***	-0.019***	-0.029***	-0.032***	-0.027***
	(0.002)	(0.005)	(0.002)	(0.002)	(0.004)
Reserve requirements adapted	-9.23e-11	3.04e-11	-4.30e-10***	-2.52e-11***	1.92e-10
	(1.02e-10)	(5.72e-10)	(1.61e-10)	(5.57e-12)	(1.45e-10)
Non-top 5	-0.6267	-	-1.298***	-0.753***	-2.379***
	(0.418)		(0.177)	(0.259)	(0.373)
Public	-0.750***	-1.232***	-1.498***	-1.278***	-0.711***
	(0.058)	(0.143)	(0.089)	(0.053)	(0.082)
Capital	0.549**	0.784***	1.085***	0.897***	0.522**
	(0.232)	(0.196)	(0.172)	(0.219)	(0.211)
Wages	-5.81e-06	0.0002***	0.00008**	-0.00005***	0.0002***
	(0.00002)	(0.00004)	(0.00003)	(0.00002)	(0.00004)

Note: p-value: *0.1; ** 0.05; *** 0.01. The standard deviations are reported inside parentheses.