V ENCONTRO DE ECONOMIA APLICADA - PPGE/UFJF
Área 01 - Economia Regional

Regional Heterogeneity in Brazil: a multivariate and spatial assessment of municipal development

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Abstract: This study examines regional socioeconomic heterogeneity across Brazil's 5,570 municipalities in 2022 by combining Principal Axis Factoring (PAF), Cluster Analysis, and Exploratory Spatial Data Analysis (ESDA). Three latent dimensions of municipal development emerge from the data: Urban and Infrastructure Consolidation, Socioeconomic Development and Productive Accumulation, and Financial Deepening. While the first two dimensions exhibit strong spatial autocorrelation and geographically contiguous patterns, Financial Deepening displays substantially weaker spatial dependence, indicating a more selective territorial organization centered on specific urban areas rather than on neighboring municipalities. These findings suggest that different dimensions of regional development follow distinct spatial regimes rather than a common process of territorial diffusion. By documenting these differentiated spatial configurations, the study contributes to the regional development and financial geography literatures through an updated multidimensional assessment of Brazilian municipalities.

Keywords: Exploratory statistical techniques; Regional heterogeneity; Brazil.

Heterogeneidade Regional no Brasil: uma avaliação multivariada e espacial do desenvolvimento municipal

Resumo: Este estudo examina a heterogeneidade socioeconômica regional dos 5.570 municípios brasileiros em 2022 por meio da combinação da Análise Fatorial por Eixos Principais (Principal Axis Factoring, PAF), da Análise de Agrupamentos (Cluster Analysis) e da Análise Exploratória de Dados Espaciais (AEDE). A análise identifica três dimensões latentes do desenvolvimento municipal: Consolidação Urbana e de Infraestrutura, Desenvolvimento Socioeconômico e Acumulação Produtiva e Aprofundamento Financeiro. Enquanto as duas primeiras apresentam elevada autocorrelação espacial e padrões geograficamente contíguos, o Aprofundamento Financeiro exibe dependência espacial substancialmente menor, indicando uma organização territorial mais seletiva, concentrada em centros urbanos específicos, em vez de se difundir entre municípios vizinhos. Esses resultados sugerem que diferentes dimensões do desenvolvimento regional seguem regimes espaciais distintos, em vez de um processo comum de difusão territorial. Ao documentar essas configurações espaciais diferenciadas, o estudo contribui para as literaturas de Economia Regional e Geografia Financeira ao oferecer uma avaliação multidimensional e atualizada dos municípios brasileiros.

Palavras-chave: Técnicas estatísticas exploratórias; Heterogeneidade regional; Brasil.

JEL Codes: C38, G21, O10, R12, R58.

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1 INTRODUCTION

Regional inequality remains a persistent feature of the Brazilian economy. Despite substantial economic and institutional transformations, economic activity continues to be disproportionately concentrated in the South, Southeast, and parts of the Central-West, whereas municipalities in the North and Northeast generally face more pronounced structural constraints (Azzoni; Castro, 2025). These disparities extend beyond differences in per capita Gross Domestic Product (GDP). They encompass unequal productive capacity, urban infrastructure, human capital, access to public services, and financial intermediation, reflecting the multidimensional nature of regional development (Araujo; Haddad, 2024; Ribeiro *et al.*, 2020).

The persistence of these disparities is consistent with a broad regional economics literature emphasizing cumulative, agglomerative, and path-dependent development processes. Circular and cumulative causation suggests that growth may reinforce existing territorial asymmetries when backwash effects outweigh the diffusion of economic gains toward peripheral regions (Myrdal, 1957). Similarly, New Economic Geography associates the spatial concentration of economic activity with increasing returns, transport costs, and factor mobility, which jointly shape the emergence and persistence of economic cores and peripheries (Krugman, 1991; Fujita; Krugman; Venables, 1999). From an evolutionary perspective, historically accumulated productive capabilities, infrastructure, and human capital further condition regional trajectories and the capacity of local economies to diversify and absorb new activities (Boschma; Martin, 2010). In Brazil, these mechanisms are reflected in the persistent concentration of industrial and productive activity across the Center-South and in the uneven capacity of municipalities to internalize development processes (Monte-Mór, 2005).

Yet regional heterogeneity is not confined to productive capacity and physical infrastructure. Financial Geography emphasizes that money, credit, and liquidity are also unevenly distributed across space and may follow a more hierarchical territorial organization (Chick; Dow, 1988). In Brazil, differences in liquidity preference, perceived risk, and information availability have been associated with the concentration of financial resources in central nodes of the urban network (Crocco; Jayme Jr., 2006). This perspective raises an important empirical issue for regional analysis: the spatial configuration of financial deepening may differ substantially from the geographic patterns observed for productive, socioeconomic, and infrastructural conditions. Identifying such differences is relevant because regional heterogeneity may reflect not only unequal levels of development but also distinct spatial configurations across its constituent dimensions.

Despite an extensive empirical literature on Brazilian regional inequality, important gaps remain in the joint assessment of these dimensions at the municipal level. Existing studies frequently examine subnational settings, focus on specific socioeconomic outcomes, or rely on data that precede recent transformations in the Brazilian economy. Faria *et al.* (2018), for example, identify patterns of spatial dependence and regional heterogeneity in the Zona da Mata region of Minas Gerais using 2010 data. Other contributions emphasize the spatial dynamics of income and poverty (Perobelli *et al.*, 2007a,b; Santos; Carvalho; Sá Barreto, 2017), but do not jointly incorporate urban infrastructure, service provision, productive conditions, and financial intermediation into a nationwide municipal assessment. Consequently, there remains scope for an updated multidimensional characterization of regional heterogeneity that simultaneously considers these attributes within a common empirical framework.

This study addresses this gap by examining all 5,570 Brazilian municipalities us-

ing data for 2022. The temporal coverage is particularly relevant because it captures the municipal socioeconomic structure after the COVID-19 pandemic and incorporates recent changes in digital connectivity, public-service provision, and the organization of the financial system. More importantly, the analysis explicitly includes indicators of health-service availability, urban infrastructure, credit, deposits, savings, and banking presence alongside conventional measures of productive capacity and socioeconomic vulnerability. Rather than relying on a predetermined synthetic development index, the study identifies latent dimensions endogenously from the covariance structure of the municipal data, allowing the empirical relationships among indicators to define the underlying dimensions of regional heterogeneity.

The multidimensional approach adopted here is consistent with the view that development cannot be adequately summarized by monetary indicators alone (Adelman, 1972; Colman; Nixon, 1981). Municipal development encompasses interrelated attributes associated with living standards, access to urban services, infrastructure, education, and public health (Larson; Wilford, 1979; Myrdal, 1970; Schwartzman, 1974). To uncover the common structure underlying these attributes, the study employs Principal Axis Factoring (PAF). Unlike Principal Component Analysis (PCA), which decomposes total variance, PAF is based on the common factor model and focuses on shared variance among observed indicators, distinguishing the latent common structure from specific variance and measurement error (Fabrigar *et al.*, 1999; Schreiber, 2021). This distinction is particularly relevant when the objective is to identify underlying dimensions rather than merely reduce the dimensionality of the dataset.

The article therefore investigates how the main dimensions of municipal development are structured and spatially distributed across Brazil. The empirical strategy follows three complementary stages. First, PAF identifies the latent dimensions underlying municipal socioeconomic heterogeneity. Second, cluster analysis uses the resulting factor scores to construct a data-driven territorial typology of Brazilian municipalities. Third, Exploratory Spatial Data Analysis (ESDA) evaluates the degree and geographic configuration of spatial autocorrelation across the identified dimensions. This sequence provides an integrated descriptive framework for examining regional heterogeneity without imposing ex ante weights on the indicators or assuming that different dimensions of development necessarily exhibit similar spatial patterns.

The results identify three latent dimensions: Urban and Infrastructure Consolidation, Socioeconomic Development and Productive Accumulation, and Financial Deepening. The first two exhibit substantial positive spatial autocorrelation and geographically contiguous patterns of association. Financial Deepening, in contrast, displays considerably weaker spatial dependence and greater concentration in specific urban centers. These findings indicate that the geography of Brazilian regional heterogeneity varies across dimensions: socioeconomic and infrastructural conditions are more strongly associated with neighboring municipal contexts, whereas financial deepening presents a more spatially selective configuration. The study contributes to the regional development literature by providing an updated nationwide assessment of municipal heterogeneity and by documenting distinct spatial patterns across productive, urban, and financial dimensions of development.

The remainder of the article is organized as follows. Section 2 describes the data and empirical methods. Section 3 presents and discusses the results. Section 4 concludes.

2 DATA AND METHODS

2.1 Description of the Dataset and Variables

The analysis of Brazil's socioeconomic and spatial structure in 2022 is based on a multidimensional dataset covering all 5,570 municipalities in the country. The data were obtained from official sources that ensure national comparability: the Population Census (IBGE, 2022) and the Regional Accounts System (IBGE, 2023), the Central Bank of Brazil (BCB, 2023), the National Telecommunications Agency (ANATEL, 2023), the Ministry of Health (CNES, 2023), the Ministry of Social Development and Fight against Hunger (MDS, 2023), and the Annual Report of Social Information (RAIS) (RAIS, 2023). The latter provides a high degree of sectoral disaggregation, which is essential for constructing proxies for agglomeration.

To this end, a set of 15 variables was selected and organized into theoretical dimensions designed to capture the diversity of development conditions and the complexity of spatial interactions (Table 1). These variables serve as inputs for Factor Analysis, which is applied to estimate factor loadings that represent the variability in the data structure. Subsequently, the resulting factor scores are used as inputs for Cluster Analysis and Exploratory Spatial Data Analysis.

Taken together, these variables are intended to capture characteristics of eight core dimensions:

a) **Demographics:** captured by the urbanization rate (PURB) and the dependency ratio, which jointly characterize urban concentration and the demographic structure of municipalities, including the relative weight of the non-working-age population;

b) **Education:** measured by the illiteracy rate among individuals aged 15 years or older as an indicator of educational deprivation and local human capital constraints;

c) **Health:** measured by the density of establishments registered in the National Registry of Health Establishments, capturing the local availability of healthcare infrastructure and services;

d) **Social Assistance:** represented by per capita Bolsa Família benefits as an indicator of socioeconomic vulnerability and the relative incidence of income transfers across municipalities;

e) **Sanitation:** measured by the percentage of households connected to the sewerage network, capturing disparities in access to basic urban infrastructure;

f) **Technology:** represented by Anatel's Brazilian Connectivity Index, which captures the quality and availability of telecommunications infrastructure and municipal digital connectivity;

g) **Development and Regional Accounts:** measured by municipal per capita Gross Domestic Product (GDP) as an indicator of local economic activity and productive capacity;

h) **Money and Credit:** composed of credit operations, savings deposits, bank deposits, and bank branch density, capturing municipal financial intermediation, liquidity, and banking presence.

Table 1: Selected indicators for Brazilian municipalities (2022)

Indicator	**Variable**	**Description**	**Source**
Demographics	PURB	Share of the urban population in the total population	IBGE
	RAZDEP	Dependency ratio	IBGE
Education	TXANAL	Illiteracy rate among individuals aged 15 years or older	IBGE
Health	CNES	Healthcare establishments per capita	Ministry of Health
Social Assistance	PBF	Ratio of Bolsa Família benefits to the total population	Ministry of Social Development
Sanitation	ESGOTO	(%) of households with access to the sewerage network	IBGE
Technology	IBC	Brazilian Connectivity Index	ANATEL
Development and Regional Accounts	PIB	Municipal GDP per capita	IBGE
Money and Credit	CREDITO	Credit operations per capita	BCB
	POUPANCA	Savings deposits per capita	BCB
	DEPOSITOS	Bank deposits per capita	BCB
	AGENCIA	Bank branches per 10,000 inhabitants	BCB
Agglomeration Proxies	GINDUST	Degree of industrialization	RAIS
	MERCADO	Market potential	RAIS

Source: Authors' own elaboration.

In addition to the indicators described above, proxy variables were constructed using employment data from RAIS (RAIS, 2023), drawing on the approaches proposed by Pereira (2002), Pereira and Lemos (2003), Lemos *et al.* (2003), Betarelli Junior and Simões (2011), and Faria *et al.* (2018). The proxy variables were defined as follows:

a) **GINDUST**, which represents the degree of industrialization, is calculated as the ratio of employment in industry, according to the IBGE classification of six broad economic sectors (PO_{ind}), to urban employment ($PO_{urb} = PO_{total} - PO_{agr}$). This proxy is intended to capture urbanization economies and industrial linkages:

$$GINDUST_i = \frac{PO_{ind,i}}{PO_{urb,i}} = \frac{\text{Employment in industry}_i}{\text{Urban employment}_i} \tag{1}$$

b) **MERCADO**, which represents the ratio of the urban wage bill (SO_{urb}), defined as the total wage bill minus the agricultural wage bill, to urban employment:

$$MERCADO_i = \frac{SO_{urb,i}}{PO_{urb,i}} = \frac{\text{Urban wage bill}_i}{\text{Urban employment}_i} \tag{2}$$

This variable is considered a factor of urban agglomeration, capturing both local purchasing power and the relative cost of labor.

2.2 Methodology

The empirical strategy comprises three sequential and complementary stages. First, Factor Analysis is used to identify latent dimensions of municipal development from the multivariate dataset. Second, Cluster Analysis constructs a data-driven territorial typology based on the estimated factor scores. Third, Exploratory Spatial Data Analysis (ESDA) examines the spatial autocorrelation and local association patterns of the identified dimensions.

2.2.1 Extraction of Latent Dimensions: Principal Axis Factoring (PAF)

Given the multidimensional nature of regional development, Factor Analysis was employed to identify the common structure underlying the observed municipal indicators. After orthogonal rotation, the extracted factors summarize shared variation in the original variables while remaining linearly uncorrelated. This approach allows latent dimensions to emerge from the empirical covariance structure rather than imposing *a priori* normative weights, as in predetermined composite indicators (Fabrigar *et al.*, 1999).

The common factor model can be expressed in matrix notation as:

$$D(X - \mu) = LF + s, \tag{3}$$

where D is a $p \times p$ diagonal standardization matrix, L denotes the matrix of factor loadings, F is an $m \times 1$ vector of unobserved common factors, and s contains variable-specific components. The factor loading l_{ij} measures the linear association between standardized variable i and latent factor j, such that the information contained in the p observed variables is represented through common and variable-specific components (Faria *et al.*, 2018; Mingoti, 2007).

The suitability of the correlation matrix for factor analysis was assessed using Bartlett's test of sphericity and the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy (Kaiser, 1974). Principal Axis Factoring (PAF) was adopted because the objective is to identify latent common dimensions rather than decompose the total variance of the observed indicators. To improve interpretability, the extracted solution was subjected to orthogonal Varimax rotation, which promotes a simpler loading structure while preserving zero linear correlation among the rotated factors (Kaiser, 1958).

Factor retention was primarily determined through Parallel Analysis (Horn, 1965), based on Monte Carlo simulations, rather than relying exclusively on Kaiser's eigenvalue-greater-than-one rule. The retained dimensionality was further evaluated using Velicer's Minimum Average Partial (MAP) criterion (Velicer, 1976) and the Bayesian Information Criterion (BIC) (Schwarz, 1978). The combined use of these criteria provides complementary evidence on the dimensional structure of the municipal indicators.

2.2.2 Territorial Typology: Cluster Analysis

Based on the estimated factor scores, Cluster Analysis was used to construct a municipal typology capturing structural heterogeneity across the Brazilian territory. Municipalities were grouped according to similarity in the latent dimensions identified by PAF, yielding internally cohesive and externally differentiated groups.

The number of clusters (k) was selected using the Gap Statistic proposed by Tibshirani, Walther, and Hastie (2001). The statistic compares observed within-cluster dispersion with that obtained under a null reference distribution and identifies whether

increasing the number of groups produces a meaningful improvement in the partitioning structure.

After selecting k, Ward's hierarchical clustering method (Ward, 1963) was applied to the factor scores using Euclidean distance:

$$d_{ij} = \sqrt{\sum_{r=1}^{p} (x_{ir} - x_{jr})^2}, \tag{4}$$

where d_{ij} is the distance between municipalities i and j, and x_{ir} and x_{jr} denote their respective factor scores for dimension r. Ward's agglomerative criterion sequentially merges groups so as to minimize the increase in total within-cluster sum of squares. The resulting partition therefore identifies municipalities with similar multidimensional development profiles without imposing predefined territorial categories.

2.2.3 Exploratory Spatial Data Analysis (ESDA)

The final stage examines whether the latent dimensions identified by PAF exhibit systematic spatial association across Brazilian municipalities. Global spatial autocorrelation was assessed using Moran's I statistic (Anselin, 1996; Cox; Cliff; Ord, 1984):

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} z_i z_j}{\sum_{i=1}^{n} z_i^2}, \tag{5}$$

where n is the number of municipalities, w_{ij} is the (i, j)th element of the spatial weights matrix W, z_i and z_j denote deviations from the mean, and $S_0 = \sum_i \sum_j w_{ij}$ is the sum of the spatial weights.

The baseline specification uses a binary first-order Queen contiguity matrix, under which municipalities are considered neighbors when they share a boundary or vertex. Bivariate Moran's I was additionally employed to examine cross-dimensional spatial association. To assess sensitivity to the definition of spatial proximity, the global statistics were re-estimated using k-nearest-neighbor (KNN) spatial weights matrices for $k = 5$, 10, 15, and 20. The factor scores were standardized as z-scores prior to the spatial analysis.

Local spatial association was examined using Local Indicators of Spatial Association (LISA). Following Anselin (1995), the local Moran statistic is defined as:

$$I_i = z_i \sum_{j=1}^{n} w_{ij} z_j, \tag{6}$$

where I_i denotes the local statistic for municipality i and $\sum_j w_{ij} z_j$ is the spatial lag of the standardized factor score. Statistical significance and the quadrants of the Moran scatterplot were combined to classify municipalities into High–High and Low–Low spatial clusters and High–Low and Low–High spatial outliers. The resulting LISA maps identify the local geographic configuration of spatial association across the latent dimensions of municipal development.

Together, PAF, Cluster Analysis, and ESDA provide an integrated exploratory framework for identifying the multidimensional structure of regional heterogeneity, constructing an empirical municipal typology, and examining its spatial configuration across Brazil.

3 RESULTS AND DISCUSSION

This section presents the empirical results in four stages. It first documents cross-municipal socioeconomic heterogeneity and identifies the latent dimensions underlying the observed indicators. The resulting factor scores are then used to construct a territorial typology, followed by an assessment of global, bivariate, and local spatial association patterns.

3.1 Descriptive Statistics

Table 2 documents substantial socioeconomic heterogeneity across Brazilian municipalities in 2022. The average urban population share is 69%, but values range from 7.3% to 100%, reflecting the coexistence of highly urbanized and predominantly rural municipalities. Similar disparities emerge in human capital and socioeconomic vulnerability: adult illiteracy reaches 36.8% in some municipalities, while the share of Bolsa Família beneficiaries ranges from 0.2% to 46.4% of the municipal population.

Infrastructure provision is also highly uneven. Access to the sewerage network averages 34.27%, with a standard deviation of 32.84 percentage points and values ranging from zero to near-universal coverage. Productive and financial indicators display even greater dispersion. Municipal GDP per capita reaches a maximum more than 22 times the national mean, while the standard deviations of credit operations, savings deposits, bank deposits, and bank branch density exceed their respective means. Several municipalities also report zero values for financial indicators, revealing pronounced distributional asymmetry in financial activity.

Table 2: Descriptive Statistics

Variable	**Description**	**Mean**	**Std. Dev.**	**Minimum**	**Maximum**
PURB	Share of the urban population	0.690	0.201	0.0733	1.000
RAZDEP	Dependency ratio	48.199	4.953	14.458	108.033
TXANAL	Illiteracy rate (age 15 and older)	11.800	7.561	0.900	36.810
CNES	Health establishments per capita	0.001	0.000	0.000	0.012
PBF	Ratio of Bolsa Família benefits	0.130	0.083	0.002	0.464
ESGOTO	Percentage of households connected to the sewerage network	34.274	32.848	0.000	99.830
IBC	Brazilian Connectivity Index	52.059	13.975	10.900	83.280
PIB	Municipal GDP per capita	15,786.83	17,715.49	2,905.42	362,027.13
CREDITO	Credit operations per capita	2,229.73	5,800.10	0.00	333,551.17
POUPANCA	Savings deposits per capita	894.68	1,151.96	0.00	13,270.29
DEPOSITOS	Bank deposits per capita	676.59	1,548.33	0.00	37,600.08
AGENCIA	Bank branches per 10,000 inhabitants	0.704	0.883	0.000	11.025
GINDUST	Degree of industrialization	0.156	0.166	0.000	0.876
MERCADO	Urban labor market indicator	2,528.050	579.606	66.012	10,086.245

Source: Authors' own elaboration.

Following the empirical assessment of territorial disparities across Brazilian municipalities, the next stage of the analysis consisted of validating the interdependence structure among the selected indicators. Inspection of the correlation matrix, presented in Table 3, reveals that nearly all coefficients were statistically significant at least at the

10% level, supporting the suitability of the dataset for extracting latent dimensions. Formal diagnostic tests consistently corroborated this assessment. Bartlett's test of sphericity rejected the null hypothesis that the population correlation matrix is an identity matrix ($\chi^2 = 31{,}035.54$; degrees of freedom = 91; $p < 0.001$). Concurrently, the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy yielded an overall value of 0.8482. This value is conventionally classified as "meritorious" and exceeds the threshold of 0.800 commonly associated with strong sampling adequacy for factor analysis (Johnson; Wichern, 2007; Mingoti, 2007). No individual variable appeared to compromise the factor solution, as variable-specific KMO values ranged from 0.805 for bank branch density to 0.937 for the degree of industrialization.

The latent constructs were extracted using Principal Axis Factoring (PAF), with the final factor loadings reported in Table 4. Unlike exploratory approaches relying exclusively on cumulative explained variance thresholds and the Kaiser criterion (eigenvalues greater than one), the number of retained factors was determined using simulation-based and information-based procedures. Factor retention was primarily guided by Parallel Analysis and corroborated by Velicer's Minimum Average Partial (MAP) criterion and the Bayesian Information Criterion (BIC). Although the eigenvalues associated with Factors 2 and 3 are below one, their retention is supported by these complementary criteria rather than by the Kaiser rule alone, providing a more robust basis for assessing the latent dimensionality of the data.

Finally, to reduce cross-loadings and enhance the economic interpretability of the regional development dimensions, the retained factor solution was subjected to orthogonal Varimax rotation (Kaiser, 1958). The rotated solution converged successfully and yielded a more clearly differentiated latent structure. The resulting factor loadings are reported in Table 4.

Table 3: Correlation Matrix of the Original Variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PURB	1													
RAZDEP	-0.40*	1												
TXANAL	-0.46*	0.32*	1											
CNES	0.19*	-0.13*	-0.35*	1										
PBF	-0.34*	0.28*	0.81*	-0.38*	1									
ESGOTO	0.58*	-0.35*	-0.36*	0.18*	-0.28*	1								
IBC	0.60*	-0.41*	-0.57*	0.23*	-0.51*	0.43*	1							
PIB	0.21*	-0.19*	-0.38*	0.18*	-0.36*	0.09*	0.25*	1						
CREDITO	0.24*	-0.18*	-0.25*	0.21*	-0.24*	0.15*	0.24*	0.20*	1					
POUPANCA	0.46*	-0.32*	-0.43*	0.40*	-0.39*	0.44*	0.48*	0.19*	0.42*	1				
DEPOSITOS	0.37*	-0.28*	-0.33*	0.29*	-0.28*	0.36*	0.37*	0.28*	0.46*	0.61*	1			
AGENCIA	0.27*	-0.11*	-0.40*	0.22*	-0.38*	0.24*	0.33*	0.19*	0.35*	0.63*	0.34*	1		
GINDUST	0.31*	-0.31*	-0.46*	0.19*	-0.46*	0.24*	0.41*	0.26*	0.10*	0.30*	0.17*	0.23*	1	
MERCADO	0.09*	-0.10*	-0.28*	0.14*	-0.26*	0.05*	0.20*	0.40*	0.16*	0.16*	0.30*	0.16*	0.19*	1

Notes: * $p < 0.100$.
Source: Authors' own elaboration.

3.2 Factor Analysis

The rotated factor solution reveals a clearly differentiated latent structure underlying regional heterogeneity across Brazilian municipalities. As reported in Table 4, loadings below 0.30 are suppressed to facilitate the identification of the dominant associations between the observed indicators and the extracted factors, thereby supporting the economic interpretation of the three latent dimensions.

Table 4: Factor Analysis Results

Variable	Description	Factor			Communal.
		1	2	3	
PURB	Share of the urban population	0.7637			0.6506
ESGOTO	Percentage of households connected to the sewerage network	0.6605			0.4882
IBC	Brazilian Connectivity Index	0.6138	0.3795		0.5710
RAZDEP	Dependency ratio	-0.4763			0.2765
PBF	Ratio of Bolsa Família benefits		-0.7981		0.7475
TXANAL	Illiteracy rate (age 15 and older)		-0.7732		0.7878
PIB	Municipal GDP per capita		0.4528		0.2507
GINDUST	Degree of industrialization	0.3316	0.4509		0.3177
MERCADO	Urban labor market indicator		0.3703		0.1893
POUPANCA	Savings deposits per capita			0.7654	0.7737
DEPOSITOS	Bank deposits per capita			0.6607	0.5275
CREDITO	Credit operations per capita			0.5358	0.3185
AGENCIA	Bank branches per 10,000 inhabitants			0.5201	0.3682
CNES	Health establishments per capita			0.3153	0.2053
Eigenvalues		4.7417	0.9326	0.7981	
Cumulative proportion		0.7327	0.8768	1.0000	

Diagnostic tests: Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy = 0.8482; Bartlett's test of sphericity: $\chi^2 = 31{,}035.54$, $p < 0.001$.
Notes: Factor loadings below 0.300 are suppressed.
Source: Authors' own elaboration.

Factor 1 emerges as the dominant latent dimension, capturing differences associated with urbanization and the provision of territorial infrastructure (Mingoti, 2007). It exhibits high positive loadings for the share of the urban population (0.764), access to the sewerage network (0.661), and digital connectivity (0.614), indicating a coherent structure linking urban concentration, basic infrastructure, and connectivity. Conversely, the demographic dependency ratio loads negatively (−0.476), suggesting that municipalities with stronger urban and infrastructural attributes are associated with a relatively larger working-age population. Taken together, these loadings characterize a latent dimension of urbanization, infrastructure provision, and demographic structure. Factor 1 is therefore interpreted as *Urban and Infrastructure Consolidation*.

Factor 2 captures socioeconomic conditions and productive accumulation, combining indicators of social vulnerability and economic performance. It exhibits substantial negative loadings for the share of Bolsa Família beneficiaries (PBF: −0.798) and the illiteracy rate (−0.773), reflecting structural vulnerabilities associated with income conditions and human capital. By contrast, GDP per capita (0.453), the degree of industrialization (0.451), and labor market dynamism (0.370) load positively on the factor, indicating stronger productive capacity and income generation. Cross-loadings for connectivity (IBC) and industrialization further suggest an overlap between productive and urban dimensions. Overall, Factor 2 defines a gradient between municipalities characterized by greater socioeconomic vulnerability and those with stronger productive structures. It is therefore interpreted as *Socioeconomic Development and Productive Accumulation*.

Finally, Factor 3 captures the financial dimension of development by combining indicators directly related to financial intermediation and the availability of banking services. Savings deposits (0.765), bank deposits (0.661), credit operations (0.536), and

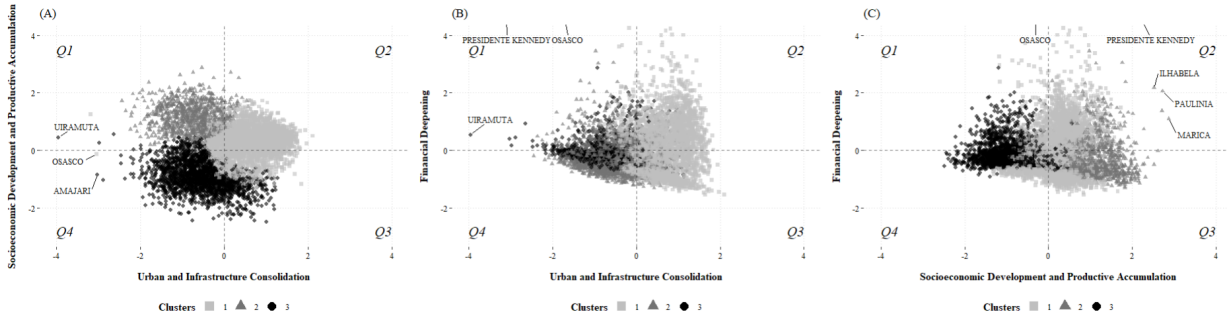
bank branch density (0.520) exhibit positive loadings, revealing a coherent latent structure of financial activity. The joint loading pattern indicates that liquidity, credit, and banking infrastructure constitute a distinct dimension of municipal development, consistent with the financial geography literature on the territorial organization of money and credit (Chick; Dow, 1988; Crocco; Jayme Jr., 2006). Factor 3 is therefore interpreted as *Financial Deepening*.

Based on these three synthetic and mutually orthogonal dimensions, the analysis next examines how Brazil's 5,570 municipalities are positioned within the resulting multidimensional factor space. The next stage combines scatterplots of the factor scores with multivariate Cluster Analysis to identify groups of municipalities sharing similar structural characteristics and, subsequently, assess the territorial configuration of the resulting typology.

To examine municipal heterogeneity within the multidimensional factor space and the clustering structure obtained using Ward's method (Ward, 1963), Figure 1 presents pairwise scatterplots of the three latent factor scores. Given the full coverage of Brazil's 5,570 municipalities, the analysis focuses on the overall separation among clusters and on extreme observations associated with specific municipal economic structures.

The relationship between *Urban and Infrastructure Consolidation* and *Socioeconomic Development and Productive Accumulation* reveals a clear separation across the three clusters (Panel A). Cluster 3 is concentrated on the left-hand side of the factor space (Q1 and Q4), comprising municipalities with lower levels of urbanization and infrastructure but heterogeneous socioeconomic performance. Uiramutã and Amajari illustrate this configuration, reflecting territorial isolation and structural constraints. By contrast, the right-hand quadrants (Q2 and Q3) are predominantly occupied by municipalities in Clusters 1 and 2, characterized by stronger urban and infrastructural attributes. Within this group, municipalities with pronounced productive dynamism stand out, such as Paulínia, whose capital-intensive economic structure is associated with its extreme position along the vertical axis. Overall, the factor space suggests that stronger urban and infrastructural attributes coexist with substantial heterogeneity in socioeconomic and productive performance.

Figure 1: Distribution of Municipal Factor Scores Across the Three Latent Dimensions



Source: Authors' own aleboration.

The introduction of the *Financial Deepening* dimension (Panels B and C) reveals a markedly different distributional pattern relative to the other factors. Unlike the urban and infrastructural dimension, which exhibits more continuous variation across municipalities, financial deepening is strongly concentrated in a limited set of observations. This pattern is reflected in a small number of extreme scores and a high density of municipalities at the lower end of the distribution. Osasco stands out as a major financial center, whereas Presidente Kennedy illustrates the role of specific local economic conditions, in-

cluding substantial oil royalty revenues, that may be associated with unusually high levels of liquidity and bank deposits. The resulting configuration indicates a highly concentrated financial dimension, consistent with the territorial hierarchy of money, credit, and banking services emphasized in the financial geography literature (Chick; Dow, 1988; Crocco; Jayme Jr., 2006).

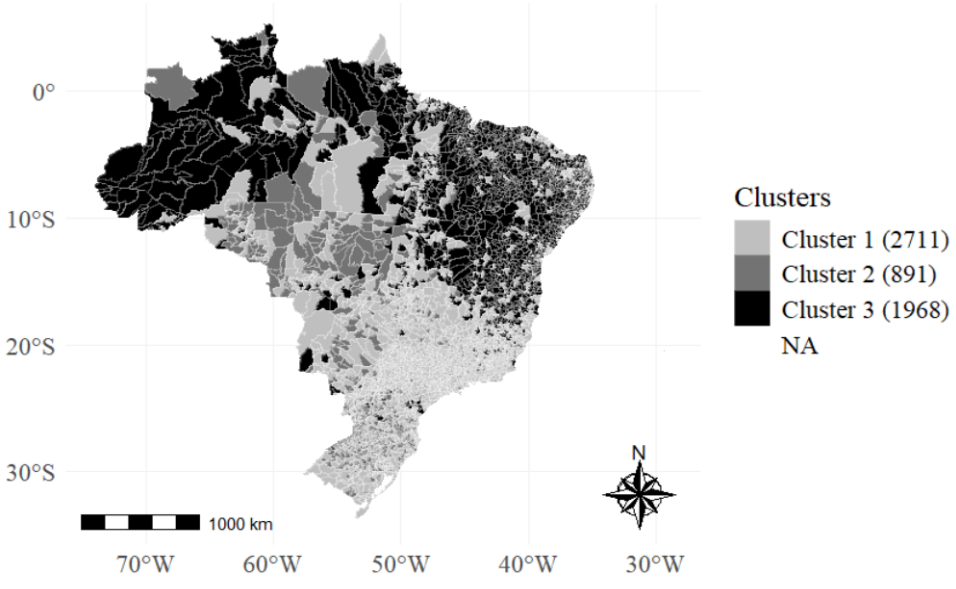
Overall, the scatterplots indicate that the clustering procedure partitions Brazilian municipalities into groups with distinct configurations of productive accumulation, urban and infrastructural consolidation, and financial deepening. However, the factor space does not directly reveal the geographic organization of these groups. To incorporate the territorial dimension of the typology and examine how the resulting clusters are distributed across Brazil, the next subsection maps their spatial configuration.

3.3 Territorial Typology of Brazilian Municipalities - Cluster

The latent dimensions identified through Principal Axis Factoring provide the basis for constructing a territorial typology of Brazilian municipalities. The optimal number of clusters ($k = 3$) was determined endogenously using the Gap Statistic proposed by Tibshirani, Walther, and Hastie (2001), based on Monte Carlo simulations. Based on this specification, Figure 2 presents the spatial distribution of the resulting typology, revealing a clearly non-random geographic pattern. Brazil's regional economic structure is characterized by pronounced contrasts between more structurally consolidated areas, concentrated primarily in the South and Southeast and extending into the Central-West, and areas exhibiting greater structural vulnerabilities, particularly in the North and Northeast.

Cluster 1 (light gray), the largest group, comprises 2,711 municipalities (48.67%) and is broadly distributed across the national territory, with a strong presence in the South and Southeast as well as in several inland areas. It represents an intermediate territorial profile in terms of urbanization and infrastructure. Although these municipalities do not exhibit the highest levels of socioeconomic and productive development, they display relatively consolidated urban structures and service provision.

Figure 2: Spatial Distribution of the Municipal Clusters



Source: Authors' own eleboration.

Cluster 2 (medium gray), comprising 891 municipalities (16.00%), exhibits a more geographically concentrated distribution, encompassing the country's principal urban centers and the most economically dynamic regions, particularly in the South, Southeast, and parts of the Central-West. This cluster displays the highest levels of socioeconomic development and productive accumulation, together with a stronger presence of financial activities, reflecting municipalities that occupy central positions within Brazil's economic structure.

By contrast, Cluster 3 (black), comprising 1,968 municipalities (35.33%), is concentrated predominantly in the North and Northeast. It encompasses municipalities characterized by comparatively low levels of urbanization, infrastructure provision, and financial deepening, together with greater socioeconomic vulnerability. These municipalities are also associated with lower productive capacity and a stronger dependence on income transfers, indicating persistent structural constraints on local development.

Taken together, the spatial distribution of the three clusters reveals the coexistence of distinct territorial development profiles across Brazil. Although the resulting typology highlights a persistent regional divide, the geographic distribution alone does not indicate whether municipalities with similar characteristics are spatially associated. The following subsection therefore employs Exploratory Spatial Data Analysis (ESDA) to examine the magnitude and configuration of spatial dependence across the latent dimensions of development.

3.4 Spatial Dependence and Local Spatial Patterns

The final stage of the empirical analysis examines the spatial organization of the three latent dimensions. Although the territorial typology reveals a persistent regional divide, it does not indicate whether municipalities with similar development profiles are spatially associated. Table 5 therefore reports the Global Moran's I coefficients estimated under alternative spatial weights matrices. The stability of the estimates across alternative neighborhood specifications indicates that the identified spatial patterns are robust to different definitions of spatial proximity.

Table 5: Global Spatial Autocorrelation Index for the Common Factors

Neighborhood Criterion	**Factor 1**	**Factor 2**	**Factor 3**
	Urban and Infrastructure Consolidation	*Socioeconomic Development and Productive Accumulation*	*Financial Deepening*
Queen	0.5331	0.8351	0.0748
K5	0.5588	0.8593	0.0687
K10	0.5368	0.8478	0.0799
K15	0.5193	0.8429	0.0842
K20	0.5076	0.8391	0.0878

Notes: Queen denotes the first-order Queen contiguity matrix. K5, K10, K15, and K20 denote k-nearest-neighbor spatial weights matrices with $k = 5$, 10, 15, and 20, respectively.
Source: Authors' own elaboration.

Socioeconomic Development and Productive Accumulation (Factor 2) exhibited the highest levels of spatial autocorrelation, with Global Moran's I exceeding 0.8351 under all spatial weights matrices. These coefficients indicate strong positive spatial association,

with municipalities displaying similar productive capacity and socioeconomic conditions clustering geographically.

Urban and Infrastructure Consolidation (Factor 1) also exhibited substantial positive spatial autocorrelation ($I = 0.5076$–0.5588), indicating significant spatial clustering, although less pronounced than that observed for the socioeconomic dimension.

By contrast, *Financial Deepening* (Factor 3) displayed consistently weak spatial dependence ($I \approx 0.07$–0.09). Unlike the other dimensions, financial activity appears to be less structured by geographic contiguity and more selectively concentrated in specific urban centers.

Table 6 reports the bivariate Moran's I coefficients. All estimated associations are positive and statistically significant ($p < 0.01$). The strongest relationship is observed between *Urban and Infrastructure Consolidation* and *Socioeconomic Development and Productive Accumulation* ($I = 0.1630$), indicating that municipalities with stronger productive performance tend to be embedded in regional environments characterized by higher levels of urbanization and infrastructure. At the national scale, this pattern is consistent with the development corridors of Brazil's Center-South and the contiguous concentration of socioeconomic vulnerabilities across much of the North and Northeast.

Table 6: Bivariate Moran's I Coefficients

Association Pair	**Moran's I**	**Mean**	**Std. Dev.**	**p-value**
Urban and Infrastructure Consolidation × Socioeconomic Development and Productive Accumulation	0.1630	-0.0001	0.0125	0.001
Urban and Infrastructure Consolidation × Financial Deepening	0.1017	-0.0005	0.0073	0.001
Socioeconomic Development and Productive Accumulation × Financial Deepening	0.1622	0.0002	0.0074	0.001

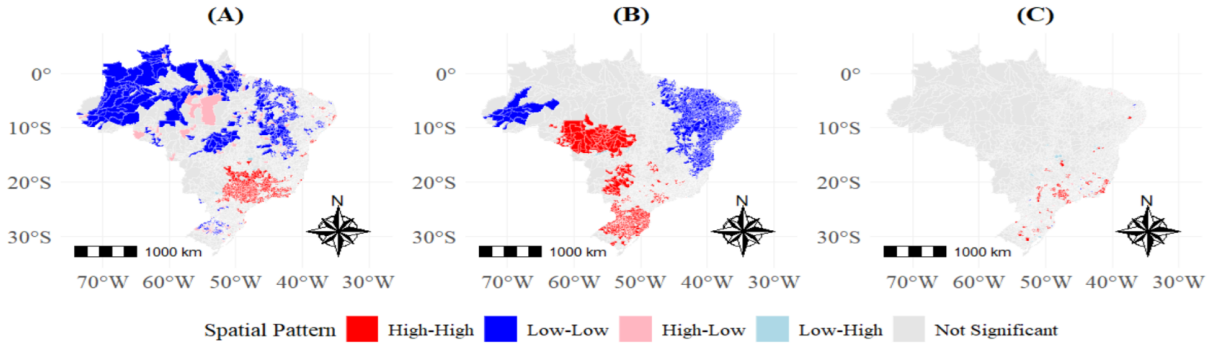
Notes: Mean and standard deviation refer to the reference distribution of the bivariate Moran's I statistic. Reported p-values are based on the corresponding significance procedure.
Source: Authors' own elaboration.

The associations involving *Financial Deepening* also reveal important spatial relationships. The bivariate Moran's I coefficients between *Financial Deepening* and *Socioeconomic Development and Productive Accumulation* ($I = 0.1622$), and between *Financial Deepening* and *Urban and Infrastructure Consolidation* ($I = 0.1017$), are both positive and statistically significant ($p < 0.01$). These results indicate that municipalities embedded in more productive and urbanized regional contexts also tend to be spatially associated with municipalities exhibiting stronger financial development.

Taken together with the Global Moran's I results, however, a more nuanced pattern emerges. Although financial deepening is spatially associated with the broader regional development context, its own spatial dependence remains comparatively weak. Credit, deposits, and banking services therefore appear to be linked to productive and urban development without reproducing the same contiguous spatial organization observed for the other dimensions. Instead, financial activity follows a more selective territorial configuration centered on specific urban nodes.

To examine how these global patterns are expressed locally, Figure 3 presents the Local Indicators of Spatial Association (LISA). The maps identify statistically significant High–High and Low–Low clusters, together with High–Low and Low–High spatial outliers, providing a detailed representation of the geography of regional disparities across Brazil.

Figure 3: LISA Cluster Maps of the Three Latent Dimensions



Source: Authors' own aleboration.

Panel (a), corresponding to *Urban and Infrastructure Consolidation*, reveals a marked concentration of High–High clusters in the South and Southeast, particularly in the São Paulo macrometropolitan area and along its expansion corridors. Conversely, extensive Low–Low clusters are concentrated in the North and parts of the interior Northeast, reflecting persistent infrastructure deficits. This configuration indicates substantial spatial continuity in urban and infrastructural conditions despite pronounced regional heterogeneity.

Panel (b), associated with *Socioeconomic Development and Productive Accumulation*, exhibits an even stronger pattern of spatial polarization. High–High clusters are concentrated primarily in the Central-West and South, whereas Low–Low clusters dominate much of the Northeast. This configuration reveals pronounced territorial segmentation, with geographically contiguous areas of both stronger and weaker socioeconomic performance, consistent with cumulative regional disparities (Myrdal, 1957).

Finally, Panel (c), corresponding to *Financial Deepening*, exhibits a markedly different spatial configuration. The predominance of statistically non-significant municipalities and the limited number of geographically dispersed High–High clusters indicate weak local spatial dependence, consistent with the Global Moran's I results. Financial activity therefore appears less structured by geographic contiguity and more selectively organized around specific urban centers, consistent with the financial geography literature (Chick; Dow, 1988; Crocco; Jayme Jr., 2006).

4 CONCLUDING REMARKS

This study examines regional heterogeneity across Brazil's 5,570 municipalities by identifying the latent dimensions underlying their socioeconomic, productive, infrastructural, and financial structures and assessing how these dimensions are organized across space. Combining Principal Axis Factoring (PAF), Cluster Analysis, and Exploratory Spatial Data Analysis (ESDA), the empirical strategy provides a multidimensional characterization of municipal development in 2022. The results show that regional heterogeneity is not structured by a single spatial process. Instead, different dimensions of development exhibit markedly distinct patterns of territorial association.

Three latent dimensions emerge from the municipal data: *Urban and Infrastructure Consolidation*, *Socioeconomic Development and Productive Accumulation*, and *Financial Deepening*. The resulting territorial typology reveals a persistent regional divide. Municipalities with stronger multidimensional profiles are concentrated primarily in the South,

Southeast, and parts of the Central-West, whereas greater structural vulnerabilities remain disproportionately concentrated in the North and Northeast. This configuration is consistent with cumulative and path-dependent development processes in which historically concentrated productive capabilities and infrastructure are associated with persistent territorial disparities (Myrdal, 1957; Boschma; Martin, 2010).

The central empirical finding concerns the distinct spatial behavior of these latent dimensions. *Socioeconomic Development and Productive Accumulation* exhibits strong positive spatial autocorrelation, while *Urban and Infrastructure Consolidation* also displays substantial, although comparatively lower, spatial dependence. Similar socioeconomic, productive, and infrastructural conditions therefore extend across geographically contiguous municipalities, consistent with the spatial concentration and agglomeration mechanisms emphasized in regional economics (Krugman, 1991). By contrast, *Financial Deepening* exhibits consistently weak spatial autocorrelation across alternative neighborhood specifications. The local analysis corroborates this result: significant financial clusters are comparatively sparse and geographically dispersed rather than forming the extensive contiguous areas observed for the other dimensions.

The contribution of the study lies precisely in this contrast. Financial deepening is not spatially disconnected from regional development. Its positive bivariate spatial association with the socioeconomic and productive dimension is comparable in magnitude to the strongest cross-spatial relationship identified in the analysis. Yet its own spatial dependence remains markedly weak. Taken together, these results indicate that financial activity is associated with the broader regional development context without reproducing the same contiguous spatial structure observed for productive capabilities and infrastructure. Credit, deposits, and banking presence instead display a more selective territorial configuration, consistent with the financial geography literature on hierarchical urban networks and differentiated territorial access to money and credit (Chick; Dow, 1988; Crocco; Jayme Jr., 2006). The evidence therefore extends conventional accounts of Brazilian regional heterogeneity by showing that its underlying dimensions coexist within distinct spatial configurations.

These findings have direct implications for regional policy. The strong spatial continuity of socioeconomic vulnerability and productive conditions supports the relevance of place-based interventions aimed at territorially concentrated development constraints (Barca, 2009). Financial deepening, however, presents a different policy challenge. Because its spatial organization is less dependent on geographic contiguity, expanding access to credit and financial services may require instruments that operate through urban hierarchies and regional nodes rather than relying exclusively on neighborhood-based spatial diffusion. In Brazil, this raises an important question regarding how regional financing instruments, including the Constitutional Financing Funds for the Central-West (FCO), Northeast (FNE), and North (FNO) (Brasil, 1989), interact with the municipal geography of financial deepening. Greater coordination among productive development strategies, territorial infrastructure, and financial inclusion may be particularly relevant for municipalities located outside the principal nodes of the urban and financial system.

The analysis is subject to important limitations. Its cross-sectional design does not permit causal interpretation or the identification of dynamic regional trajectories. ESDA identifies spatial associations but does not recover the mechanisms generating them, while the latent dimensions remain conditional on the indicators included in the factor model. Moreover, the 2022 cross-section may reflect post-pandemic adjustments in labor markets, income transfers, and financial activity. The results should therefore be interpreted as a multidimensional spatial diagnosis of Brazilian municipalities rather than evidence

of causal or long-run effects. Future research could extend this framework to longitudinal municipal data and examine whether the spatial configurations identified here persist over time. Spatial panel models and quasi-experimental designs could further investigate whether changes in financial access affect local productive diversification and whether financial development propagates through urban hierarchies rather than geographic contiguity.

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