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MORALITY BEFORE KNOWLEDGE

Applying spatial autocorrelation concept for pawnshop business insight

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ABSTRACT

Background: Pawnshop businesses play a strategic role in supporting financial inclusion and regional liquidity; however, nationally aggregated indicators may obscure substantial variations in business activity at finer geographical scales. **Methods:** This study examines the spatial patterns and geographic dependence of pawnshop business activity in the Jabodetabek metropolitan region from May 2024 to May 2025 using a combination of Local Moran's I (LISA), Local Getis–Ord Gi*, and Local Geary's C. Due to the absence of district transaction data, regency/municipality-level customer and loan totals from the Financial Services Authority (OJK) were disaggregated using population and land-area proxies from Statistics Indonesia (BPS). These proxy-based estimates were then analyzed within a GIS framework using a row-standardized spatial weight matrix to capture local spatial dependence. **Findings:** The results reveal a segmented spatial structure, characterized by strong customer and total-loan concentrations in Central Jakarta and Tangerang City, transitional and outlier patterns in surrounding areas, and a high-intensity corridor of average loan value per account (AL) in Bogor City and adjacent districts. **Conclusion:** The findings demonstrate that pawnshop business development should not rely solely on national or metropolitan averages but should adopt cluster-based and context-sensitive strategies for branch expansion, service optimization, and regional resource allocation. **Novelty/Originality of this article:** The originality of this study lies in integrating three complementary local spatial statistics at the district level to transform pawnshop indicators into geoeconomic business insights, while explicitly acknowledging that the proxy-derived values represent exploratory estimates that require further validation using branch- or transaction-level data.

KEYWORDS: cluster-based business strategy; local spatial statistics; metropolitan financial geography; pawnshop business; spatial autocorrelation.

1. Introduction

Pawn-based financial institutions (pawnshop business) occupy a strategic position within the financial inclusion ecosystem (Hung & Lin, 2022; Rodríguez-Pose & Sandu, 2025), particularly in developing economies characterized by pronounced socio-economic heterogeneity and spatial inequality across regions (Hassan et al., 2021; Leong et al., 2024), where access to formal financial services is unevenly distributed across geographic space. Unlike conventional banking systems that rely heavily on creditworthiness assessments and formal financial histories (Iddrisu & Danquah, 2024; Nguyen et al., 2021; Wang & Wang,

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2025), pawnshop businesses provide relatively rapid and flexible collateral-based liquidity (Fitzpatrick, 2024; Hung & Lin, 2022), which makes them highly responsive to localized financial demand conditions. Beyond Features position pawn services as a critical financial instrument for low- and middle-income households, micro-entrepreneurs, and populations residing in areas with limited access to formal financial services (Fitzpatrick, 2024; Hisham et al., 2013; Hung & Lin, 2022; Mago & Modiba, 2022), particularly in spatially underserved and economically fragmented regions.

In Indonesia, a developing country marked by vast geographic dispersion, uneven urbanization, and substantial interregional economic disparities, pawnshop businesses have become increasingly central to inclusive finance (Sahputri et al., 2024; Yang et al., 2024). According to Pawnshop Business Statistics 2025, published by the Financial Services Authority (OJK), the period from May 2024 to May 2025 was characterized by sustained growth in customer numbers, total loan disbursements, and average loan value per account (AL). Figures 1–3 collectively indicate that although the pawnshop sector in Indonesia is expanding, its performance and utilization are unlikely to be evenly distributed across geographical areas. The divergence between national-level trends and metropolitan dynamics indicates strong spatial heterogeneity in service utilization and pawnshop business characteristics, reflecting underlying differences in socio-economic structures and financial accessibility across regions.

As Indonesia's largest metropolitan area, Jabodetabek demonstrates dynamics that do not fully align with national patterns. In this study, Jabodetabek is defined as a functional metropolitan region comprising 13 regencies and municipalities: the five administrative cities of DKI Jakarta—Central Jakarta, North Jakarta, West Jakarta, South Jakarta, and East Jakarta—and the surrounding areas of West Java and Banten, namely Bogor Regency, Bogor City, Depok City, Bekasi Regency, Bekasi City, Tangerang Regency, Tangerang City, and South Tangerang City. This delineation follows established practices in urban and regional economic studies, excluding the Thousand Islands Regency due to its distinct geographic and economic characteristics relative to the metropolitan core (Aritenang, 2022).

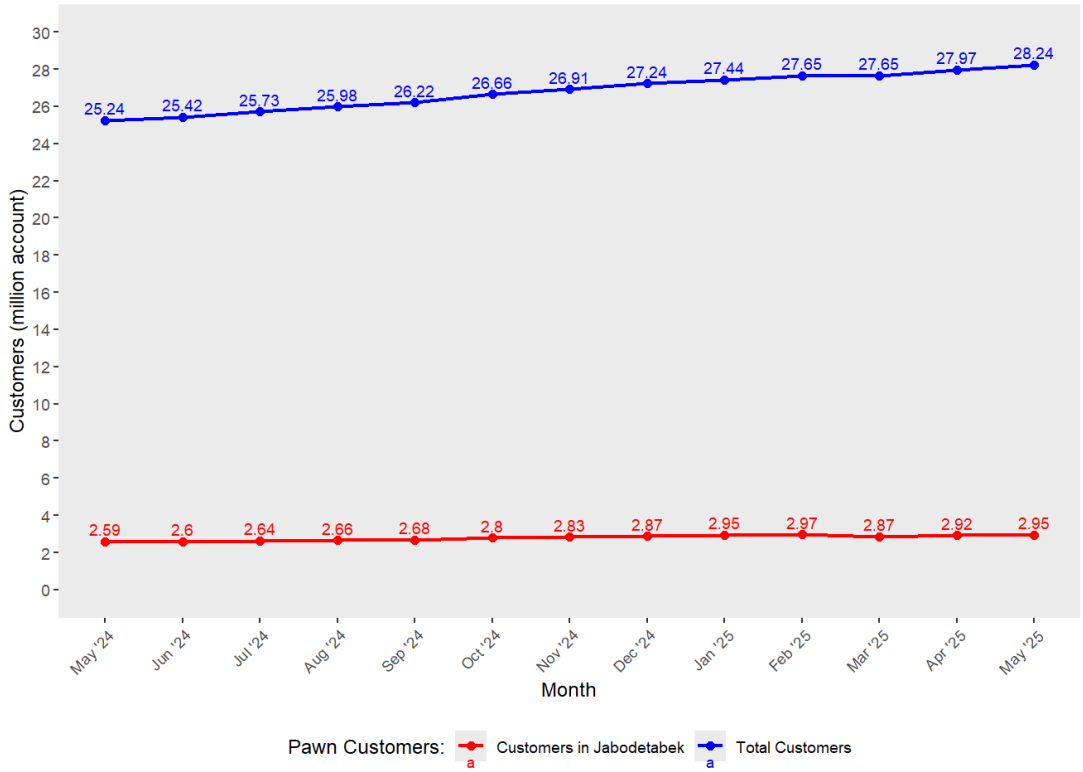


Fig. 1. Number of pawnshop customers from May 2024 to May 2025 in Indonesia and Jabodetabek (Pawnshop Business Statistics by the Financial Services Authority (OJK), 2025)

Figure 1 shows that the national number of pawnshop customers increased steadily from approximately 25.24 million accounts in May 2024 to around 28.24 million accounts in May 2025. This near-linear growth trajectory reflects a stable and broadly distributed expansion of the customer base across Indonesia. In contrast, Jabodetabek recorded a smaller absolute number of customers, ranging from 2.59 to 2.97 million accounts, while still following the national trend. Compared with the national series, Jabodetabek exhibited greater short-term fluctuation, including a moderate decline in March 2025 followed by a subsequent recovery. This pattern may indicate that pawnshop activities in metropolitan areas respond more dynamically to short-term changes in living costs, household financing needs, and urban consumption behavior (Freedman & Li, 2024; Huggett & Luo, 2023; Liu & Dong, 2025). Conceptually, national-level growth reflects extensive expansion through broad customer acquisition, whereas Jabodetabek exhibits a more adaptive and locally responsive growth pattern (Aritenang, 2022; Sahputri et al., 2024).

As shown in Figure 2, total pawn loan disbursements increased from approximately IDR 77.6 trillion to over IDR 103 trillion. This growth followed a relatively smooth trajectory, with acceleration observed in early 2025, indicating strengthening aggregate demand for financing. Conversely, loan dynamics in Jabodetabek display higher volatility, characterized by a pronounced decline in June 2024 followed by gradual recovery and growth through May 2025. This pattern indicates that financing volumes in metropolitan areas are more exposed to short-term economic fluctuations and changing urban consumption patterns (Freedman & Li, 2024; Huggett & Luo, 2023; Liu & Dong, 2025). Although Jabodetabek's proportional contribution to national loan totals remains smaller, its loan growth after February 2025 exceeded the national growth trend, indicating its increasing role as a metropolitan center of pawn-based financing, while the national aggregate maintained greater overall stability (Freedman & Li, 2024; Maket et al., 2024).

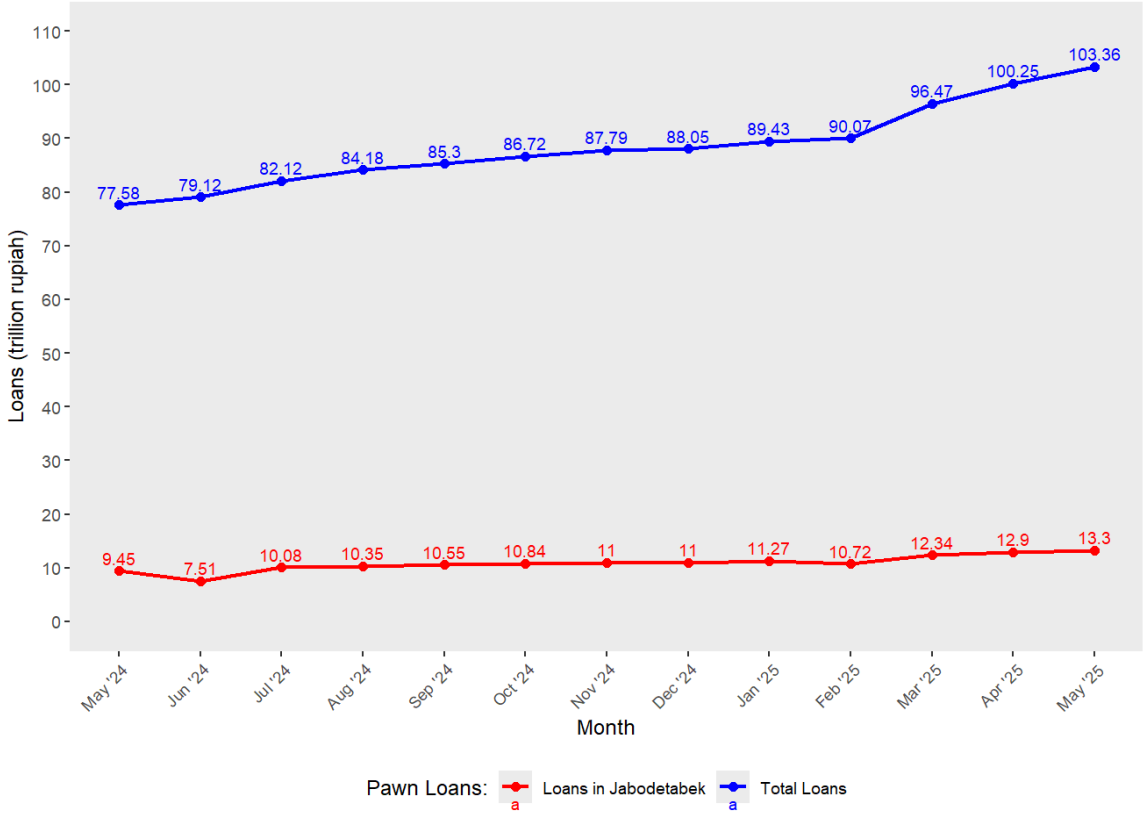


Fig. 2. Total pawn loans disbursements from May 2024 to May 2025 in Indonesia and Jabodetabek (Pawnshop Business Statistics by the Financial Services Authority (OJK), 2025)

Figure 3 presents the development of AL, which increased gradually from approximately IDR 3.07 million to IDR 3.66 million per account, indicating a relatively stable

aggregate pattern of financing intensity during the observation period. In contrast, Jabodetabek consistently recorded higher AL, exceeding IDR 4.5 million by May 2025. The increase after February 2025 indicates rising demand for higher-value financing in the metropolitan region, which may reflect higher living costs, non-routine consumption needs, and the financing requirements of informal economic activities (Freedman & Li, 2024; Hung & Lin, 2022; Liu & Dong, 2025). Greater volatility in this indicator further underscores the heterogeneity of financial behavior among metropolitan customers compared to national averages (Badrudin et al., 2025; Bahri et al., 2025; Budiyanto et al., 2025).

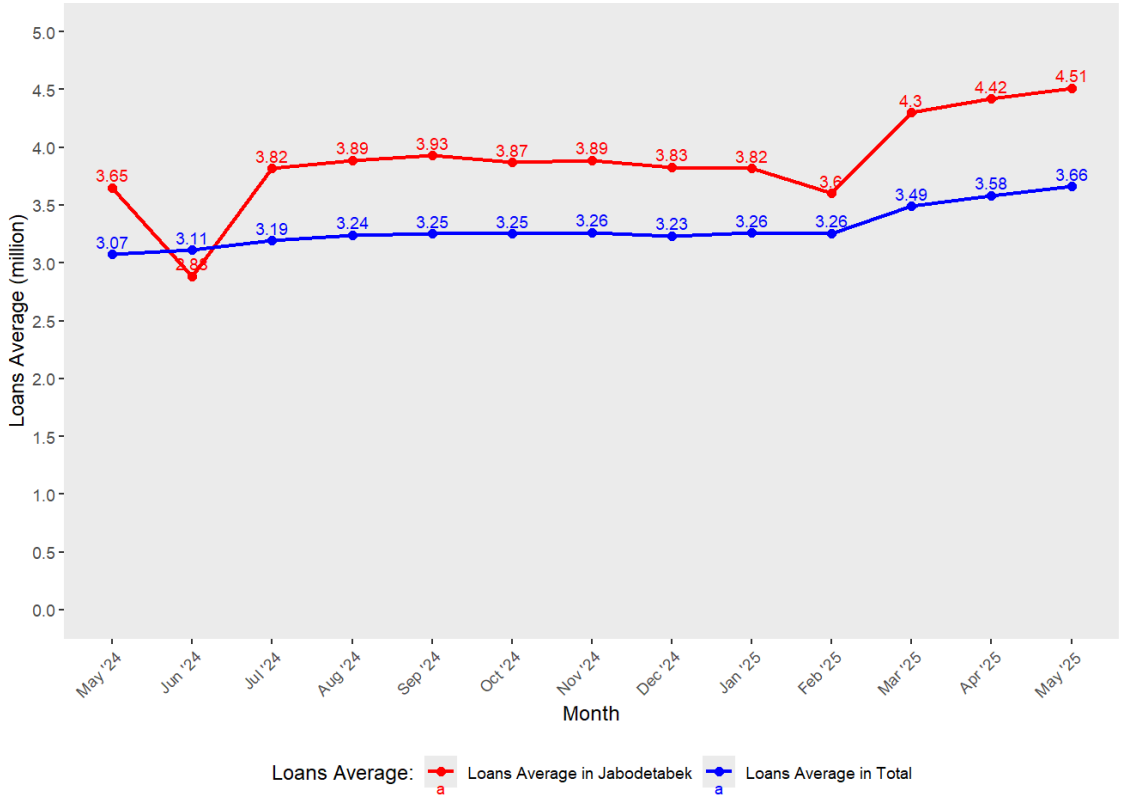


Fig. 3. Average loan value per account (AL) from May 2024 to May 2025 in Indonesia and Jabodetabek
(Pawnshop Business Statistics by the Financial Services Authority (OJK), 2025)

Despite positive aggregate growth signals, reliance on aggregated indicators presents a fundamental limitation by potentially masking substantial spatial variation at finer geographic scales. Divergent patterns between national and metropolitan indicators suggest that pawnshop business performance is unevenly distributed and shaped by local characteristics such as population density, regional economic structure, income levels, and geographic proximity. Accordingly, pawnshop business dynamics cannot be fully understood as spatially independent phenomena. For pawn institutions operating nationwide, the primary challenge has shifted from merely increasing transaction volumes to identifying strategic locations for expansion, service optimization, and efficient resource allocation (Fitzpatrick, 2024; Hung & Lin, 2022). Conventional non-spatial analytical approaches, such as descriptive analysis, demographic segmentation, and standard regression models, may overlook relationships among neighboring areas when spatial dependence is not explicitly incorporated into the analytical framework (Abdul Razak & Asutay, 2022; Fitzpatrick, 2024; Vithessonthi, 2023).

Although the literature on spatial finance and regional economics has expanded rapidly, most studies continue to focus on individual or household-level determinants (Fitzpatrick, 2024; Yang et al., 2025) or large-scale regional aggregates (Freedman & Li, 2024; Huggett & Luo, 2023), often overlooking interregional linkages at the micro scale. In

the context of pawnshop business, such approaches risk oversimplifying spatial dynamics, as customer activity and loan distributions are shaped by geographic proximity (Alsagr & Apergis, 2025; He & Niemeier, 2026), local economic structures (Gräser, 2025; Liu et al., 2026), and interactions among neighboring areas (Aritenang, 2022; Janke et al., 2023). Accordingly, this study adopts a spatial autocorrelation approach that is more appropriate for identifying geographic clustering, spatial outliers, and relationships among neighboring districts. The use of a row-standardized spatial weight matrix enables a proportional representation of neighborhood relationships across districts (Baltagi & Shu, 2025; Song & Cibin, 2024), ensuring that the spatial influence exerted on a given area reflects the average conditions of its surrounding areas rather than being biased by differences in the number of neighbors (Wang et al., 2023). This framework is further extended through local analysis, where Local Moran's I (LISA) facilitates the identification of spatial clusters with similar characteristics as well as contrastive transition areas (Cheruiyot, 2022; Wang et al., 2023), offering more granular spatial insights than global indicators alone.

To complement this perspective, Local Getis–Ord Gi* is applied because of its ability to detect intensity-based hotspots and cold spots (Tabarej et al., 2024), making it particularly relevant for identifying strategically important concentrations of pawnshop business activity. In addition, Local Geary's C provides further analytical leverage by explicitly measuring spatial similarity and dissimilarity across neighboring areas (Yamada, 2024), thereby uncovering zones of high spatial homogeneity as well as sharp local discontinuities that are often overlooked by mean-based correlation measures. The integration of standardized spatial weights and multiple complementary local spatial statistics yields a comprehensive analytical framework for capturing clustering patterns, intensity concentrations, spatial outliers, and local heterogeneity in pawnshop business activity. The novelty of this study lies in positioning pawnshop business activity as a spatially interconnected geoeconomic phenomenon and in integrating Local Moran's I (LISA), Local Getis–Ord Gi*, and Local Geary's C at the district level to generate location-based insights for service development, regional expansion, and data-driven resource allocation.

2. Methods

2.1 Research design

This study adopts a quantitative exploratory spatial research design based on the assumption that socio-economic phenomena observed across administrative units may be structured by geographic proximity and interactions among neighboring areas. The unit of analysis is the district (*Kecamatan*), represented as an administrative polygon, with each district treated as a spatial observation containing proxy-derived estimates of pawnshop customer numbers, total loan values, and AL. The primary objective of this design is to identify whether pawnshop business indicators exhibit statistically significant local clustering, spatial outliers, concentrations of high or low values, and local heterogeneity across neighboring districts. Conceptually, this framework positions space not merely as a cartographic backdrop but as an explicit analytical dimension that enables the transformation of quantitative indicators into territorial patterns, which can be interpreted to support location-based prioritization and spatial segmentation strategies.

2.2 Data sources and variables

The data employed in this study consist of two main components: spatial data and attribute data. The spatial data consist of GIS-based polygon shapefiles representing the administrative boundaries of districts within the Jabodetabek metropolitan region. These district polygons serve as the spatial support for the entire analytical process, ranging from the definition of observational units to the visualization of spatial clusters. Based on these polygons, spatial relationships among districts are defined using a contiguity-based structure, in which two districts are considered neighbors when they share an

administrative boundary. The monthly series from May 2024 to May 2025 was used to describe national and metropolitan trends, while the May 2025 values were used for the district-level spatial analysis. The geographic location and spatial extent of the study area are illustrated in Figure 4.

Attribute data at the district level were estimated using proportional proxy-based downscaling to represent key indicators of pawnshop business activity. The variables analyzed comprised Customers (C), representing the estimated number of pawnshop customer accounts; Loans (L), representing the estimated total value of pawnshop loans; and Average Loan Value per Account (AL), calculated by dividing the estimated loan value by the estimated number of customer accounts in each district. Official customer-account and loan totals at the regency or municipality level were obtained from the Financial Services Authority (OJK), whereas district-level population and land-area data were obtained from Statistics Indonesia (BPS). Because official pawnshop transaction data were unavailable at the district level, proportional proxy-based downscaling was applied to derive district-level estimates.

Although the proxy-based downscaling approach enables regency- or municipality-level OJK data to be transformed into district-level estimates, the method is subject to several important limitations. The use of population shares assumes that customer accounts are distributed proportionally to the population of each district. However, this assumption may not reflect differences in household income, financial inclusion, demand for pawnshop services, or accessibility to pawnshop branches. Similarly, the use of land-area shares assumes a constant loan value per unit of land area across districts. This assumption may not adequately capture variations in economic activity, population density, urban concentration, branch locations, or demand for financing. Therefore, the resulting district-level values should be interpreted as relative spatial approximations rather than precise measurements of actual financial transactions. The estimated customer value is calculated as follows Equarion 1.

$$C_{ir} = C_r \left(\frac{P_{ir}}{\sum_{k \in r} P_{kr}} \right) \quad \text{(Eq. 1)}$$

Where C_{ir} is the estimated number of customers in the district $i$within the region r, C_r is the official customer total reported by OJK for the region r, and P_{ir} is the population of the district i obtained from BPS. The estimated loan value was calculated as follows Equation 2.

$$L_{ir} = L_r \left(\frac{A_{ir}}{\sum_{k \in r} A_{kr}} \right) \quad \text{(Eq.2)}$$

Where L_{ir} denotes the estimated loan value in district (i) within regency or municipality (r), L_r denotes the official total loan value for regency or municipality (r), A_{ir} denotes the land area of district (i), and $\sum_{k \in r} A_{kr}$ represents the total land area of all districts (k) located within regency or municipality (r). The AL was subsequently calculated by dividing the estimated total loan value by the estimated number of customer accounts in each district, as follows Equation 3.

$$AL_{ir} = \frac{L_{ir}}{C_{ir}} \quad \text{(Eq.3)}$$

Where AL_{ir} denotes the estimated average loan value per customer in district (i) within regency or municipality (r); L_{ir} denotes the estimated total loan value for the corresponding district; and C_{ir} denotes the estimated number of customers in that district. Because both L_{ir} and C_{ir} are proxy-derived values, AL_{ir} should be interpreted as an estimated indicator of financing intensity rather than a directly observed transaction value.

These proportional allocation procedures preserve consistency with the official aggregate data reported by OJK. The estimated number of customer accounts across all

districts within a regency or municipality sums to the corresponding official regional customer-account total. Similarly, the estimated loan values across all districts reproduce the official regional loan total. Consequently, each district is characterized by three attributes: Customers (C), Loans (L), and Average Loan Value per Account (AL). These proxy-based indicators were subsequently analyzed to determine whether districts with similar or contrasting values exhibited statistically significant local spatial patterns.

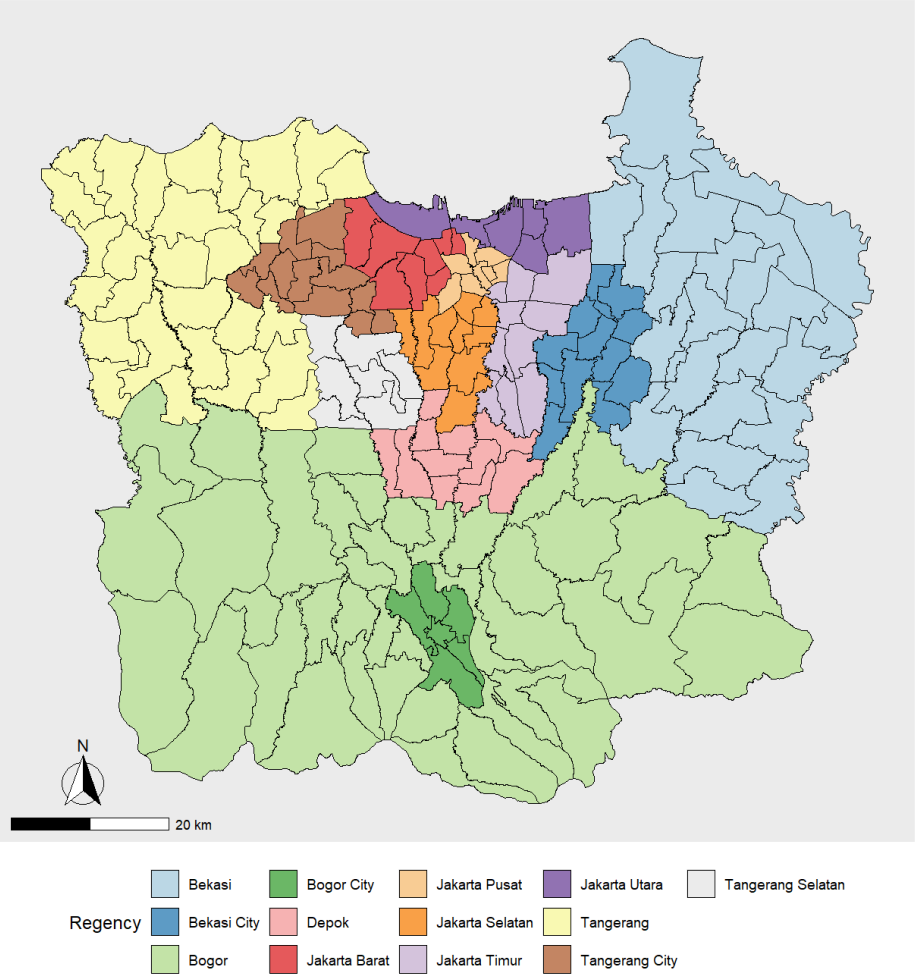


Fig. 4. Research location

2.3 Data analysis

This study employs an integrated local spatial analysis framework to examine the spatial distribution of estimated customer numbers, total loan values, and AL at the district level. The approach combines complementary local spatial statistics to examine clustering and spatial outliers, concentrations of high or low values, and similarities or dissimilarities among neighboring districts. The analytical integration is implemented through four main components: a row-standardized spatial weight matrix (W), Local Moran's I (LISA), Local Getis–Ord Gi*, and Local Geary's C.

2.3.1 Row-standardized spatial weight matrix (W)

The core element of spatial autocorrelation analysis is the spatial weight matrix (W), which formalizes "who is adjacent to whom" and the extent to which neighboring units contribute to spatial statistical calculations. In this study, *W* is constructed using a queen contiguity, whereby two districts were treated as neighbors when their polygons shared either a boundary segment or a vertex. Operationally, the spatial weight w_{ij} is assigned a

value of 1 when districts *i* and *j* are contiguous and w_{ij}= 0 otherwise, while w_{ii} = 0 because a district is not considered its own neighbor.

To ensure that spatial influence across districts is proportional and comparable across space, row standardization is applied. This procedure normalizes the weights in each row such that the sum of weights for row *i* equals 1, thereby allowing the spatial effect on each district to reflect the average condition of its neighboring areas rather than being driven by differences in the number of adjacent units. This normalization ensures that each district is influenced by the average conditions of its neighboring areas, rather than by the sheer number of neighbors it has. As a result, spatial lags are comparable across districts and are not mechanically larger merely because a district has more adjacent neighbors.

$$w_{ij}^{*} = \frac{w_{ij}}{\sum_{j} w_{ij}} \tag{Eq.4}$$

2.3.2 Local moran's I (LISA) analysis for mapping local spatial structure

Local Moran's I (LISA) is employed in this study to identify and map patterns of local spatial dependence at the district level. Through this analysis, each district can be classified into four principal categories based on the relationship between its indicator value and those of its surrounding areas: High–High (HH), representing a high-value district surrounded by high-value neighbors; Low–Low (LL), representing a low-value district surrounded by low-value neighbors; High–Low (HL), representing a high-value spatial outlier surrounded by low-value neighbors; and Low–High (LH), representing a low-value spatial outlier surrounded by high-value neighbors. Mathematically, the Local Moran's I (LISA) statistic for each district i is formulated as follows:

$$.I_i = \frac{(x_i - \bar{x})}{m_2} \sum_{j} w_{ij} \, (x_j - \bar{x}) \tag{Eq.5}$$

$$m_2 = \frac{\sum_i (x_i - \bar{x})^2}{n} \tag{Eq.6}$$

Where x_i denotes the value of the variable in district *i*, $\bar{x}$ represents the mean value across all districts, w_{ij} indicates the spatial weight between districts *i* and *j*, and *n* is the total number of districts. This statistic measures the association between the standardized value of a district and the spatially weighted standardized values of its neighbors, thereby identifying local clusters and spatial outliers. The results of the Local Moran's I (LISA) analysis are presented in two primary forms. First, Local Moran's I (LISA) cluster maps visualize the spatial distribution of the HH, LL, HL, and LH categories at the district level, enabling the identification of local spatial patterns and their interpretation as territorial segmentation. Second, the cluster maps provide a visual summary of the distribution of districts across the identified spatial categories and highlight the geographical concentration of pawnshop business indicators within each cluster. This presentation facilitates more operational interpretation and enables the transformation of spatial findings into territory-aware analytics capable of generating location-based business insights.

All spatial analyses were conducted in RStudio using the sf package for geospatial data management, the *spdep* package for spatial weight construction and local spatial statistics, and the *ggplot2* package for map visualization. The choice of these tools supports analytical transparency, reproducibility, and alignment with contemporary spatial research practices. Methodologically, this study applies Local Moran's I (LISA), Local Getis–Ord Gi*, and Local

Geary's C to proxy-derived district estimates rather than directly observed operational data. The resulting spatial patterns serve as exploratory evidence for identifying potential clusters, concentrations, outliers, and transition areas that require validation with observed branch- or transaction-level data. Accordingly, the primary methodological focus is on ensuring coherent construction of spatial units, neighborhood weights, and cluster identification procedures, thereby enabling systematic and replicable interpretation of territorial patterns.

2.3.3 Local Getis-Ord Gi analysis*

Local Getis–Ord Gi* analysis is employed to identify intensity-based spatial clustering**,** particularly to detect hot spots (high-value concentrations) and cold spots (low-value concentrations) of pawnshop business activity at the district level. Whereas Local Moran's I (LISA) identifies local associations and spatial outliers, Local Getis–Ord Gi* evaluates whether high or low values are significantly concentrated within a district and its neighboring areas. Mathematically, the Local Getis–Ord Gi* statistic for area *i* is expressed as follows Equation 7.

$$G_i^* = \frac{\sum_{j=1}^{n} w_{ij}x_j - \bar{X}\sum_{j=1}^{n} w_{ij}}{S\sqrt{\frac{n\sum_{j=1}^{n} w_{ij}^2 - \left(\sum_{j=1}^{n} w_{ij}\right)^2}{n-1}}} \quad \text{(Eq.7)}$$

Where x_j represents the value of the pawnshop business variable, such as the number of customers or loan amounts in area *j*; w_{ij} denotes the spatial weight capturing the neighborhood relationship between areas *i* and *j*; *n* is the total number of areas analyzed; $\bar{X}$ indicates the mean value of the variable under study; and *S* is the standard deviation of the variable, serving as a measure of data dispersion. A statistically significant positive Gi* z-score indicates a hotspot, whereas a statistically significant negative Gi* z-score indicates a cold spot; values that are not statistically significant are not classified as either. This analysis complements Local Moran's I (LISA) by identifying statistically significant concentrations of high or low values, rather than classifying the relationship between an individual district's value and those of its neighbors.

2.3.4 Local geary's C analysis

Local Geary's C is employed to measure the degree of similarity and dissimilarity in pawnshop business characteristics between a given area and its neighboring regions. In contrast to Local Moran's I (LISA), which is sensitive to value correlations, Local Geary's C places greater emphasis on absolute differences across areas, making it particularly effective for detecting local heterogeneity and identifying spatial boundaries. The Local Geary's C statistic for area i is defined as follows Equation 8.

$$C_i = \frac{\sum_{j=1}^{n} w_{ij}(x_i - x_j)^2}{\sum_{j=1}^{n}(x_i - \bar{X})^2} \quad \text{(Eq. 8)}$$

Where $x_i$and x_j denote the values of the variable in areas *i* and *j*, respectively; w_{ij}represents the spatial weight capturing the neighborhood relationship between the two areas; and $\bar{X}$ denotes the mean value of the variable. Relatively low Local Geary's C values indicate greater similarity between a district and its neighbors, whereas relatively high values indicate stronger local dissimilarity. These patterns should be interpreted together with their statistical significance. Accordingly, Local Geary's C is particularly useful for

identifying transition zones or areas exhibiting significant localized changes in pawnshop business characteristics. Because local statistics are calculated separately for multiple districts, the resulting significance patterns are interpreted as exploratory spatial evidence rather than definitive confirmatory tests, particularly when no multiple-testing correction is applied. Statistical significance was assessed using permutation-based pseudo-p-values generated from 999 random permutations. Districts with pseudo-$p<0.05$ were classified as statistically significant. Because no multiple-testing correction was applied, the local significance results were interpreted as exploratory spatial evidence.

3. Results and Discussion

The spatial patterns presented in this section are derived from proxy-based estimates and therefore should be interpreted as exploratory spatial evidence rather than direct representations of actual transaction behavior. Therefore, the spatial patterns should be interpreted as exploratory evidence of local clustering, concentration, and heterogeneity. This patterns presents the spatial autocorrelation patterns of pawnshop business customers, loan volumes, and average loan value per account (AL) across Jabodetabek.

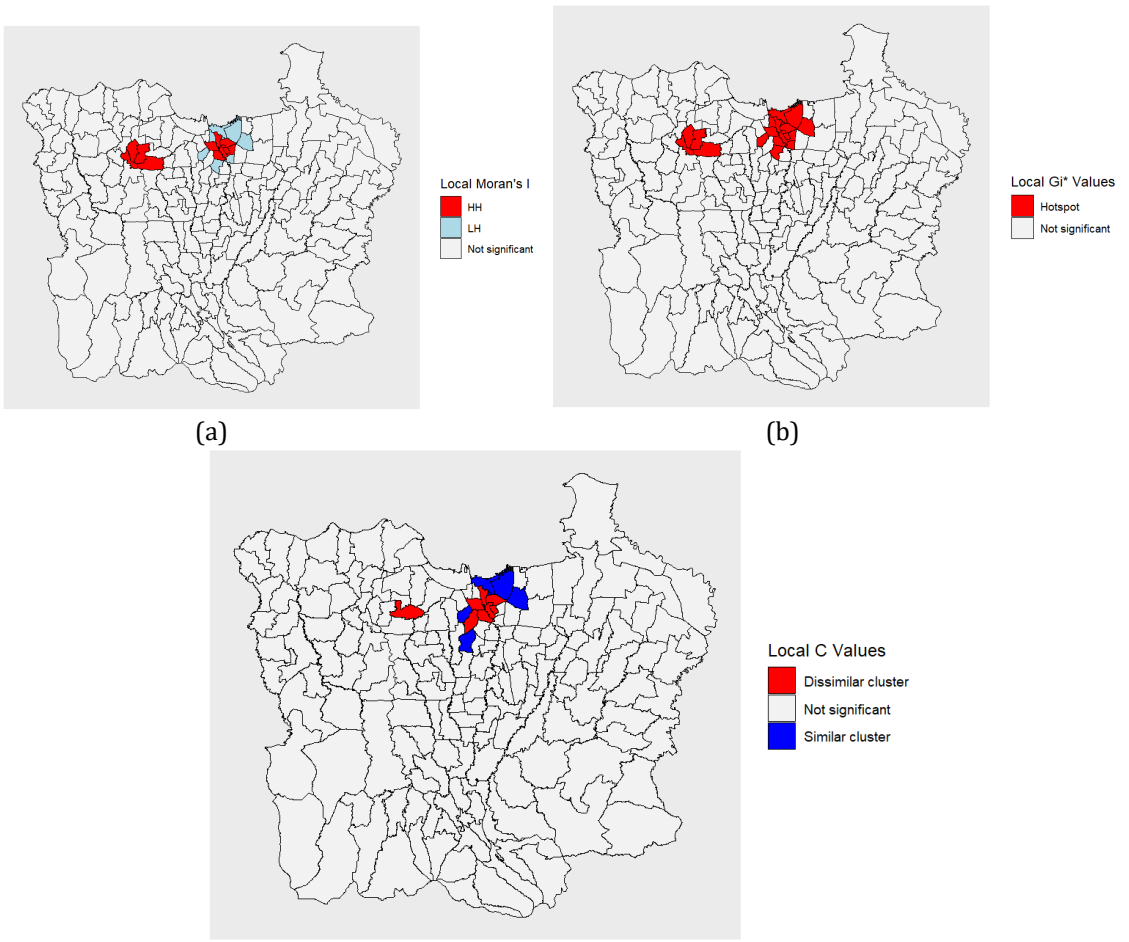
3.1 Spatial autocorrelation patterns of pawnshop business customers in Jabodetabek

The Local Moran's I (LISA) analysis identifies statistically significant customer clusters and spatial outliers in selected districts of Jabodetabek, indicating the presence of localized spatial dependence rather than uniform spatial association across the entire metropolitan region. This finding is consistent with spatial autocorrelation theory and Tobler's First Law of Geography, which suggests that geographically proximate areas may exhibit more closely related economic characteristics than geographically distant areas (Santoso et al., 2019; Zheng et al., 2023). Areas highlighted in red represent HH clusters, in which districts with relatively high estimated customer numbers are surrounded by neighboring districts with similarly high values.

Empirically, HH clusters are concentrated in Jakarta's urban core, particularly across seven districts in Central Jakarta, such as Cempaka Putih, Gambir, Johar Baru, Kemayoran, Menteng, Sawah Besar, and Senen. This pattern extends into Tangerang City, including Cibodas, Karawaci, Pinang, and Tangerang. The concentration of HH clusters in these areas is consistent with agglomeration theory, which associates dense trade, service activity, and economic mobility with the geographical concentration of markets (Che'Man & Bin Jamaluddin, 2020; Kuchiki, 2022; Maket et al., 2024).

In the context of pawnshop business, spatial proximity among high-value areas may facilitate information diffusion, improve service visibility, and reduce customer search costs, thereby potentially supporting service utilization across neighboring areas (Baltagi & Shu, 2025; Henderson & Thisse, 2024; Song & Cibin, 2024). Districts within HH clusters indicate areas with relatively high estimated values; however, these patterns should not be directly interpreted as mature markets. Instead, they may serve as preliminary spatial signals for further investigation using operational branch- and transaction-level data before any business decisions are made (Duan & Zheng, 2024; He et al., 2019; Rahman & Mustafa, 2017). Moreover, HH clusters may serve as potential anchor areas from which service networks, area-based promotion, and regional value-chain connections could be developed toward neighboring districts (Hou et al., 2025; Kotíková, 2023; Sen & Sensarma, 2026).

Fig. 5(a) illustrates the LH areas, indicated in light blue, which are classified as spatial outliers, districts with relatively low customer numbers located adjacent to high-value clusters. These include Setiabudi (South Jakarta); Palmerah and Taman Sari (West Jakarta); Matraman (East Jakarta); and Kelapa Gading, Pademangan, and Tanjung Priok (North Jakarta). Theoretically, LH patterns indicate local spatial contrasts between districts and their neighbors; however, the underlying socio-economic mechanisms such as accessibility or financial literacy, are not directly observed in this study and therefore remain speculative (Choi & Rocheteau, 2024; Davis & Hashimoto, 2022; Delli Gatti et al., 2024).



(a) (b)

(c)

Fig. 5. Spatial patterns of estimated pawnshop customers in Jabodetabek: (a) Local Moran's I (LISA); (b) Local Getis–Ord Gi*; (c) Local Geary's C

The spatial position of LH areas suggests the need for further location-specific assessment before expansion or service interventions are implemented. Subject to validation using branch- and customer-level information, possible measures include reassessing branch accessibility and service hours, adapting products to local socio-economic profiles, strengthening financial literacy initiatives, and developing community-based marketing strategies (Pasco & Bendezu, 2024; Permana, 2023; Putra Cahyono, 2024). From a spatial diffusion perspective, LH districts may be considered potential locations for further market assessment because they are adjacent to high-value customer clusters, although their actual demand and service integration require additional validation (He & Niemeier, 2026; Pardue & Shelton, 2025).

Meanwhile, non-significant (white) districts, covering most of Bogor City and Regency, Depok City, Bekasi City and Regency, Tangerang Regency, and South Tangerang City, exhibit no statistically significant spatial autocorrelation. This condition indicates that the analysis does not provide sufficient statistical evidence of significant local customer clustering or outlier patterns in these districts; it does not necessarily demonstrate spatial randomness or the absence of neighboring influences. The absence of statistically significant local patterns may be consistent with the heterogeneous economic structures and less consolidated market orientations commonly observed in metropolitan fringe areas (Maduekwe & de Vries, 2019; Wang et al., 2025).

Fig. 5(b) presents the Local Getis–Ord Gi* analysis for Jabodetabek, where red areas denote hotspots, districts with statistically significant concentrations of customers relative to their surroundings. These hotspots are strongly concentrated in the core of DKI Jakarta, particularly Central Jakarta (Cempaka Putih, Gambir, Johar Baru, Kemayoran, Menteng, Sawah Besar, and Senen), which function as major centers of trade and services. The hotspot

pattern extends into West Jakarta (Palmerah and Taman Sari), South Jakarta (Setiabudi), East Jakarta (Matraman), North Jakarta (Kelapa Gading, Pademangan, Tanjung Priok), and Tangerang City (Cibodas, Karawaci, Pinang, Tangerang). This compact hotspot concentration is consistent with the clustering of market activity in the metropolitan core, where trade, services, mobility, and economic interactions are relatively intensive (Pang & Nie, 2025; Saraiva & Caiado, 2025; Xiong et al., 2025). Non-significant areas in the Gi* analysis, including Bogor, Depok, Bekasi, Tangerang Regency, South Tangerang City, and peripheral parts of East and South Jakarta, do not exhibit statistically significant concentrations of high or low estimated customer values under the applied spatial specification. The hotspot pattern indicates a stronger concentration of estimated customer activity in Jakarta's urban core than in most surrounding areas, consistent with an uneven metropolitan spatial structure (An et al., 2024; Aritenang, 2022).

Finally, Fig. 5(c) presents Local Geary's C results, offering additional insight into spatial similarity and dissimilarity. Blue areas indicate similar clusters, where districts exhibit relatively homogeneous customer characteristics with their neighbors, forming zones of spatial homogeneity. Such clusters appear in Kebayoran Baru (South Jakarta), Palmerah (West Jakarta), and Kelapa Gading, Pademangan, and Tanjung Priok (North Jakarta). These clusters indicate local similarity in estimated customer values among neighboring districts, which may be consistent with relatively homogeneous market conditions across adjacent areas (Delli Gatti et al., 2024; Hasanah & Qibtiyah, 2025).

In contrast, areas highlighted in red represent dissimilar clusters, where customer volumes differ markedly from those of adjacent districts. Such patterns are predominantly concentrated in Central Jakarta, particularly in Tanah Abang, Senen, Sawah Besar, Menteng, Kemayoran, Johar Baru, and Gambir, as well as in Cipondoh, Tangerang City. These districts exhibit significant local dissimilarity from their neighbors, which may be associated with differences in urban functions or concentrations of economic activity; however, these underlying factors require separate empirical examination (Deppner & Cajias, 2024; Yamada, 2024). Meanwhile, white (non-significant) areas, encompassing most of Bogor City and Regency, Depok City, Bekasi City and Regency, the majority of Tangerang City, Tangerang Regency, South Tangerang City, and large portions of West, East, North, and South Jakarta, indicate the absence of sufficiently strong spatial similarity or dissimilarity to constitute statistically meaningful clusters.

Overall, the integrated results from Local Moran's I (LISA), Local Getis–Ord Gi*, and Local Geary's C demonstrate that the spatial pattern of pawnshop business customers in Jabodetabek is geographically heterogeneous and segmented. Jakarta's metropolitan core forms strong clusters and hotspots characterized by pronounced spatial dependence, while surrounding areas exhibit combinations of localized hotspots, spatial outliers, and non-significant patterns reflecting transitional metropolitan dynamics. Statistically non-significant districts provide insufficient evidence of identifiable local spatial association under the applied method and should not automatically be interpreted as spatially random. These findings suggest that customer-development strategies may be spatially differentiated by evaluating established clusters, hotspots, and adjacent outlier areas rather than applying a uniform metropolitan strategy. This exploratory spatial evidence can provide an initial basis for developing more adaptive and context-sensitive business and regulatory strategies, provided that the results are subsequently validated using observed operational data.

3.2 Spatial autocorrelation patterns of pawnshop business loans in Jabodetabek

The local spatial analysis of total loan values identifies statistically significant clusters, outliers, and concentrations in selected districts, indicating localized spatial association within Jabodetabek. This finding reinforces insights from the spatial economics and regional finance literature, which posit that financial activities tend to concentrate geographically due to the interaction of spatial proximity, the intensity of economic activity, and local demand structures (Pardue & Shelton, 2025; Wang et al., 2025). As shown in the Local

Moran's I (LISA) map in Fig. 6(a), the red HH areas represent districts with relatively high estimated loan values surrounded by neighboring districts with similarly high values. These HH clusters are primarily concentrated in Central Jakarta and Tangerang City. In Central Jakarta, the clusters include Cempaka Putih, Gambir, Johar Baru, Kemayoran, Menteng, Sawah Besar, Senen, and Tanah Abang, while in Tangerang City, they encompass Cibodas, Karawaci, and Tangerang. This spatial configuration is consistent with agglomeration-economy theory, which associates high concentrations of trade, services, and financial mobility with the geographic concentration of economic activity (An et al., 2025; Wang & Gao, 2025).

Within the pawnshop business context, the concentration of high estimated loan values in agglomerated areas may be associated with demand pooling (Fitzpatrick, 2024), greater operational efficiency (Chen et al., 2025), and lower information and transaction costs (Wang et al., 2025). However, these mechanisms are not directly tested in this study. Spatial proximity among high-loan areas may support economic and financial linkages that strengthen the potential role of core areas as regional financing centers (Anderson & Jackson, 2021; Chen et al., 2025; He & Niemeier, 2026; Vithessonthi, 2023).

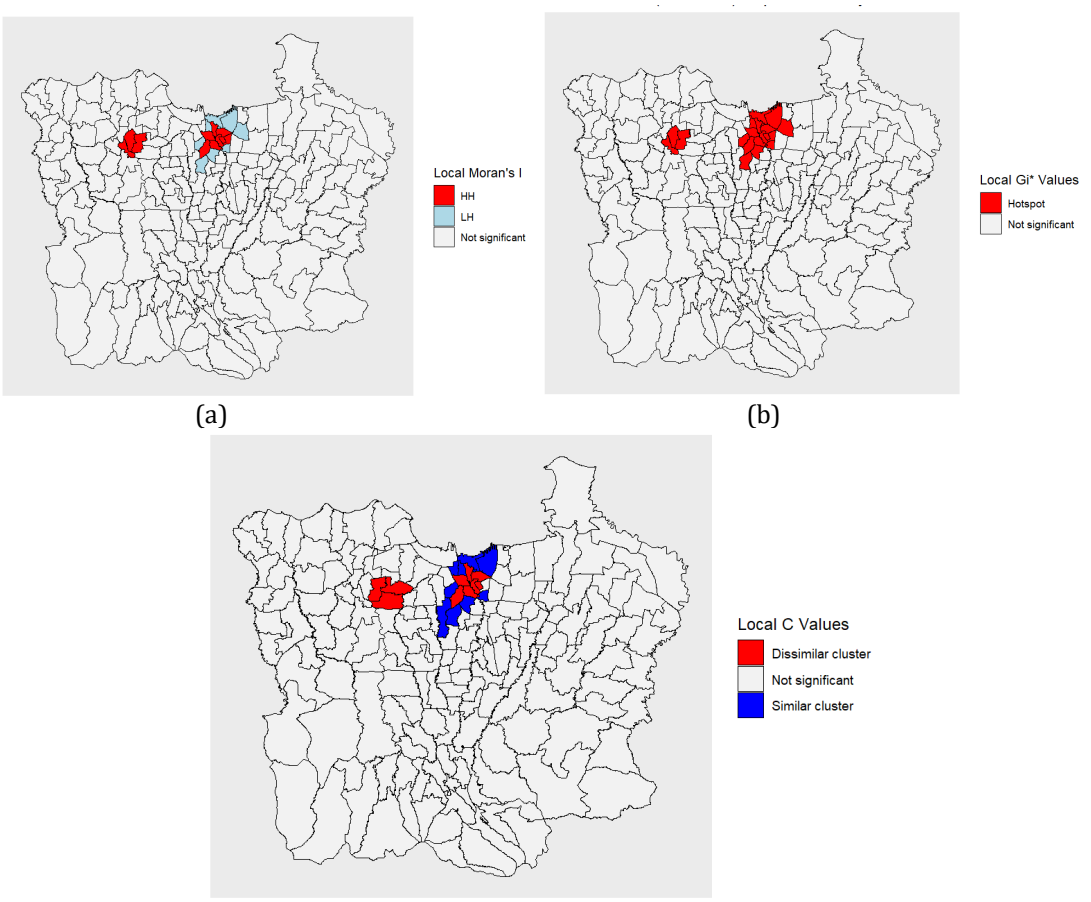


Fig. 6. Spatial patterns of estimated pawnshop loan values in Jabodetabek: (a) Local Moran's I (LISA); (b) Local Getis–Ord Gi*; (c) Local Geary's C

On the other hand, LH areas, shown in light blue, represent districts with relatively low loan values located adjacent to high-value clusters. This pattern is evident in parts of West Jakarta, South Jakarta, and North Jakarta. In West Jakarta, LH districts include Palmerah and Taman Sari; in South Jakarta, Kebayoran Baru and Setiabudi; and in North Jakarta, Kelapa Gading, Pademangan, and Tanjung Priok. The presence of these LH outliers indicates a local contrast in estimated loan values between the identified districts and their high-value neighbors; however, this result alone does not establish intra-urban inequality or the mechanisms producing the contrast. This pattern may be interpreted through the concepts

of spatial mismatch and uneven financial-service diffusion, although differences in socio-economic structure, customer risk profiles, collateral characteristics, and service penetration are not directly measured in this study (Mohd Daud et al., 2024; Trotta et al., 2026).

From a policy and business strategy perspective, LH areas may require selective and context-sensitive assessment rather than uniform expansion. Subject to validation using observed operational data, possible measures include adjusting financing products to local income structures, improving branch accessibility and visibility, and strengthening community-based financial literacy initiatives (Cheruiyot, 2022; Su & Zheng, 2025). Within the framework of spatial diffusion theory, LH districts may warrant further market assessment because of their proximity to high-value clusters, although their suitability for expansion requires validation using branch-level, customer-level, accessibility, and actual transaction data (Cheruiyot, 2022; Kuchiki, 2022).

Districts shown in white (non-significant), covering Bogor City and Regency, Depok City, Bekasi City and Regency, Tangerang Regency, South Tangerang City, and East Jakarta, exhibit no strong spatial autocorrelation in loan values. This result indicates that the identified districts do not exhibit statistically significant local loan clusters or outlier patterns under the applied LISA specification. The absence of significant local clusters may be consistent with structural heterogeneity in metropolitan fringe areas; however, the relative influence of demographic composition, dominant economic sectors, financing preferences, and spatial proximity is not directly tested in this analysis (Janke et al., 2023).

The Local Getis–Ord Gi* results shown in Fig. 6(b) for total loans further highlight spatial concentration. Red areas denote loan hotspots, indicating districts with statistically significant concentrations of loan values relative to their surroundings. These hotspots are strongly concentrated in West Jakarta, Central Jakarta, East Jakarta, North Jakarta, and Tangerang City**.** Specifically, West Jakarta includes Palmerah and Taman Sari; Central Jakarta comprises Cempaka Putih, Gambir, Johar Baru, Kemayoran, Menteng, Sawah Besar, Senen, and Tanah Abang; East Jakarta includes Matraman; North Jakarta includes Kelapa Gading, Pademangan, and Tanjung Priok; and Tangerang City includes Cibodas, Karawaci, and Tangerang. These areas are well known as centers of economic activity, trade, and financial services. The relatively compact hotspot pattern indicates a statistically significant concentration of high estimated loan values across neighboring areas and is consistent with interconnected metropolitan financial environments (Liu & Dong, 2025; Trotta et al., 2026).

Conversely, non-significant areas in the Local Getis–Ord Gi* analysis indicate the absence of sufficient spatial intensity to form hotspots. These districts do not exhibit statistically significant Gi* concentrations, but this finding does not establish that they play a passive financing role or that their loan values are determined primarily by internal conditions. The stronger concentration of hotspots in central areas is consistent with core–periphery dynamics, although the specific economic roles and degree of financial integration of surrounding regions require additional operational evidence (Khan et al., 2024; Rothenberg et al., 2025).

Results from the Local Geary's C analysis, shown in Fig. 6(c), provide a more nuanced view of spatial structure through patterns of similarity and dissimilarity across districts. Blue areas indicate similar clusters, where loan levels are relatively comparable to those of neighboring areas, forming zones of spatial homogeneity. These clusters appear as corridors across West, South, East, and North Jakarta. In West Jakarta, they include Palmerah, Taman Sari, and Tambora; in South Jakarta, Kebayoran Baru and Kebayoran Lama; in East Jakarta, Matraman; and in North Jakarta, Pademangan and Tanjung Priok. From a spatial perspective, such homogeneity indicates that neighboring districts have relatively similar estimated loan values, but it does not directly demonstrate equilibrium between financing demand and supply (Liu et al., 2024; Wójcik, 2025).

In contrast, red areas represent dissimilar clusters, where loan values differ sharply from those of neighboring districts. These patterns are concentrated in Central Jakarta, including Gambir, Johar Baru, Kemayoran, Menteng, Sawah Besar, Senen, and Tanah Abang, and in Tangerang City, particularly Cipondoh, Pinang, and Tangerang. These locations

represent significant local deviations from neighboring loan values and may be associated with differentiated economic or financing functions, although these mechanisms are not directly observed in the available data (Peng & Qiu, 2023; Wei et al., 2024).

Meanwhile, white (non-significant) districts, including Bogor City and Regency, Depok City, Bekasi City and Regency, Tangerang Regency, and South Tangerang City, exhibit no statistically meaningful spatial similarity or dissimilarity. These areas do not exhibit statistically significant local similarity or dissimilarity, and the analysis cannot determine whether their estimated loan values are driven by internal factors or by interactions with neighboring areas. This does not imply the absence of financial activity, but rather indicates insufficient statistical evidence to identify local spatial dependence under the applied method.

The Local Geary's C analysis further enriches the understanding of the spatial structure of pawnshop business loans in Jabodetabek by demonstrating that the metropolitan region is shaped not only by high-intensity clusters but also by significant local deviation points. Districts forming similar clusters exhibit relatively comparable estimated loan values with their neighbors, whereas dissimilar clusters identify areas with pronounced local contrasts that may warrant further investigation. These findings underscore the importance of micro-level, context-sensitive policy and business strategies, as loan patterns cannot be fully explained by aggregated metropolitan characteristics alone (An et al., 2024; Aritenang, 2022; Bahri et al., 2025).

Overall, the spatial autocorrelation patterns of pawnshop business loans in Jabodetabek reveal a combination of strong core clusters (HH)**,** potential outliers (LH)**,** and pronounced local heterogeneity (dissimilar clusters)**.** The results provide exploratory evidence that estimated pawn-financing values are spatially differentiated and exhibit significant local associations in selected parts of Jabodetabek. Consequently, the identified clusters and local contrasts may be used as an initial basis for developing locally contextualized strategies, but operational decisions should be supported by branch, customer, and transaction-level validation.

3.3 Spatial pattern of average loan value per account (AL) in Jabodetabek

The spatial analysis of AL provides a perspective distinct from customer numbers and total loan values because it represents the ratio of estimated total loans to estimated customer accounts within each district. This indicator describes differences in estimated loan value per account across districts but cannot independently measure customer borrowing capacity, risk preferences, income, or economic ability. The mapping results presented in Fig. 7 indicate that districts with the highest AL are not evenly distributed across Jabodetabek. Instead, statistically significant local patterns are concentrated in selected areas, indicating that the proxy-derived AL values vary geographically within the metropolitan region.

Based on the mapping of AL at the district level in Jabodetabek using Local Moran's I (LISA), as shown in Fig. 7(a), red areas (HH) indicate districts with the highest AL that are surrounded by neighboring districts with similarly high characteristics, thereby forming high-value spatial clusters. These HH clusters are strongly concentrated in Bogor City, particularly in the districts of West Bogor, South Bogor, Central Bogor, East Bogor, North Bogor, and Tanah Sareal. This concentration indicates local spatial association in the estimated AL, but the analysis does not directly identify the socio-economic mechanisms underlying the pattern.

This pattern is consistent with spatial sorting and neighborhood effects theories, which posit that households and economic activities with similar characteristics tend to cluster geographically (Eliasson & Westerlund, 2023; Yang et al., 2025). In the context of pawnshop business activity, higher AL may be associated with differences in collateral profiles, income, and financing needs; however, these characteristics are not directly observed in the data used in this study. Proximity among districts with similar characteristics may facilitate common market conditions and financial behavior, although market learning, perceived

risk, and borrowing normalization are not directly tested in this study (Liu, 2021; Peng & Qiu, 2023).

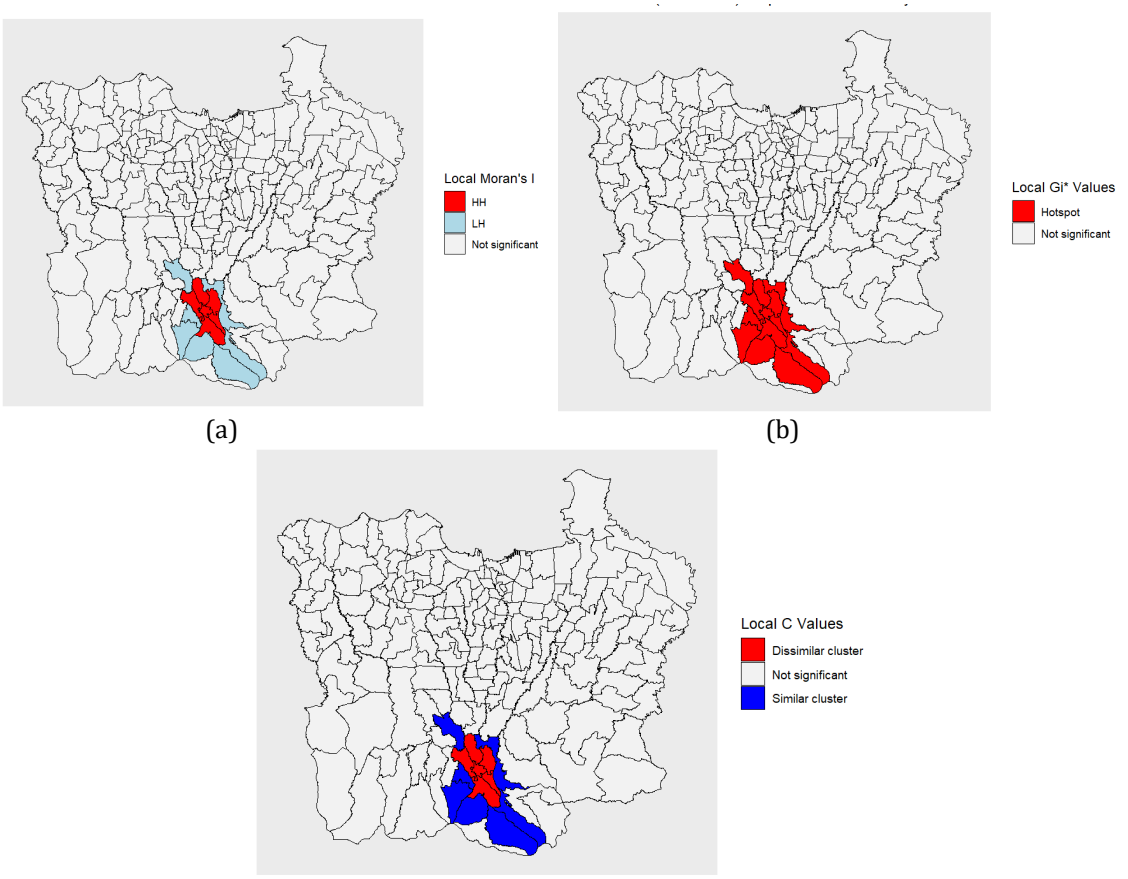


Fig. 7. Spatial patterns of estimated AL in Jabodetabek: (a) Local Moran's I (LISA); (b) Local Getis–Ord Gi*; (c) Local Geary's C

By contrast, light-blue areas (LH) represent districts with relatively lower AL that are located adjacent to high-value clusters. These LH areas primarily surround the core clusters in Bogor Regency, including Caringin, Ciawi, Cijeruk, Ciomas, Kemang, Sukaraja, and Taman Sari**.** This configuration indicates a local spatial contrast between lower-value districts and neighboring HH areas but does not independently establish a causal spillover effect. Theoretically, this pattern may be interpreted as incomplete spatial diffusion, although the transmission of high-value lending characteristics between neighboring areas is not directly examined in this study (Jin, 2018; Kim et al., 2021; Kotíková, 2023).

LH patterns may be associated with differences in pledged assets, risk preferences, or borrowing capacity; however, these potential explanations require customer- and transaction-level evidence (Bekturganova & Kurmasheva, 2025). From a financial-capability perspective, LH districts may be prioritized for further assessment before implementing tailored financing schemes, asset-based product segmentation, or changes in loan ceilings (Okello et al., 2025; Xiao et al., 2022). Conversely, white (non-significant) districts cover most of the remaining areas of Jabodetabek, including the entirety of DKI Jakarta, Depok City, Bekasi City and Regency, Tangerang City and Regency, and South Tangerang City. These areas exhibit no strong spatial clustering in the AL variable. This result indicates insufficient statistical evidence of significant local clustering in the estimated AL and does not establish whether internal district characteristics are more influential than spatial proximity effects (Janke et al., 2023).

The Local Getis–Ord Gi* analysis further reinforces these findings by revealing pronounced hotspots of AL concentrated in Bogor City and Bogor Regency. Districts in Bogor City, such as West Bogor, South Bogor, Central Bogor, East Bogor, North Bogor, and

Tanah Sareal, as well as Caringin, Ciawi, Cijeruk, Ciomas, Kemang, Sukaraja, and Taman Sari in Bogor Regency, emerge as areas with statistically significantly higher per-customer financing intensity relative to surrounding districts. The elongated configuration of these hotspots indicates a potential financial-intensity corridor characterized by spatially concentrated high estimated AL (Baeza-González & Kamakura, 2025; Dai et al., 2023; Georg et al., 2023).

Conceptually, this hotspot pattern aligns with urban socio-economic stratification theory**,** whereby areas dominated by middle- to upper-income residential zones and business centers generate distinct financing demand structures compared with other regions (Anderson & Jackson, 2021; Moral-Carcedo, 2024). The higher estimated average loan values may indicate the use of higher-value collateral or different financing needs, although collateral types and loan purposes are not available in the data. The results show that districts with high estimated average loan values do not necessarily correspond to those with the largest estimated customer numbers, indicating that customer concentration and loan value per account represent different spatial dimensions.

By contrast, the absence of statistically significant hotspots across most other parts of Jabodetabek indicates that the analysis does not identify significant local concentrations of high estimated AL in these areas. This pattern indicates that significant concentrations of estimated AL are geographically limited, but the analysis cannot determine whether socio-economic factors are more influential than geographic proximity. Furthermore, the Local Geary's C results shown in Fig. 7(c) illustrate the spatial distribution of the highest AL across districts. This map identifies statistically significant areas of local similarity and dissimilarity in estimated AL, while the remaining districts are classified as non-significant.

The similar clusters**,** indicated in blue, include districts such as Caringin, Ciawi, Cijeruk, Ciomas, Kemang, Sukaraja, and Taman Sari in Bogor Regency. These areas exhibit locally similar estimated AL; however, the Local Geary's C classification itself does not establish that the values are uniformly high or identify the factors causing their similarity. This pattern may be described as a financial-intensity corridor in which neighboring areas exhibit similar estimated AL, although the alignment of their financial-demand profiles is not directly measured (Georg et al., 2023; Nguyen et al., 2021).

In contrast, the dissimilar clusters**,** shown in red, encompass West Bogor, South Bogor, Central Bogor, East Bogor, North Bogor, and Tanah Sareal in Bogor City. These districts exhibit pronounced local differences in estimated AL relative to their neighbors; possible explanations such as economic inequality, accessibility, and local policy differences require additional empirical evidence. Such heterogeneity indicates local spatial contrasts that may be relevant to the distribution and integration of financial services, but it does not independently demonstrate inequitable service distribution (He & Niemeier, 2026; Nguyen et al., 2021; Yu et al., 2023).

These findings are consistent with spatial autocorrelation theory, which recognizes that neighboring areas may exhibit either similarity or local contrast in economic characteristics (Deppner & Cajias, 2024; Liu, 2021). This interpretation is also consistent with Tobler's First Law of Geography, which emphasizes stronger relationships among geographically proximate areas while allowing localized heterogeneity to occur (Wang et al., 2025; Yu et al., 2023; Zheng et al., 2023). Overall, Fig. 7 provides exploratory evidence of HH clusters, LH outliers, hotspots, and local similarity or dissimilarity in the proxy-derived AL across selected parts of Jabodetabek. The integrated results from Local Moran's I (LISA), Local Getis–Ord Gi*, and Local Geary's C demonstrate that customer numbers, total loan values, and estimated AL exhibit different local spatial configurations across Jabodetabek. Accordingly, the spatial results may support preliminary market segmentation by distinguishing areas with customer concentration, total-loan concentration, and higher estimated AL; however, final business decisions require validation using observed operational and customer data. Such an approach may provide a more context-sensitive basis for evaluating the heterogeneous financial characteristics of a metropolitan region such as Jabodetabek.

4. Conclusions

This study provides exploratory evidence that proxy-derived indicators of pawnshop business activity exhibit heterogeneous local spatial patterns across Jabodetabek. The integration of Local Moran's I (LISA), Local Getis–Ord Gi*, and Local Geary's C identifies local clusters, concentrations, spatial outliers, and heterogeneity that are broadly consistent with a metropolitan core–periphery structure. Central Jakarta and Tangerang City contain significant concentrations of estimated customer numbers and total loan values, whereas many surrounding areas do not exhibit statistically significant local patterns. A different spatial configuration is observed for estimated AL, with significant clusters and hotspots concentrated in Bogor City and neighboring parts of Bogor Regency, forming a potential financial-intensity corridor. These findings demonstrate that customer concentration, total loan concentration, and AL represent different spatial dimensions of pawnshop business activity and should therefore be evaluated jointly.

From a business perspective, the identified patterns can support the preliminary differentiation of strategies across territories. Areas with significant customer and loan concentrations may be interpreted as preliminary spatial signals for further assessment in service optimization and resource planning. However, any operational or strategic decisions should be supported by validation using branch-level and transaction-level data. Spatial outliers and non-significant areas should be treated as locations requiring further empirical validation rather than immediate operational prioritization. From a regional economic perspective, the results may assist financial institutions and local authorities in identifying areas where pawnshop services could support household liquidity, micro-enterprise financing, and broader financial inclusion. Nevertheless, the spatial clusters should not be interpreted as direct measures of regional welfare, financial accessibility, or economic inequality.

The findings should be interpreted cautiously because the district indicators were generated through proxy-based proportional downscaling rather than direct observations of pawnshop transactions. Population and land-area shares cannot fully capture actual customer utilization, loan demand, branch accessibility, collateral availability, or local economic activity. Future research should validate the identified patterns using branch- or transaction-level data and incorporate variables such as branch locations, accessibility, population density, household income, local business activity, collateral characteristics, and customer profiles. Comparative analysis across alternative spatial-weight specifications and time periods would further strengthen the robustness and practical relevance of the findings.

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Author Contribution
All authors have equally contributed to the conception, writing, and revision of this article, ensuring its accuracy and integrity.

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Ethical Review Board Statement
Not available. This study used aggregated secondary data and did not involve human participants.

Informed Consent Statement
Not available.

Data Availability Statement

The aggregated pawnshop data used in this study are available from the Financial Services Authority of Indonesia (OJK), while population and land-area data are available from Statistics Indonesia (BPS). The proxy-derived dataset is available from the authors upon reasonable request.

Conflicts of Interest

The authors declare no conflict of interest.

Declaration of Generative AI Use

During the preparation of this work, the authors used Grammarly to assist in improving grammar, clarity, and academic tone of the manuscript. After using this tool, the authors reviewed and edited the content as needed and took full responsibility for the content of the publication.

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