Spatial Dependence of Local Development in Mongolia

International Journal of
Business and Innovation
6 (2) 72-85, 2026
www.ijbi-irc.com

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Abstract

The concept of local development in Mongolia has gained prominence in recent years, driven largely by the government's new efforts to strengthen provincial financial self-governance. Although the revised Budget Law was enacted in 2011 sought to enhance local revenue generation, Mongolia's unique characteristics, its sparse population, vast territory and harsh climatic conditions continue to pose significant barriers to achieving balanced development across 21 provinces. This study examines whether the determinants of Local Development Index exhibit spatial correlation across provinces, using panel data from 2016 to 2024. Three alternative spatial model specifications are employed to identify the most appropriate model for analyzing spatial correlation. The results reveal the presence of significant unobserved factors that contribute to spatial dependence on provincial development outcomes. These findings underscore the critical role of unobserved structural and spatial characteristics in shaping provincial disparities in Mongolia.

Keywords

LDI, LISA, spatial model, Moran's I.

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https://doi.org/10.65194/IJBI-2026-1009
Received 7 February 2026; Received in revised form 19 April 2026; Accepted 25 April 2026

Introduction

The Ministry of Economy and Development was established in 2012 to strengthen FDI and promote national economic growth. However, the ministry was later dissolved due to the absence of a coherent and unified policy framework that considered not only national level but also provincial and regional priorities (JICA research, 2017). With the passage of the Development policy and Planning Law in 2015, new requirements were introduced for long-term development planning at all administrative levels, including provincial, municipal and capital city annual development plans. The law emphasized aligning local project implementation with appropriate budgeting mechanism and identifying financial sources to support provincial and regional initiatives. In reality, economic growth and the development index have been deteriorating in recent years (Gan-Ochir, 2019), highlighting the need for policymakers and scholars to identify the key determinants of development.

To provide a more structured long-term direction, the Government of Mongolia introduced several overarching strategies. The State Great Khural adopted the “Sustainable development vision 2030” in 2016 and followed by the “Vision 2050: Long-term development policy of Mongolia” in 2020, thereby making a renewed commitment to comprehensive and sustained national development planning (Ministry of Education, Culture, Science and Sports, 2020). However, existing initiatives address economic, financial, social and demographic dimensions, decision makers largely overlook geographical factors at the regional and provincial levels.

To strengthen balanced economic development across regions and provinces and to enhance oversight of administrative functions, the government must incorporate a spatial dependence analysis into provincial and regional development planning. The LDI, for example, is used to guide the optimal distribution of grants-in-aid when local governments require additional resources from the Local Development Sovereign Fund (Nadmid & Budjav, 2022). However, Mongolia’s small and dispersed population, vast geographic size, and political biases in central budget allocations have contributed to asymmetric local development. Under these conditions, policymakers need deeper analysis of the relationship between spatial dependence and the key determinants of local development. Insights from spatial dependence assessments can support more equitable and evidence-based grant allocations and enhance the financial capacity and autonomy of local governments.

Literature Review

Mongolia’s economic development has heavily relied on mining sectors, and other sectors’ contributions are small. While conventional livestock husbandry plays huge role in provincial and regional areas over the past 20 years (Avirmed et al, 2025). However, implementation of regional economic development has failed due to harsh weather conditions and inefficient structure of the livestock sector.

Highlighting a territorial aspect of Mongolia, total 1.5 million square kilometers, and has a climate with four seasons with extreme Siberian atmospheric pattern resulting in long cold winter and short summer. Total 3.5 million people sparsely reside in 21 provinces and over 60 percent of total population live in the capital city, Ulaanbaatar (NSO, 2023). Thus, income inequality and development between the capital city and provinces have huge gaps. Strengthening local economy and provincial development in medium and long term is necessary action asymmetric development across the nation (Dashnyam & Gungaa, 2021).

Recent studies by Avirmed et al, (2025) and Dashnyam & Gungaa (2021) emphasize economic sectors and key determinants of development. Although these contributions offer important insights, they omit spatial characteristics, thereby constraining their capacity to account for geographical disparities in development across provinces.

In addition to challenges in supporting local revenue, numerous demographics, socioeconomic, and territorial issues have arisen (Gurragchaa & Yadam, 2006). To address these matters, a new law concerning Mongolia's budget relations mechanism was introduced in 2013, which aims to ensure that regional and local budgets develop equally. Each province has different characteristics depending on population, number of livestock, weather conditions, and distance from the city (NSO, 2025). As a consequence, Mongolia needs to improve living conditions for locals by providing more an equal distribution of public goods from the central government (Khyargas, 2009). Although the papers extensively discuss territorial and financial factors, they do not account for spatial characteristics, which limit their ability to explain geographic disparities in development.

In this context, localities lack sufficient funds to support their finances and often have to rely on grants-in-aid from the central budget. In addition to challenges in supporting local revenue system, numerous demographics, socioeconomic, and territorial issues have arisen. To address these matters, a new law concerning Mongolia's budget relations mechanism was introduced in 2013, which aims to ensure that regional and local budgets develop equally (JICA, 2017).

First, power of localities operates free from central government; second, localities have the power to legislate and regulate behavior of residents. Further theory explained that local self-governance depends on financial aspects and development factors. To identify which part of the world and which countries have been struggling with their own definitions and irregularities in local government and its development autonomy. Starting with European countries, ample of the academic literature review on local governments treats Eastern Europe as an "unknown land", where countries are trying to adopt new forms of local democracy Swianiewcz (2014). Geographical products (spatial equity) have been identified as a key determinant distinguishing development pattern between Western and Eastern European countries (Sanchez Carrera et al, 2021).

The European charter of self-government was updated in 1996 (Congress of Local and Regional Authorities, 1996) to promote an equal economic development between Eastern and Western Europe through comprehensive legislation. The law consists of seven principles: adequacy, proportionality, elasticity, equalization, cooperation, autonomy and borrowings (ECLG, 1996). All of them offered financial opportunities, such as the ability to generate local own financial resources and spend within their power, increase local government competences, support weaker local communities and access financial assets to promote local development (Hacek, 2020).

Tobler's First Law of Geography is "everything is related to everything else, but near things are related more than distant things" (Tobler.W.R.,1970) is fundamental principle in spatial analysis, providing basis for understanding geographical patterns and their influence on economic development.

Data and Methodology

Panel data for LDI were collected from National Institute for Regional Development and are organized by year and province. Total sample was 21 provinces and the capital city. However, ultimate purpose of this study is to identify spatial correlations of local development based on each province geometric data of longitude, latitude and polygons. For modeling purposes, the Capital city Ulaanbaatar was excluded from the dataset. Although this choice departs from Tobler's First Law of Geography (Tobler, 1970), it is warranted due to Ulaanbaatar's exceptional population density and fundamentally different from urban structure relative to other provinces and sub cities. After the omission, the dataset comprises 21 provinces collected over 9-year period, yielding a total n=189 observations.

National Institute for Regional Development (Mongolia) constructs provincial and regional development index based on 33 items including education, health, economic and business conditions, social factors, infrastructure and environmental indicators, along with two additional variables of GDP and poverty index (Nadmid & Budjav, 2022). To ensure spatially dependent between provinces, the study employed an average provincial population and local GDP per capita as key explanatory variables. Provincial border polygon dataset of Mongolia was obtained from Database for Global Administrative Areas (GADM). In order to determine steady spatial dependence (Anselin, 1995) of Local Indicators of Spatial Association (LISA), Global Moran's I (Moran, 1950) test have computed prior (Tiefelsdorf & Boots, 2010).

Two different spatial weights matrices (Queen and k-nearest neighbors) were tested alongside the primary four neighbor matrix to evaluate potential clustering or dispersion patterns. Given the panel structure of the data and year-to-year volatility in LDI values, the four-neighbor matrix was selected, as most Mongolian provinces bordered by two to six neighboring provinces on average. A single reference year was extracted to construct a consistent weight matrix, using provincial longitude and latitude coordinates from the year 2016 to 2024. Three spatial model specifications SRA, SEM and SEM-RE were estimated, and Lagrange Multiplier tests for spatial error dependence and random provincial effects (Baltagi, Song, & Koh, 2003) were conducted to identify the best fitting model. The spatial model equations are presented in the following section to provide the theoretical foundation for the empirical specifications used in this study.

Three spatial panel specifications were estimated: the spatial lag model (SAR), the spatial error model (SEM), and the spatial error model with random effects (SEM-RE). The SAR model captures outcome spillovers through the spatially lagged dependent variable (ρ), indicating that a province's development level is influenced by that of its neighbors:

$$LDI_{it} = \rho \sum_{j=1}^{N} w_{ij} LDI_{jt} + \beta_1 Pop_{it} + \beta_2 GDPpc_{it} + \alpha_i + \varepsilon_{it}, \tag{1}$$

where LDI_{it} denotes the Local Development Index of province i at the time t. w_{ij} is the (i, j)-th element of the spatial weight matrix, representing the spatial connection between provinces i and j. ρ is the spatial autoregressive coefficient, measuring the spillover effect from neighboring provinces. Pop_{it} denotes the average population of province i at the time t, while $GPDpc_{it}$ denotes the GDP per capita of province i at the time t. α_i captures province-specific fixed effects, and ε_{it} is the idiosyncratic error term.

In contrast, SEM model captures spatial dependence arising from unobserved provincial characteristics through spatially autocorrelated error term (λ):

$$\begin{gathered} LDI_{it} = \beta_1 Pop_{it} + \beta_2 GDPpc_{it} + \alpha_i + u_{it}, \\ u_{it} = \lambda \sum_{j=1}^{N} w_{ij} u_{ij} + \varepsilon_{it}, \end{gathered} \tag{2}$$

where the term u_{it} represents the spatially correlated error component, which follows a spatial autoregressive process. λ is the spatial error autocorrelation parameter, measuring the degree of spatial dependence in the error terms.

The SEM-RE model extends this framework by incorporating both spatial error dependence and unobserved province-specific heterogeneity.

$$\begin{gathered} LDI_{it} = \rho \sum_{j=1}^{N} w_{ij} LDI_{jt} + \beta_1 Pop_{it} + \beta_2 GDPpc_{it} + \mu_i + u_{it}, \\ u_{it} = \lambda \sum_{j=1}^{N} w_{ij} u_{jt} + \varepsilon_{it}, \end{gathered} \tag{3}$$

where μ_i represents random effects, capturing unobserved province-specific heterogeneity.

A later section will examine the results of the best model specification.

Data Analysis and Findings

Global Moran's I

Prior to applying spatial regression models, it is crucial to assess whether spatial econometric methods are appropriate. To do this, spatial dependence in the local development index is examined using Global Moran's I to detect overall clustering and LISA to identify local spatial patterns. The Global Moran's I values for 2017 (I=0.129, p=0.075) and 2019 (I=0.186, p>0.05) show evidence of spatial dependence in those 2 two years (See table 1). However, for all other years, the spatial autocorrelation is statistically non-significant, indicating no meaningful geographical clustering.

Table 1: Global Moran's I Results

Year	Moran I	Expected	Variance	z-value	p-value	Significance
2016	0.0885	-0.05	0.020	0.980	0.164	Not significant
2017	0.1299	-0.05	0.016	1.440	0.075	Weak
2018	0.1082	-0.05	0.018	1.185	0.118	Not significant
2019	0.1856	-0.05	0.020	1.685	0.046	Moderate
2020	0.0560	-0.05	0.014	0.895	0.186	Not significant
2021	0.0413	-0.05	0.016	0.716	0.237	Not significant
2022	-0.0468	-0.05	0.016	0.026	0.490	Not significant
2023	-0.2504	-0.05	0.021	-1.367	0.914	Not significant
2024	-0.1131	-0.05	0.021	-0.438	0.669	Not significant

Authors source: Global Moran I summary by years

Local Moran's I

Results of Global Moran's I indicate no significant overall spatial clustering of LDI across Mongolia. To further explore local spatial patterns, Local Indicators of Spatial Association (LISA) were computed for all provinces and on a year-by-year basis. Considering Mongolia's vast territorial characteristic and its sparsely distributed population nationwide, apart from one-third of population concentrated in the capital city (Dashnyam & Gungaa, 2021), two types of spatial weight matrices were applied: Queen contiguity and k-nearest neighbors (KNN=6).

Uvs (Zldi +0.25, lagz -0.71) in 2016 appeared as a HL outlier under KNN=6, also indicating that Uvs had a relatively higher LDI compared with nearest neighbors, whose LDI value were substantially lower. By 2017, however, Uvs (Zldi -0.12, lagz -0.56) experienced a decline in its LISA relative to nearby provinces and appeared as LL cluster UVS (Zldi -0.28, lagz -0.73) in 2021, suggests that both the province and its neighbors exhibited similarly low LDI levels. Across the 9 years period, LISA values ranged from 0.48 to 0.60), and Uvs did not show a consistent development trajectory. Instead, its development pattern fluctuated year by year, largely independent of any stable spatial structure.

Across 2016-2024, Bayan-Olgiy LISA values ranged from Zldi -1.39 to -0.30 and (lagz - 0.30 to 0.54) indicating consistently lower development levels compared with its neighboring provinces. The pattern persisted until 2023 and 2024, when the values rose (lagz 0.42 to 0.51), suggesting that neighboring provinces experienced substantial improvement while Bayan-Olgiy's LISA deteriorated in relative terms. Under the KNN=6 term, Bayan-Olgiy was classified as LL in 2021, one of the lowest values among its nearest neighbors. Hovd shows a similar overall trajectory to Bayan-Olgiy, with notable difference that its LISA scores in 2023-2024 (ZIdi 0.49 to 0.43) that improved substantially in last 2 years. Relative to its k-nearest, Hovd's values (lagz=0.10 and 0.23) indicate moderate gains, although its LL cluster in 2021 confirms that it was among the lowest performing provinces in its region during that period.

Dzavhan in 2018 (ZIdi =0.38) was the only province recorded a slightly higher LISA than its neighboring provinces. However, from 2022 to 2024, the surrounding provinces consistently showed much stronger development performance (LAGz 0.24, 0.89 and 0.86). Under KNN=6 weight matrix, Dzavhan's LH cluster designation in the last two years indicates that it had one of the lowest LISA scores despite being surrounded by higher-performing provinces. Govi-Altay appears to be following a similar dynamic pattern. In 2024, it merged as LH cluster, making it the lowest-performing province within its regional peer group. The Lagz values for Govi-Altay from 2022 to 2024 (0.16, 0.63 and 0.78) suggest that while its neighbors improved substantially over the past three years, Govi-Altay's relative development gains were limited.

In 2024, Hovsgol (ZIdi=+0.28, lagz=2.31) shows a positive lag value, indicating that its bordering and nearest provinces recorded strong LISA effect and that Hovsgol followed a similar upward development pattern. Although no outlier cluster was identified under 6-neighbor weights, the direction of change remains consistent. The steady increase in Hovsgol's LISA statistics over time suggests that its improvement is part of a broader regional, parallel progression, rather than evidence of localized spatial clustering. Bulgan demonstrates weaker development relative to its 6 neighbors. Nevertheless, Bulgan's development index improved in 2017 and 2019 (ZIdi=+0.26, ZIdi=+0.05). The consistently positive Lagz values indicate that neighboring provinces have shown persistent progress throughout the period.

For Selenge, the values (ZIdi= -0.01 in 2017, ZIdi= -0.30 in 2022, ZIdi= -0.13 in 2023) indicate that the province had lower LISA scores than its neighbors in those specific years, although the pattern is not consistent across the entire panel period. The Lagz values for 2023-2024 (-0.15 and 0.19) show that neighboring provinces experienced a slight decline followed by an increase, while Selenge's LISA (Zlid =1.52 in 2023 and Zlid =1.44 in 2024) moved in the opposite direction, suggesting divergence from its six nearest neighbors. The Tov's LISA classification of LH indicates that it was the lowest performing within a cluster of relatively high performing bordering provinces. The Heat map (see Figure 1) shows that Tov in 2017 (ZIdi=1.14, lagz=0.23) initially aligned with the positive development trends of its neighbors, but it exhibited consistently negative LISA scores throughout most of the panel period. The weakest year for Tov was 2022, where its value declined to 0.90.

Darhan-Uul is province the economic focal pointin the northern region, shows strong spatial correlation with its neighboring provinces. However, its LISA results for 2022-2024 (ZIdi=-0.16, ZIdi=-0.99, ZIdi=-1.077) indicate a recurring decline in development relative to surrounding provinces. Despite this recent deterioration, Darhan-Uul experienced steady LISA growth from 2016 to 2021, closely mirroring the upward trend observed among its six nearest neighbors. In contrast, Orhon is province and the second largest city in Mongolia, displays opposite pattern. Its 2022 LISA result (Zldi=3.28, lagz=-0.21) suggest that the city reached its peak development level in 2022 while neighboring provinces were experiencing a decline of approximately by negative 0.21. Moreover, Orhon maintained a positive development index for all nine years, underscoring its sustained and robust performance relative to its peers.

The three provinces Arhangay, Bayanhongor and Ovorhangay show broadly similar LISA trends that align with the development direction of their neighboring provinces. However, Ovorhangay displays more variation across years, with (Zldi=-.063, Zldi=-0.24, Zldi=-0.21) in last 3 years. Arhangay and Bayanhongor demonstrate LISA growth consistently with their growing neighbors, Ovorhangay diverges from this trajectory. In 2024 Arhangay (Zldi=1.39, lagz=0.43) reached its peak development level relative to Bayanhongor and Ovorhangay. Overall, none of these provinces form statistically significant clusters under KNN=6 weight matrix, and their development pattern exhibit gradual year-to-year variation rather than stable spatial clustering.

Omnogovi (Zldi ranging from -0.009 to 3.49) consistently maintained one of the highest development levels in the region, surpassing the national average for most of the period. However, its LISA (Zldi=-0.009, lagz=0.21) indicates a notable decline in development relative to its neighbors. Between 2018 and 2020, the lagz value shows that Omnogovi ranked the lowest performing province within its immediate neighborhoods. Although no statistically significant outlier clusters were detected for this province, its LISA has clearly decreased over the past three years. Dornogovi exhibited a moderate development pattern compared with its two nearest neighbors, generally following similar spatial trends. The declines observed in 2023 and 2024 (Zldi=-1.33, Zldi=-1.31) point to a weakening in its relative performance during the latter years. A particular notable province is Dundgovi, under the k-nearest terms, it appeared as LH outlier in 2016, 2018, 2019 and 2021. Although these years are not consecutive, the recurrence of this pattern across four out of nine years indicates that Dundgovi consistently had the lowest development levels within a cluster of stronger neighboring provinces. The only year in which Dundgovi aligned with regional growth was 2017, when it was classified as HH, reflecting development consistent with its high-performing neighbors. Govisumber shows strong development LISA in the last 3 years (Zldi ranging from 0.48 to 0.84), contrasting sharply with neighboring provinces, which exhibit persistently below-average development LISA (lagz =-0.33, lagz =-0.53, lagz =-0.62) throughout the last 3 years.

The Eastern provinces of Hentiy, Dornod and Suhbaatar, display similar LISA trends in development, consistently recording below-average LDI values accompanied by negative spatial lags. Hentiy and Dornod initially shared a comparable pattern, being surrounded by higher-performing neighbors until 2022. Their subsequent LISA values for Hentiy (lagz =-0.88 in 2022, lagz =-0.02 in 2023, lagz =-0.08 in 2024) and Dornod (lagz =-0.22 in 2022, lagz =-0.59 in 2023, lagz =-0.62 in 2024), indicate that both provinces have recently become bordered by lower LISA neighbors. Suhbaatar, meanwhile has been surrounded by negative spatial valued neighbors throughout the entire panel period. No k-nearest cluster outliers were detected in this region.

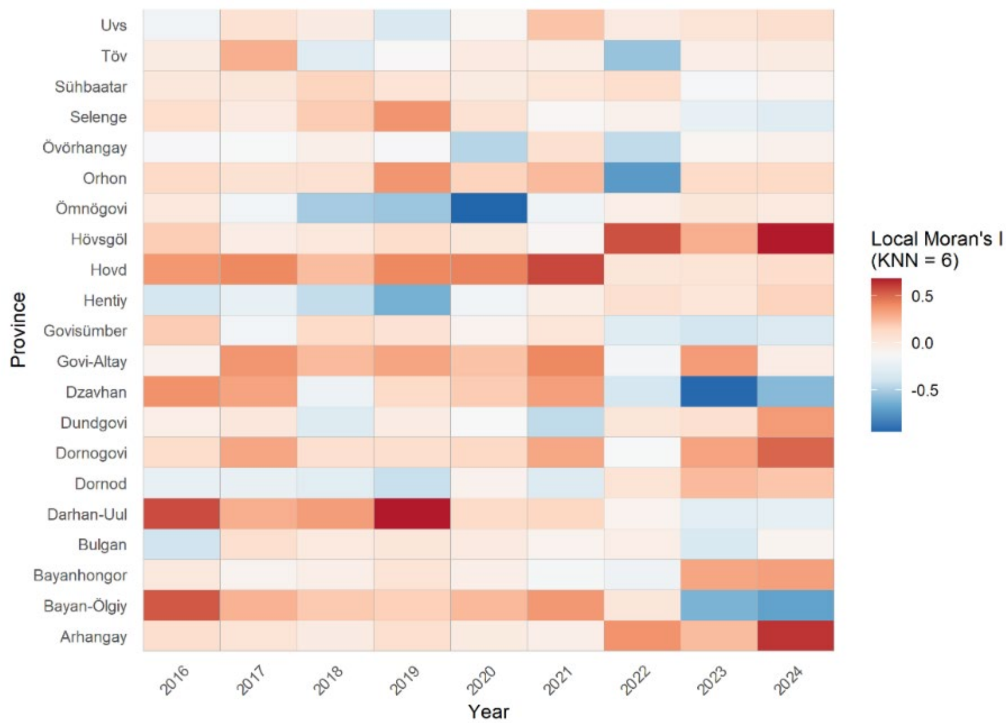

Figure 1. Heat Map of Local Moran’s I (KNN = 6) by Province and Year

The Queen LISA Heat map (see Figure 2) shows that local spatial autocorrelation among neighboring provinces is generally weak and inconsistent across the panel period. Most LISA values indicate minimal clustering under the Queen contiguity matrix. Dornod and Darhan-Uul in 2019 exhibit brief periods of positive local LISA, reflecting temporary similarity with their neighboring provinces. In contrast, Omnogovi (2016), Orhon (2017), and Ovorhangay (2023) display opposite LISA patterns relative to nearby provinces. Overall, the results indicate an absence of meaningful local spatial cluster in LISA, suggesting that provincial development patterns are driven primarily by non-spatial heterogeneity.

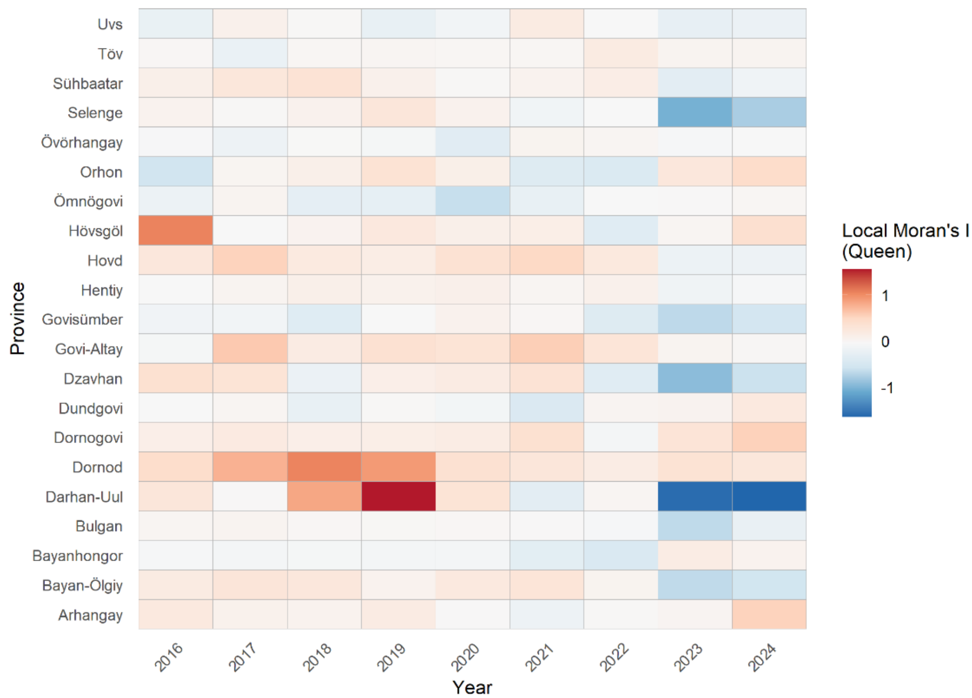

Figure 2. Heat Map of Local Moran's (Queen) by Province and Year

In both the Queen contiguity and KNN=6 weighting matrices, the vast majority of provinces have p-values greater than 0.05. Per the Rule of Thumb proposed by (Anselin, 1995), indicates insufficient evidence of local clustering or spatial dependence in LDI, a result that aligns with the weak Global Moran's I findings. Given the limited spatial dependence across provinces, the study proceeded to estimate SAR, SEM and SEM-RE models using the full panel of 189 observations across the 9 years period.

The regression results for the selected year indicate that a 1% increase in average population is associated with a 0.5% reduction in the LDI. Similarly, a 1% increase in local GDP corresponds to a 0.11% decline in LDI. The findings also reveal a modest downward trend in LDI from 2016 through 2024.

Model Fit

Diagnostic tests strongly favored the SEM-RE specification. The LM2 and LM-lambda (see Table 2) statistics were highly significant, indicating pronounced spatial error dependence, whereas tests for spatial lag dependence were not significant. The SAR model LM (Anselin et al, 1996) did not provide additional explanatory power, as the lag coefficient remained insignificant. Consequently, the SEM model with random provincial effects emerges as the most appropriate specification for explaining spatial variation in Mongolia's Local Development Index.

Table 2: Lagrange Multiplier Results

Model test	Value	Purpose	p value	Model fit
LM-H	20.829	Joint test for random effects and spatial autocorrelation	p = 0.00001	both present
LM1	-1.2110	Marginal test for random effects only	p = 1.774	random effects not alone
LM2	4.5639	Marginal test for spatial autocorrelation only	p = 5.021e-06	spatial autocorrelation strong
LM-λ	8.9118	Conditional LM for spatial error	p < 2.2e-16	spatial error dependence very strong
LM-μ	7.9513	Conditional LM for random effects	p = 1.846e-15	random effects also present

Confirming the appropriate model specification, the analysis identifies the spatial error model with random effects as the best-fitting approach. The diagnostic results (LM*mu=7.9513 and LM*-lambda=8.9118), reject the null hypothesis of no random regional effects and no spatial error dependence (Baltagi, Song & Koh, 2003), indicating significant unobserved province-specific heterogeneity in the Local Development Index. These findings suggest that unobserved determinants such as demographic, social, geographic characteristics are spatially correlated across provinces, reinforcing the need for a spatial error model with random effects to capture these underlying structures.

Regression Results

The spatial random-effects error model (see Table 3) indicates substantial spatial dependence in the error term ($\lambda = 0.616$, $p < 0.001$), demonstrating strong and statistically significant spatial clustering in the unobserved factors affecting local development. This suggests that provinces share unobserved characteristics which are not captured by the variables included in the LDI factors calculation. The random-effects variance component is also statistically significant ($\rho = 1.669$, $p = 0.009$), confirming the presence of province-specific unobserved heterogeneity, whereby some provinces consistently exhibit higher or lower LDI values over time. Among the covariates, local GDP per capita shows a significant negative association with the LDI ($\beta = -0.00257$, $p < 0.001$), indicating that higher local GDP per capita is correlated with lower levels of local development. This relationship suggests that economic growth does not necessarily translate into balanced development, rather, such growth may be unevenly distributed across provinces.

Wealthier provinces may experience rising inequality or insufficient expansion of public services compared with less affluent provinces. The results further indicate that development is not primarily driven by financial factors but instead shaped by spatial or institutional characteristics, as reflected in the significant statistical parameters. Average population size does not significantly influence LDI once spatial dependence and unobserved heterogeneity are considered. In addition, neither economic growth nor population size directly affects the Local Development Index. However, the significant ρ parameter reveals strong spatial clustering in unobserved development factors, suggesting that provinces resemble one another due to shared structural and institutional conditions rather than direct spillovers.

Table 3: SEM with Random Effects Results

Parameter	**Estimate**	**Std. Error**	**t-value**	**p-value**	**Significance**
Error Variance parameters					
ρ	1.6692	0.6413	2.6028	0.009248	**
λ	0.6159	0.0613	10.0478	<2.2e-16	***
Regression Coefficients					
Coefficients	**Estimate**	**Std. Error**	**t-value**	**p-value**	**Significance**
Intercept	0.5630	0.0270	20.8872	<2.2e-16	***
Pop	0.0000	0.0000	-0.5291	0.5967	
GPDpc	-0.0026	0.0000	-5.8261	5.67E-09	***

Overall, these findings validate the spatial error with random effects as the most appropriate specification for capturing the spatially interdependent dynamics of development across Mongolia's provinces.

Conclusion

Despite the Global and Local Moran's I tests indicate that LDI exhibits only weak and inconsistent spatial clustering across years, the spatial error model with random effects (SEM-RE), also reveals significant spatial dependence in the error structure, as reflected in the large and statistically significant spatial error and random-effects (LM-λ =8.9119 and LM-μ=7.9513) coefficients. This finding indicates that, even after accounting for GDP, population, and geographic location (longitude and latitude), the residual variation in LDI remains spatially correlated. In other words, unobserved or omitted influences such as geographical similarities, shared infrastructure, or regional policy, and environments exhibit spatial patterns across neighboring provinces. Consequently, the raw LDI values do not display strong or consistent spatial clustering, the significant spatial autocorrelation in the residuals supports SEM-RE model as the most appropriate specification compared with the SAR and SEM alternatives.

Limitation: A key limitation of this study is the inability to explicitly identify the unobserved common and province-specific factors represented in the error component.

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