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Investigation Tourism Development on Geopark Caldera Toba with Spatial Autocorrelation Approach

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Abstract

This study analyzes the spatial linkage of economic growth in 8 (eight) Lake Toba Districts with a time period of 2010 - 2022. This study focuses on hypothesis testing that examines the influence of the determinants of regional economic growth by considering spatial aspects. The estimation method is carried out using the spatial panel data estimation method, namely the dynamic spatial Durbin models (SDM) method. In the estimation of the research using the help of Stata and Geoda software. Determinants of economic growth from other districts (there is spatial spillover); Determinants of economic growth from the district itself include physical capital investment, human capital investment, population, tourism sector contribution, road infrastructure, and tourism and cultural spending have a significant impact on economic growth in the eight districts of the Lake Toba region of North Sumatra Province, and Determinants of economic growth from other districts (there is positive spatial spillover) on regional economic growth in the eight districts of the Lake Toba region of North Sumatra Province include real per capita income of other districts, physical capital investment of other districts, human capital investment of other districts, population growth of other districts, contribution of tourism sector of other districts, and road infrastructure of other districts.

Keywords: *Economic growth; spatial econometrics; north Sumatera; lake Toba.*

Introduction

Economic growth is closely related to spatial factors that influence the development of a region. One of the influencing factors is geographical location, where regions that have good accessibility tend to have faster economic growth. In addition, the availability of natural resources and infrastructure also play an important role in the economic growth of a region (Chirwa & Odhiambo, 2016). Rural communities in their daily lives still uphold traditions, values and customs for generations. Development for settlements in coastal areas can lead to social conflicts due to inequality in the land administration process and weak spatial policies (Ningrum et al., 2023) (Yudistira & Sohibien, 2019). In addition, demographic conditions are also an important factor in economic development in a region.

This phenomenon of spatial linkages also has an impact on regional development, income distribution, and inequality between regions. Therefore, an understanding of spatial linkages in economic growth is essential for designing sustainable and equitable development policies in various regions.

An understanding of spatial linkages is essential in designing sustainable and equitable development policies across regions. One concrete example is the development of transportation infrastructure that can improve connectivity between regions and accelerate economic growth. In addition, the presence of natural resources such as agriculture, mining, and fisheries also plays a role in the economic growth of a region .

However, it is important to remember that rapid economic growth can also increase disparities between regions. Therefore, there is a need for equitable income distribution and policies that support the development of marginalized regions. In addition, understanding demographic conditions such as population size, age structure, and urbanization rate is also important in planning inclusive economic development.

Spatial linkages of economic growth essentially describe the economic relationship between a region and its surrounding environment. This linkage occurs because it is influenced by several aspects, namely, the limitations of a region that are a barrier to meeting the needs of the region itself, the similarity of economic interests of several regions will cause economic cooperation, and awareness to form inter-regional

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cooperation to build regional economic strength (Aini et al., 2018).

The National Tourism Development Master Plan in 2010-2025 is for equitable development in the tourism sector. When viewed from its age, Lake Toba is the first tourist destination to be discovered than the other 5 Priority Super Destinations, which was around 74,000 years ago.

North Sumatra Province has very diverse and beautiful tourism potential. The tourism industry in North Sumatra can be an opportunity that can be utilized to improve the standard of living and prosperity of the community. The tourism sector can be used as a leading sector that can increase the economic scale of North Sumatra and make a better source of economic growth. The level of domestic and foreign tourist visits can be used as a driver of the North Sumatra economy which provides a multiplier effect on various business fields and contributes to regional Income.

The development of Lake Toba as one of the Super Priority Destinations makes tourism in North Sumatra more advanced. The amount of infrastructure development can create convenience for people to visit Lake Toba. The increasing number of tourists coming to Lake Toba will increase income for North Sumatra which will help the economy. The development of Lake Toba will have an impact on the areas around Lake Toba.

This research uses a quantitative approach that emphasizes mathematical formulations. The research place that is the object of this research is eight districts in the Lake Toba Region. The eight districts in the Lake Toba Region include Toba Samosir, Samosir, Simalungun, North Tapanuli, Humbang Hasundutan, Karo, Pakpak Bharat, and Dairi.

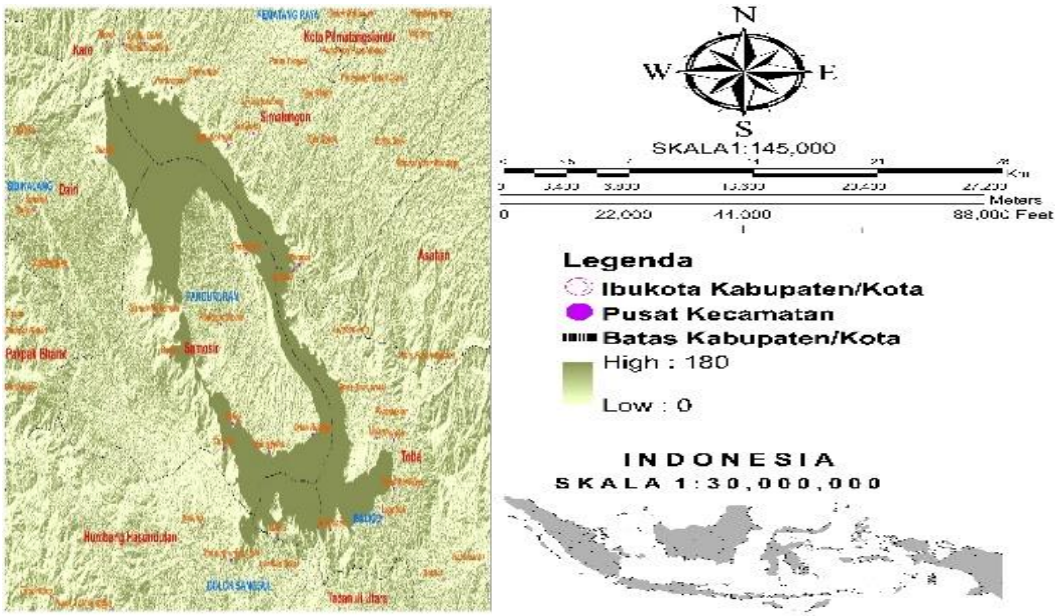

Figure 1. Toba Caldera Geopark.

Source: Toba Caldera Geopark Management Agency, Master Plan Geopark Kaldera Toba, 2018

Methodology

This research uses a quantitative approach that emphasizes the form of computation in mathematical formulation by looking at the spatial aspects based on the theory of space economics. The eight districts in the Toba Lake Area include Toba Samosir, Samosir, Simalungun, Tapanuli North, Humbang Hasundutan, Karo, Pakpak Bharat, and Dairi.

The spatial weight matrix based on contiguity in this study uses the queen contiguity type. This matrix is a spatial weight matrix based on the intersection of the angles of the boundaries of the region. This matrix illustrates that spatial interactions occur between neighboring regions that have a common boundary. In the calculation, the spatial weight matrix will be normalized so that each row will add up to 1 (row-

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normalized). The calculation of the spatial weight matrix with the queen contiguity approach was used by several previous studies such as (Ertur & Koch, 2007) (Álvarez & Barbero, 2016), (Kementerian Lingkungan Hidup dan Kehutanan RI, 2018), and (Aspiansyah & Damayanti, 2019). In this study, the calculation of the spatial weight matrix with queen contiguity uses Stata software.

In this study, the spatial weight matrix based on distance uses the inverse distance matrix approach. Regional linkages based on distance, neighborly interactions are determined by the distance between these areas. According to the law of gravity, the closer the distance between two neighboring regions, the stronger the interaction. The distance approach assumes that the closer the distance between districts/cities, the stronger the relationship between them (Caroline, 2020). (Ertur & Koch, 2007), (Vidyattama, 2014), (Álvarez & Barbero, 2016), (Sun et al., 2017) and (Aspiansyah & Damayanti, 2019) are studies that use a spatial weight matrix using the inverse distance matrix approach.

The distance between districts/cities in the Lake Toba Region in this study is determined using Euclidean distance where the distance calculation uses GeoDa Software. Furthermore, the calculation of the spatial weight matrix with the inverse distance matrix by entering the Euclidean distance between districts/cities using Stata Software.

The spatial panel data estimation technique is used in this study to estimate equation. The use of spatial panel data estimation technique is because this estimation technique can control cross section heterogeneity and spatial dependence simultaneously (Arbia et al., 2005).

The spatial dependence test or spatial autocorrelation test is used to determine whether the panel data estimation considers aspects of spatial dependence (spatial panel data model) or not (non-spatial panel data model). In this study, the spatial dependence test uses Moran's I statistics and Pesaran test. Spatial dependence occurs when the spatial distribution of the variables under study shows a systematic pattern (Bivand, 2018).

Spatial dependence is positive/negative when geographies tend to be surrounded by neighbors with the same or different values of the variable under study. Moran's I statistics is a measure used to detect and explain spatial clustering not only because of its interpretative simplicity, but also because it can be decomposed into local statistical forms by providing graphical evidence of spatial clustering. To test for global spatial dependence, this study uses the Global Moran's I statistic from (Dubé & Legros, 2014), and (Anselin & Bera, 1998).

The significance of global Moran's I depends on the distribution of the test statistic. There are two approaches to find out the observation test value of global Moran's I, namely the random permutation test approach, and the distribution approach of global Moran's I. A global Moran's I coefficient that is more than the expectation of -1/(n-1) identifies positive spatial autocorrelation, and a global Moran's I coefficient that is less than the expectation identifies negative spatial autocorrelation ((Fischer, 2011); (Bailey & Gatrell, 1995)). The approach with the observed regional distribution x_i assumes the observed data values are normal ((Fortin & Dale, 2009); (Bailey & Gatrell, 1995)).

The local spatial autocorrelation model is also called Local Indicators of Spatial Association (LISA). LISA is an analysis of Local Moran's I. In addition, LISA is also a technique to provide graphical visuals of spatial clustering like Moran's Scatterplot ((Fotheringham et al., 2000); (Haining, 2003)). Local spatial autocorrelation indicates the individual contribution to global spatial autocorrelation.

Local spatial autocorrelation is the value of observation i that is positive (similar) or negative (different) to its neighboring observation j.

Result and Discussion

The distance between districts/cities in the Lake Toba Region in this study was determined using Euclidean distance. In calculating the Euclidean distance, the longitude and latitude coordinates of the eight districts in the Lake Toba Region were obtained from Google Maps.

Using GeoDa software, the connectivity between districts in the Lake Toba Region is presented in Figure 1. Calculation of the spatial weight matrix with the inverse-distance approach using Stata software produces an 8×8 matrix (W_(8×8)). The minimum value of the spatial weight matrix W is zero (0), the minimum

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value > 0 is 0.0655, and the average value and maximum value are 0.125; and 0.3516 respectively .

Figure 2. Inter-District Connectivity in the Lake Toba Region Lake Toba**.**

Source: GeoDa (2024).

Spatial Weight Matrix Based on Queen Contiguity

The spatial weight matrix of the queen contiguity approach is based on the intersection of the angles of the district boundaries between the eight districts in the Lake Toba Region. This matrix illustrates that spatial interaction occurs between neighboring regions that have a common boundary. Two districts that intersect the corner directly are given a value of one (1), otherwise given a value of zero (0).

The calculation of the spatial weight matrix using the queen contiguity approach using Stata software produces an 8×8 matrix (W_(8×8)). The minimum value of the spatial weight matrix W is zero (0), the minimum value > 0 is 0.3333, and the average value and maximum value are 0.125; and 0.5, respectively.

Pesaran Test

This study uses Pesaran test to test the presence of spatial linkage/dependence in the panel data model. The results of this statistical test reject the null hypothesis that there is no cross-sectional independence. Thus, the panel data in this study have spatial linkages/dependence.

Table 1. Pesaran Test.

Pesaran's test of cross-sectional independence	12,985
Probabilitas	0,000
Average absolute value of the off-diagonal elements	0,735

Source: processing results with Stata

The results of this statistical test reject the null hypothesis that there is no cross-sectional independence. Thus, the panel data in this study have spatial linkages/dependence.

Spatial Interaction Patterns

Global Moran's I to look at patterns of spatial interaction globally. With Global Morans I, this study wants to prove whether or not there is a global spatially autocorrelation in the data. However, the space form of autocorrelation with the Global moran' s I method only reads the value mark of the coefficient, that is, positive or negative. (Caroline, 2020).

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Table 2. Z-Value Statistics and Moran's Global Index I.

Year	PDRBK	PMTB	IPM	JP	KSP	IJ	BPB
	Nilai Z-Statistik						
2010	0,222	-0,363	0,139	0,357	0,348	-0,151	0,095
2011	0,147	0,337	-0,079	0,313	0,048	-0,027	-0,053
2012	-0,089	0,251	-0,203	-0,367	-0,408	-0,013	-0,232
2013	0,306	0,311	0,139	0,978	0,447	-0,373	0,056
2014	-0,085	0,441	-0,001	0,912	-0,091	-0,324	-0,071
2015	0,228	0,073	0,245	-0,662	-0,023	-0,039	0,050
2016	-0,153	0,447	-0,102	-0,240	0,272	0,311	0,480
2017	0,028	-0,080	-0,020	0,657	0,067	0,129	-0,137
2018	-0,361	0,151	0,185	-0,707	-0,407	0,139	0,095
2019	0,205	-0,318	0,057	-0,466	0,202	0,070	-0,272
2020	-0,500	0,588	0,039	0,569	-0,198	0,002	0,053
2021	-0,255	0,184	-0,023	0,213	0,355	0,059	0,049
2022	-0,509	0,175	-0,300	-0,145	0,078	0,004	-0,150
2010-2022	*Global Moran's I* 's Value						
	-0,143	-0,143	-0,143	-0,143	-0,143	-0,143	-0,143

Note: Description: **) significant on α=5%. Source: processing results with Stata (2024).

This Global Moran's I value indicates that the spatial interaction pattern of the seven variables in the eight districts in the Lake Toba Region is random. Or in other words, there is no spatial interaction pattern (within in group) either similar or not similar in the eight districts in the Lake Toba Region. Globally, the eight districts in the Lake Toba Region show no clustering and no similarity in per capita income of neighboring regions with each other. This is because there is no clear feature pattern in the eight districts. The implication is that the per capita income of a district in the Lake Toba Region is not determined or independent of the per capita income of its neighbors.

In addition to the Global Moran's I index value, Table 2 also presents the Z-statistic value for the Global Moran's I index. The Z-statistic values have negative and positive signs and are not significant for the seven variables during the period 2010-2022. It is possible that the spatial distribution of feature attribute values is the result of a random spatial process. In other words, the observed spatial value pattern could be one of many possible versions of complete spatial randomness.

Besides global, spatial interaction patterns can also be seen locally. Local spatial interaction patterns are tested with Local Indicator Spatial Association (LISA).

In addition to global, spatial interfacing patterns can also be seen locally. Local spatial interaction patterns were tested with the Local Indicator Spatial Association (LISA). To analyze the local space pattern, the study used 2010 as the beginning of the study and 2022 as the end of the research in the period 2010-2022.

Local Spatial Interaction Patterns

Economic growth

Economic growth is represented by real per capita GRDP for eight districts in the Lake Toba Region. In full, the Local Moran's value and the spatial interaction pattern of real GRDP per capita for the Lake Toba Region districts are as follows.

Table 3. Local Moran's Values and Spatial Interaction Patterns of GDP per Real Capita

District	Year			
	2010	2014	2015	2022
Local Moran's				
Karo	-0,463**	-0,403**	-0,387**	-0,475**
Pakpak Bharat			-0,315*	-0,358*
Spatial Interaction Patterns				
Karo	HL	HL	HL	HL
Pakpak Bharat	LH	LH	LH	LH

Note: *), **), ***): significant at α=10, 5, and 1% Source: processing results with Stata (2024).

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The spatial interaction pattern of real GRDP per capita locally in 2010 was only in one district, namely Karo Regency. Its Local Moran's value is -0.463 with a significance level of 5%. This means that there is a spatial interaction pattern of real per capita GRDP of Karo Regency in a divergent manner with other districts in the Lake Toba Region in 2010.

The spatial interaction pattern of real GRDP per capita locally in 2010, 2014, 2015, and 2022 includes two districts, namely Dairi and Simalungun. Based on Figure 5.2, Dairi Regency and Simalungun Regency in these four years are included in the Low-High (LH) cluster or spatial outliers. This means that these two districts have low real GRDP per capita surrounded by districts with high real GRDP per capita in 2010, 2014, 2015 and 2022.

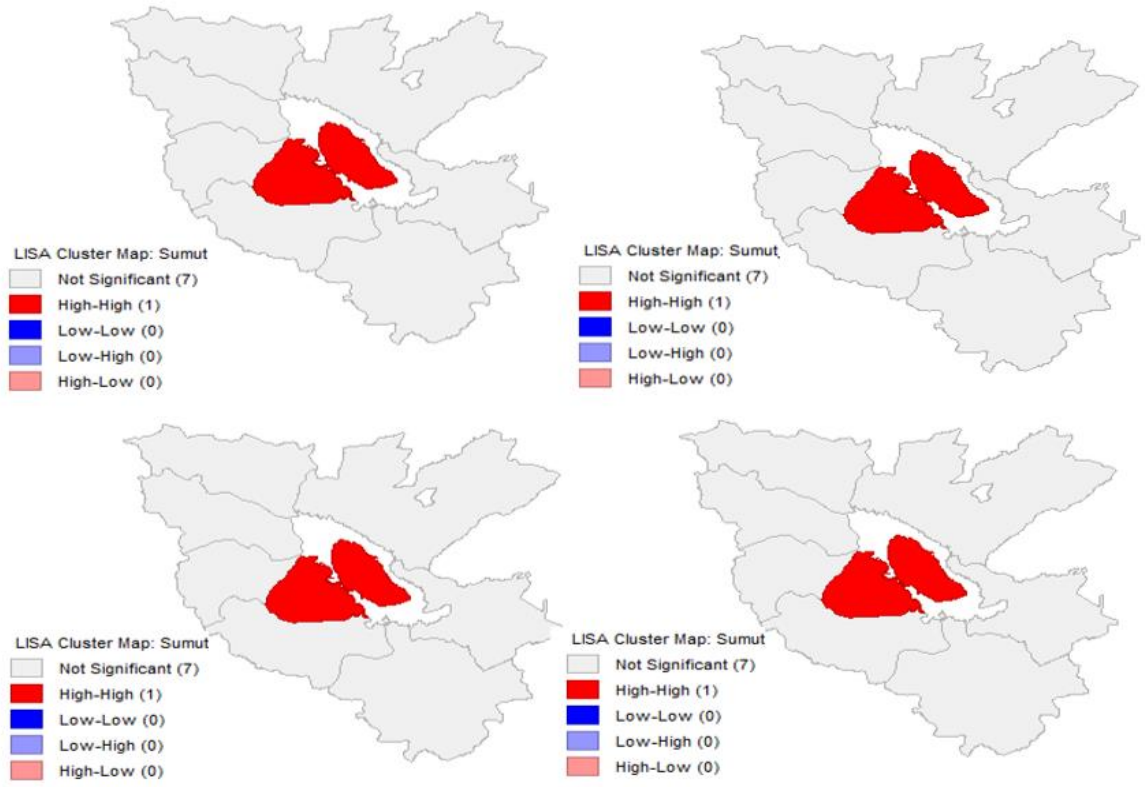

Figure 3. Cluster Map of Eight Regencies in the Lake Toba Region Based on Economic Growth in 2010, 2014, 2018, 20222

Human Development Index (HDI)

Human capital investment is represented by the Human Development Index (HDI) for the eight districts in the Lake Toba Region.

Tabel 4. Local Moran's Value and Spatial Interaction Patterns of HDI.

District	**Year**			
	2010	**2014**	**2018**	**2022**
Local Moran's				
Pakpak Bharat	-0,399**	-0,322*	-0,337**	-0,439**
Spatial Interaction Patterns				
Pakpak Bharat	LH	LH	LH	LH

Notes: *), **), ***): significant at α=10, 5, and 1%.

Source: processing results with Stata (2024).

The spatial interaction pattern of HDI locally in 2010 was only in one district, namely Pakpak Bharat District. Its Local Moran's value is -0.399 with a significance level of 5%. This means that the spatial interaction pattern of HDI of Pakpak Bharat Regency is divergent with other districts in the Lake Toba Region in 2010.

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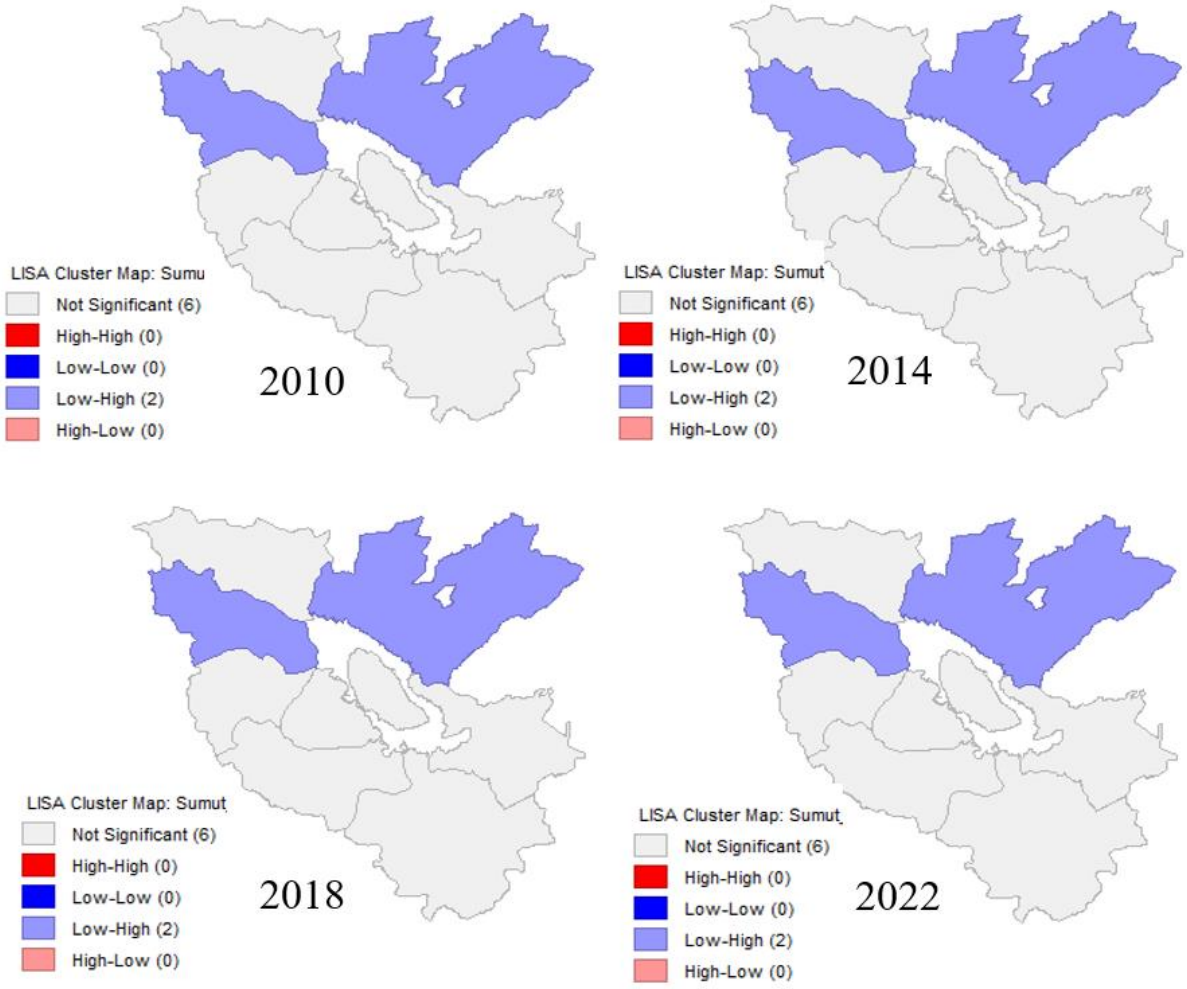

Figure 4. Cluster Map of Eight Lake Toba Regencies Based on Human Development Index in 2010, 2014, 2018, and 2022.

Samosir Regency in these four years was included in the High-High (HH) cluster. This means that Samosir Regency has a high HDI which is surrounded by districts with a high HDI in 2010, 2014, 2018 and 2022.

Samosir Regency is expected to provide a multiplier and booster effect for other districts that may be geographically adjacent to the cluster. Samosir Regency can be a leader in encouraging HDI development in other clusters.

Gross Fixed Capital Formation (PMTB)

The spatial interaction pattern of PMTB locally in 2010 and 2014 was only in one district, namely Samosir Regency. The Local Moran's value is -0.778 (2010) and -0.701 (2014) with a significance level of 1%. This means that there is a divergent spatial interaction pattern of Samosir Regency's FDI with other regencies in the Lake Toba Region in 2010 and 2014.

Table 5. Local Moran's Values And PMTB Spatial Interaction Patterns

District	**Year**			
	2010	**2014**	**2018**	**2022**
Local Moran's				
Samosir	-0,778***	-0,701***	-0,618***	-0,543**
Spatial Interaction Patterns				
Samosir	LH	LH	LH	LH

Note: *), **), ***): significant at α=10, 5, and 1%.

Source: processing results with Stata (2024)

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The spatial interaction pattern of PMTB locally in 2010 and 2014 was only in one district, namely Samosir Regency. Its Local Moran's value is -0.778 (2010) and -0.701 (2014) with a significance level of 1%. This means that there is a divergent spatial interaction pattern of Samosir Regency's FDI with other regencies in the Lake Toba Region in 2010 and 2014. This shows that the spatial interaction pattern of FDI during the period of President SBY's administration (2010-2014 period) did not change either the district or the nature of the spatial interaction pattern. In addition, the spatial pattern of FDI in Samosir Regency in 2010 and 2014 did not change, namely clusters with the LH category or spatial outliers.

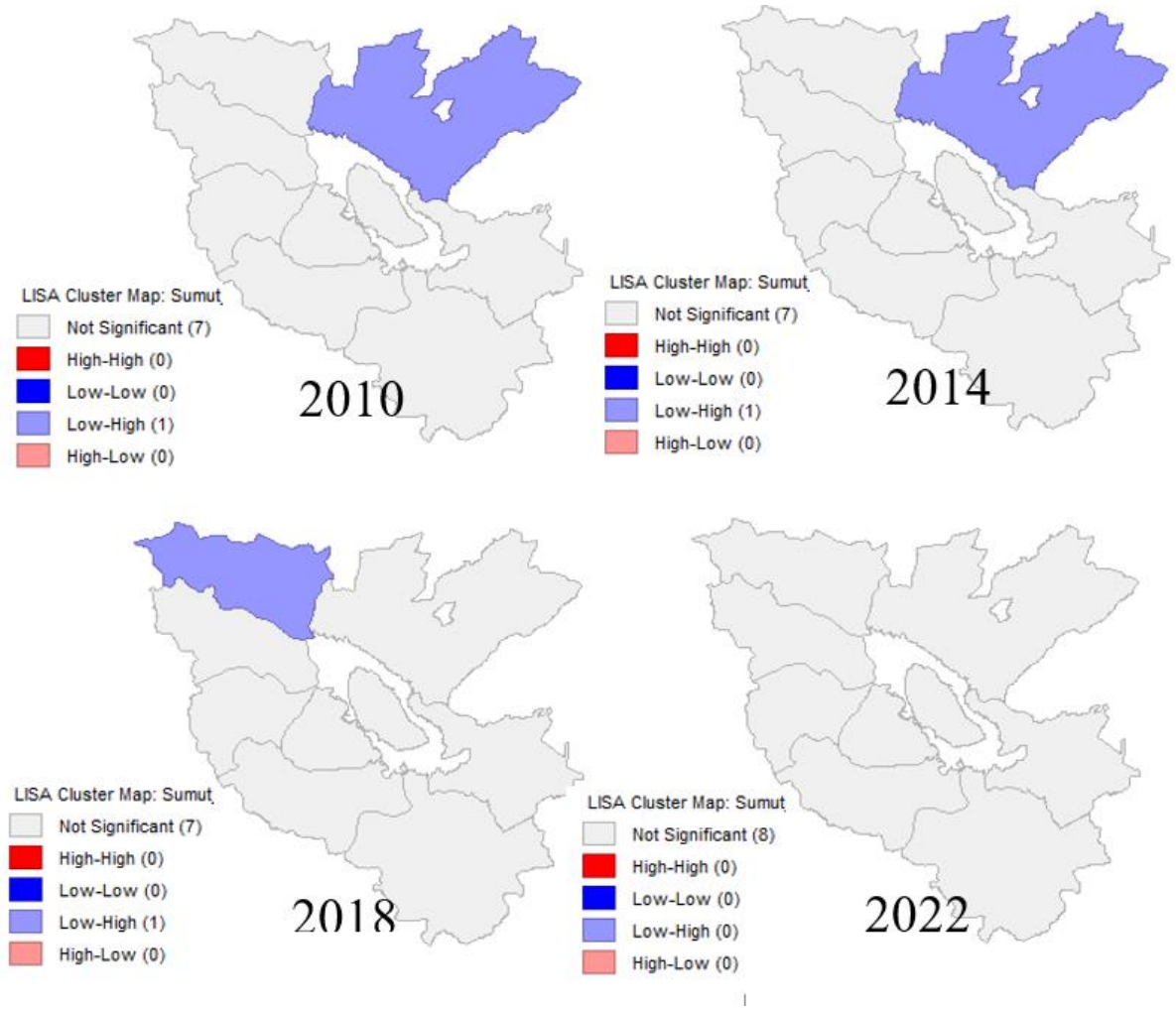

Figure 5. Cluster map of eight lake Toba regencies by gross fixed capital Iormation in 2010, 2014, 2018, and 2022.

Simalungun Regency has low PMTB surrounded by regencies with high PMTB in both 2010 and 2014.

Karo Regency in 2018 was also included in the Low-High (LH) cluster. This means that Karo Regency had low PMTB surrounded by districts with high PMTB in 2018. However, there are no regencies that have a spatial interaction pattern of FDI locally in 2022.

Total Population

The spatial interaction pattern of the population variable locally in 2010, 2014, 2018, and 2022 there are two districts, namely Simalungun and Pakpak Bharat. The Local Moran's value of the population variable for Simalungun Regency is -0.408 (2010), -0.409 (2014), -0.409 (2018), and -0.454 (2022) with a significance level of 10%. Then, the Local Moran's value of the population variable for Pakpak Bharat Regency in 2010, 2014, 2018, and 2022 is -0.561; -0.544; -0.540; and -0.513, respectively. This means that the spatial interaction pattern of population variables in Simalungun and Pakpak Bharat Regencies is divergent or spread with other regencies in the Lake Toba Region in those four years. population in Simalungun and Pakpak Bharat Regencies is divergent or spread with other regencies in the Lake Toba Region in those four

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years.

Tabel 6. Local Moran's Value and Spatial Interaction Patterns of Population Number

District	Year			
	2010	2014	2018	2022
Local Moran's				
Simalungun	-0,408*	-0,409*	-0,409*	-0,454*
Pakpak Bharat	-0,561**	-0,544**	-0,540**	-0,513**
Spatial Interaction Patterns				
Simalungun	HL	HL	HL	HL
Pakpak Bharat	LH	LH	LH	LH

Notes: *), **), ***): significant at α=10, 5, and 1%.

Source: processing results with Stata (2024).

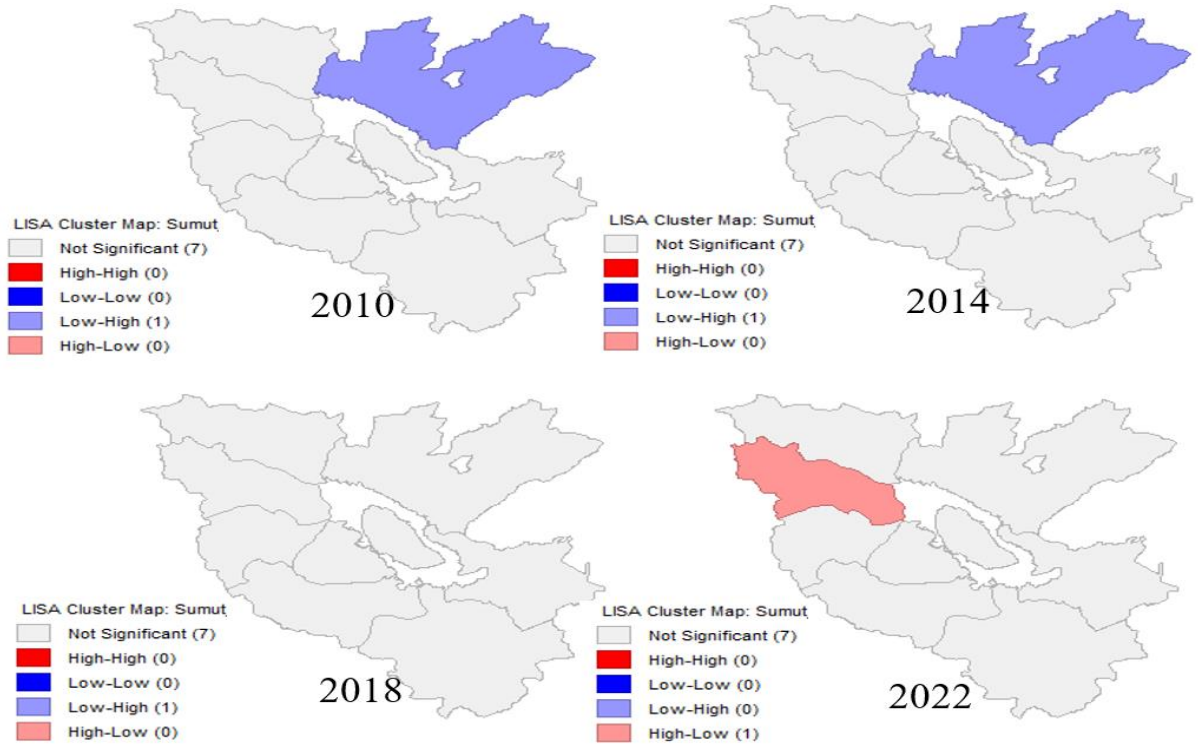

Figure 6. Cluster Map of Eight Regencies in the Lake Toba Region Based on Population in 2010, 2014, 2018, and 2022

In those four years, Samosir Regency was included in the High-High (HH) cluster. This means that Samosir Regency has a high population surrounded by regencies with high populations in 2010, 2014, 2018 and 2022.

Tourism Sector Contribution

The contribution of the tourism sector is represented by the ratio of revenue contribution from the tourism sector to GRDP in the eight districts in the Lake Toba Region. In full, the value of Local Moran's and the interaction pattern of tourism sector contribution variables for districts in the Lake Toba Region.

Table 7. Local Moran's Value and Patterns of Spatial Interaction Contribution to the Tourism Sector.

	Year			
District	**2010**	**2014**	**2018**	**2022**
Local Moran's	-0,524**	-0,004	-0,652***	-0,004
Samosir	-0,005	-0,454**	-0,026	-0,012
Pakpak Bharat	-0,137	-0,308	-0,088	-0,647***
Spatial Interaction Patterns				

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Samosir	LH	LH	LH	HL
Pakpak Bharat	HL	HL	HL	HL
	LH	LH	LH	LH

Note: *), **), ***): significant at α=10, 5, and 1%.

Source: processing results with Stata (2024).

The spatial interaction pattern of tourism sector contribution variables locally in 2010, 2014, and 2018, there is one district, namely Pakpak Bharat Regency. The Local Moran's value of the tourism sector contribution variable for Pakpak Bharat Regency in the three years was -0.511 (2010), -0.578 (2014), and -0.571 (2018) with a significance level of 1%; 1%; and 5%, respectively. However, the spatial interaction pattern of tourism sector contribution variables locally in 2022 is Samosir Regency. Local Moran's value of tourism sector contribution variable for Samosir Regency in 2022 is -0.841 with a significance level of 1%. The spatial interaction pattern of the tourism sector contribution variable for both Pakpak Bharat and Samosir Regencies is divergent or spread with other regencies in the Lake Toba Region.

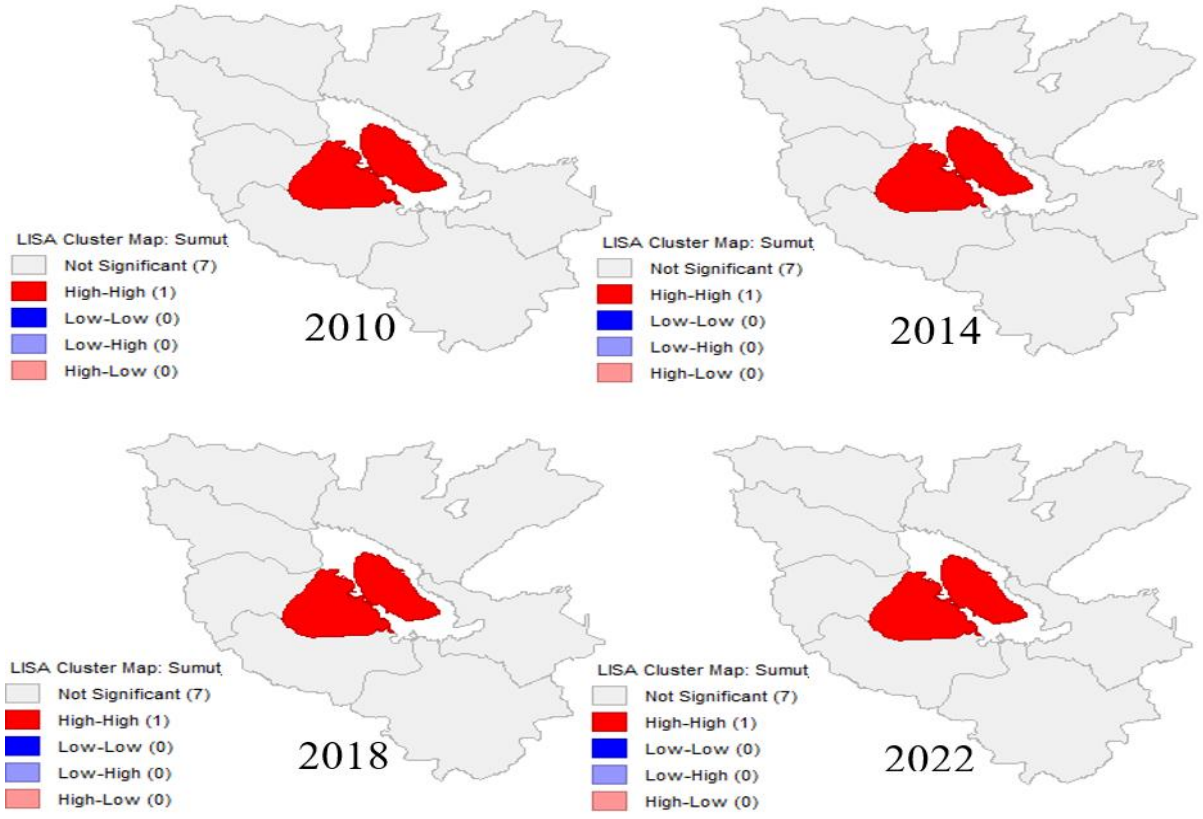

Figure 7. Cluster Map of Eight Regencies in the Lake Toba Region Based on Tourism Sector Contribution in 2010, 2014, 2018, and 2022.

The spatial interaction pattern of tourism sector contribution variables locally occurs in Dairi Regency. Based on Figure 5.6, the tourism sector contribution variable of Dairi Regency in 2022 is included in the High-Low (HL) cluster. This means that Dairi Regency has a high tourism sector contribution surrounded by regencies with low tourism sector contribution in 2022.

Tourism and Cultural Expenditure

Tourism and cultural expenditures are represented as a budget from the APBD spent by the local government of each district in the Lake Toba Region.

Table 8. Local Moran's Value and Spatial Interaction Patterns of Shopping Variables Tourism and Culture.

District	**Year**			
	2010	**2014**	**2018**	**2022**
Local Moran's				

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Humbang H.	-0,524**	-0,004	-0,652***	-0,004
Simalungun	-0,005	-0,454**	-0,026	-0,012
Pakpak Bharat	-0,137	-0,308	-0,088	-0,647***
Spatial Interaction Patterns				
Humbang H.	LH	LH	LH	HL
Simalungun	HL	HL	HL	HL
Pakpak Bharat	LH	LH	LH	LH

Note: *), **), ***): significant at α=10, 5, and 1%.

Source: processing results with Stata (2024).

Like the road infrastructure variable, the spatial interaction pattern of tourism and cultural spending variables locally in 2010, 2014, 2018, and 2022 is one district, however, different districts. In 2010, the spatial interaction pattern of tourism and cultural expenditure variables is Humbang Hasundutan Regency where the Local Moran's value of tourism and cultural expenditure variables is -0.524 with a significance level of 5% each. The spatial interaction pattern is LH.

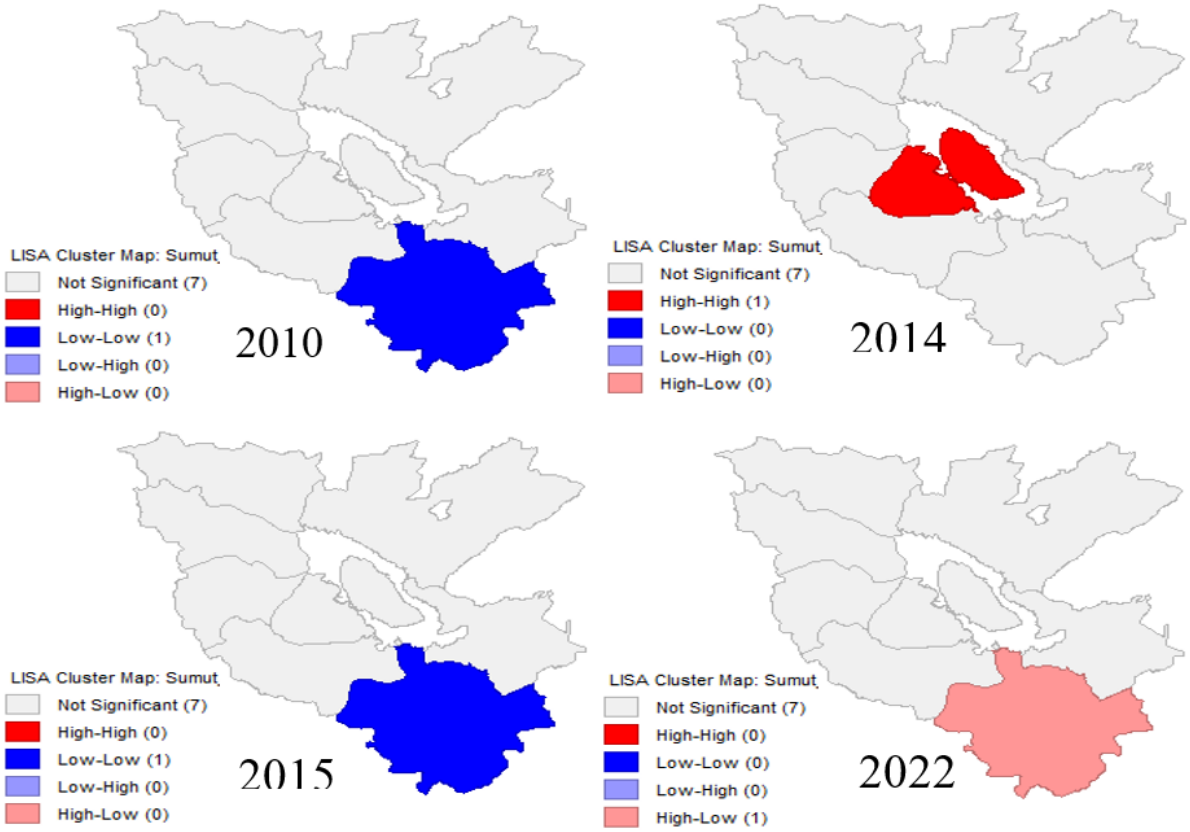

Figure 8. Cluster Map of Eight Lake Toba Regencies Based on Tourism and Culture Expenditure in 2010, 2014, 2018, and 2022

Conclusion

This research also confirms that spatial linkages support in eight districts in the Lake Toba area in the 2010-2022 period. This is indicated by the β value of the real per capita income variable for the previous period [ln(y_(i,t-1))] which lies between 0 and -1 in both spatial panel models with spatial weighting matrices based on the inverse-distance and queen contiguity approaches. Based on these things, there is a technology spillover mechanism between districts in the Lake Toba area. When inter-district linkages run well, technology transfer will also occur well. As a result, districts that were previously lagging behind were able to catch up with other districts whose technology was advanced. Meanwhile, the speed of economic growth in developed districts has slowed ((Barro, 2016), (Ertur & Koch, 2007); (Álvarez & Barbero, 2016)

Spatial dependence on economic growth in eight districts in the Lake Toba area indicates the occurrence

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of positive spatial spillover. The source of positive spatial spillover comes from real per capita income in other districts, physical capital investment in other districts, human capital investment in other districts, population growth in other districts, contribution from the tourism sector in other districts, and road infrastructure in other districts. With this positive spatial spillover, the regional governments of the districts in the Lake Toba area must collaborate to formulate policies to increase these positive spatial spillover variables. The implication is that regional economic growth in the eight districts in the Lake Toba area has increased.

This study also confirms that spatial linkages in the eight districts of the Lake Toba Region in the 2010-2022 period. This is indicated by the β value of the previous period's real per capita income variable [ln(y_(i,t-1))] which lies between 0 and -1 in both the spatial panel model with a spatial weighting matrix based on the inverse-distance and queen contiguity approaches. Based on this, there is a technology spillover mechanism between the districts of the Lake Toba Region. When linkages between districts work well, technology transfer will also occur well. As a result, districts that were previously left behind can catch up with other districts whose technology is already advanced.

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