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Original Article

Annual Choropleth Mapping and Spatial Autocorrelation of Physicians in Türkiye: A 22-Year Analysis of Provincial Physician Distribution Patterns (2002-2023)

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What is already known on this topic?

- *Health workforce distribution exhibits geographic inequalities in many countries, with rural and economically disadvantaged regions typically experiencing physician shortages.*
- *Spatial autocorrelation methods, including Global Moran's I and Local Indicators of Spatial Association, can effectively identify clustering patterns in health workforce distribution.*
- *Türkiye's Health Transformation Program (2003-present) has improved overall physician numbers, but regional disparities in physician distribution persist across provinces.*

What does this study add on this topic?

- *This is the first comprehensive 22-year spatial autocorrelation analysis of physician distribution across all 81 Turkish provinces, providing quantitative evidence of significant spatial clustering (Moran's I = 0.235, P = .003).*
- *The study identifies 10 specific provinces with significant Low-Low clustering that require immediate policy intervention, enabling targeted health workforce planning rather than uniform national approaches.*
- *Results demonstrate that market-oriented physician allocation mechanisms appear insufficient to reduce geographic inequalities over 2 decades, with the gap between the highest and lowest performing provinces spanning 5.38 standard deviations, indicating the need for active policy intervention.*

ABSTRACT

Objective: To examine spatial clustering patterns of physician distribution across Turkish provinces from 2002 to 2023 using spatial autocorrelation analysis and identify geographic disparities requiring policy intervention.

Methods: Cross-sectional spatial analysis with longitudinal components across 81 Turkish provinces. Global Moran's I and Local Indicators of Spatial Association (LISA) statistics quantified spatial autocorrelation using k-nearest neighbors spatial weights ($k = 5$). Z-score standardization enabled temporal comparisons. Monte Carlo permutation testing (999 iterations) assessed statistical significance at $\alpha = 0.05$.

Results: Significant positive spatial autocorrelation exists in physician distribution (Moran's $I = 0.235$, $P = .003$). The LISA analysis identified 4 cluster types: Low-Low clusters (29 provinces, 35.8%), High-High clusters (25 provinces, 30.9%), Low-High outliers (15 provinces, 18.5%), and High-Low outliers (12 provinces, 14.8%). The gap between highest and lowest performing provinces spanned 5.38 standard deviations. This value refers to the difference between the average z-scores of the top- and bottom-ranked provinces across the study period, whereas the 7.02 SD figure represents the difference between annual extremes across the entire period.

Conclusion: Turkish physician distribution exhibits significant spatial clustering with persistent Low-Low clustering in southeastern provinces. Spatial autocorrelation methods effectively identify priority areas for targeted health workforce interventions. The 10 provinces with significant Low-Low clustering require immediate policy attention to address systematic regional disadvantages in physician access.

Keywords: Geographic disparities, health workforce distribution, LISA clustering, spatial autocorrelation, Türkiye healthcare

Introduction

Health workforce distribution determines healthcare accessibility and population health outcomes across geographic regions.[1,2] Türkiye's provincial physician distribution displays systematic spatial variation, influenced by economic and geographic disparities. Wealthier regions attract more physicians, while eastern provinces remain underserved.[3,4] These patterns reflect persistent structural inequalities tied to income and infrastructure differences,[5,6] highlighting the need for continued quantitative analysis to guide workforce planning.[4]

This investigation examines spatial clustering patterns of physician distribution across 81 Turkish provinces from 2002 to 2023. The analysis applies Global Moran's I[7] and Local Indicators of Spatial Association

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(LISA)[8] to quantify spatial autocorrelation and identify discrete clustering configurations. Results demonstrate significant positive spatial autocorrelation ($I = 0.235$, $P = .003$) with distinct high-high and low-low cluster formations.

Provincial analysis reveals marked disparities in standardized physician density. The methodology employs z-score standardization, k-nearest neighbors spatial weights ($k = 5$),[9] and Monte Carlo permutation testing to assess statistical significance across the 22-year temporal framework.

The study contributes to health workforce research by documenting spatial clustering persistence and identifying provinces requiring targeted intervention strategies. Findings support the development of spatially informed policies to address geographic inequities in healthcare access.[10]

Literature Review

Theoretical Framework

Spatial Autocorrelation Theory

Spatial autocorrelation theory builds on Tobler's First Law of Geography, i.e. proximity creates influence.[9] Geographic closeness produces variable similarity through systematic clustering or dispersion patterns across spatial units. Health workforce studies apply this principle to identify whether physician distributions exhibit random patterns or demonstrate spatial dependencies reflecting socioeconomic, geographic, or policy factors.

Health resource allocation reflects complex interactions between population needs, economic capacity, infrastructure availability, and policy interventions.[11] Physician density in 1 province may be influenced by neighboring provinces through spillover effects, migration patterns, or shared regional characteristics.

Methodological Foundations

Spatial autocorrelation measurement employs 2 approaches: Global Moran's I and LISA. Global Moran's I measures overall spatial clustering across study areas, with values from −1 (perfect negative autocorrelation) to +1 (perfect positive autocorrelation).[7] The statistic quantifies whether similar values cluster spatially more than random chance would predict.[8]

The LISA methodology decomposes spatial autocorrelation into local contributions, identifying specific geographic clusters and spatial outliers. The LISA statistics identify local spatial nonstationarity and assess individual locations' influence on global statistics. The methodology distinguishes 4 spatial association types: High-High clusters, Low-Low clusters, High-Low outliers, and Low-High outliers.

Turkish Health System Context

Health Transformation Program Impact

Türkiye's Health Transformation Program (HTP), initiated in 2003, restructured the health system through performance-based payments, hospital autonomy reforms, and health insurance unification. The HTP's impact on health workforce distribution showed mixed regional results. Public hospital efficiency analysis revealed productivity improvements through technological advancement, but socioeconomically disadvantaged provinces did not achieve significant gains.[12]

Regional variations in HTP outcomes were pronounced. Southeast Anatolia Region showed the highest hospital financial performance improvement, with average profit ratios increasing from negative values to 20.6%. East Anatolia and Black Sea Regions remained behind other regions, showing no significant profit ratio increases.

Geographic and Economic Disparities

Türkiye's health workforce shows significant regional disparities. Physician density increased from 139 to 172 per 100 000 population (2002-2012), with specialist physicians growing 54.2% vs. 25.8% for general practitioners. Private sector employment increased from 15.7% to 22.4%, concentrating in urban areas.[13,14]

Research Gaps and Policy Applications

Current literature demonstrates spatial autocorrelation methods' value for understanding geographic inequalities and informing policy interventions. Methodological advances in LISA decomposition and permutation-based testing enable sophisticated local clustering analysis while maintaining statistical rigor.

Research gaps include limited longitudinal analysis of spatial patterns, insufficient multi-scale assessments, and minimal integration with health outcome measures. Future studies should emphasize temporal stability analysis, cross-scale validation, and workforce-outcome relationships.

Policy applications include targeted intervention identification, resource allocation optimization, and monitoring system development for health workforce programs. Spatial clustering identification enables evidence-based approaches to addressing workforce inequalities and improving population health outcomes.

Methods

Study Design and Data Sources

This study employs cross-sectional spatial analysis with longitudinal components spanning 2002-2023. The unit of analysis comprises 81 Turkish provinces (NUTS-3 administrative level). The data on the number of physicians by province and year were obtained from official statistics of the Turkish Statistical Institute (TÜİK).[15] Population figures for each province were also used in order to account for population size in measuring per-capita physician availability.

The analysis examines physician distribution patterns using standardized density measures calculated as physicians per 100 000 population. The dataset encompasses 1782 province-year observations across the 22-year study period.

Ethics Statement

This study utilized publicly available, aggregated data from the TÜİK at the provincial level. It did not involve any intervention or interaction with individuals, nor did it collect any personal, identifiable, or sensitive information. Therefore, ethical approval was not required under current regulations.

Informed Consent

As this study did not involve human participants, informed consent was not applicable.

Spatial Weight Matrix Construction

Spatial relationships between provinces are defined using k-nearest neighbors' spatial weights with $k = 5$. This specification identifies the 5 geographically closest provinces for each observation unit based on centroid-to-centroid distances. The k-nearest neighbors approach ensures each province has exactly 5 neighbors, creating balanced neighborhood structures across regions with varying geographic sizes.

Distance calculations employ great circle distances between provincial geographic centroids. The resulting spatial weight matrix W is row-standardized, where each row sums to unity (Equation 1):

$$w^*_{ij} = \frac{w_{ij}}{\sum_j w_{ij}} \quad (1)$$

Row standardization enables meaningful comparison of spatial autocorrelation measures across provinces with identical neighborhood sizes. In line with common practice, k = 5 nearest neighbors were adopted, a specification explicitly employed in several applied spatial analyses.[16,17] This choice balances local sensitivity and comparability while avoiding isolated units.

Variable Standardization

Physician density standardization employs z-score transformation applied annually (Equation 2):

$$z_{it} = \frac{x_{it} - \mu_t}{\sigma_t} \quad (2)$$

where z_{it} is standardized density, x_{it} is observed density, μ_t is national mean, and σ_t is standard deviation.

Annual standardization accounts for temporal changes in overall physician supply while preserving relative provincial rankings. Z-scores enable identification of provinces with physician densities above (positive values) or below (negative values) national averages. The standardization procedure facilitates temporal comparisons and spatial autocorrelation analysis across the study period.

Global Spatial Autocorrelation Analysis

Global Moran's I statistic quantifies overall spatial autocorrelation across all provinces (Equation 3):

$$I = \left(\frac{n}{S_0}\right) \times \left[\frac{\sum_i \sum_j w_{ij}\left(x_i - \bar{x}\right)\left(x_j - \bar{x}\right)}{\sum_i \left(x_i - \bar{x}\right)^2}\right] \quad (3)$$

where n represents the number of provinces (81), S_0 equals the sum of all spatial weights, w_{ij} denotes spatial weight between provinces i and j, x_i indicates standardized physician density for province i, and $\tilde{x}$ represents the mean standardized density across all provinces.

Moran's I values range from −1 (perfect negative spatial autocorrelation) to +1 (perfect positive spatial autocorrelation). Values near 0 indicate random spatial distribution. Positive values suggest spatial clustering of similar values, while negative values indicate spatial dispersion.

Local Indicators of Spatial Association

Local Moran's I statistics decompose global spatial autocorrelation into province-specific contributions (Equation 4 and Equation 5):

$$I_i = \left(x_i - \bar{x}\right) \sum_j \frac{w_{ij}\left(x_j - \bar{x}\right)}{m_2} \quad (4)$$

Where

$$m_2 = \sum_i \frac{\left(x_i - \bar{x}\right)^2}{n} \quad (5)$$

represents the variance of standardized physician densities.

The LISA statistics identify 4 types of local spatial association:

- High-High clusters: Provinces with above-average physician density surrounded by provinces with above-average density.
- Low-Low clusters: Provinces with below-average physician density surrounded by provinces with below-average density.
- High-Low outliers: Provinces with above-average physician density surrounded by provinces with below-average density.
- Low-High outliers: Provinces with below-average physician density surrounded by provinces with above-average density.

Statistical Significance Testing

Monte Carlo permutation tests assess statistical significance for both global and local spatial autocorrelation measures. The procedure randomly redistributes observed physician density values across provinces while maintaining the spatial weight matrix structure. Each test employs 999 permutations to generate reference distributions.

For global Moran's I, the permutation procedure calculates (Equation 6):

$$I^* = \left(\frac{n}{S_0}\right) \times \left[\frac{\sum_i \sum_j w_{ij}\left(x_i^* - \overline{x^*}\right)\left(x_j^* - \overline{x^*}\right)}{\sum_i \left(x_i^* - \overline{x^*}\right)^2}\right] \quad (6)$$

where x_i^* represents randomly permuted physician density values.

Local significance testing follows identical permutation logic applied to individual LISA statistics. Pseudo p-values are calculated as the proportion of permuted statistics exceeding observed values. The critical significance threshold is set at $\alpha = 0.05$ for both global and local tests.

Temporal Analysis Framework

Temporal stability analysis examines changes in spatial autocorrelation patterns across the 2002-2023 study period. Annual calculation of global Moran's I statistics identifies trends in overall spatial clustering. The LISA cluster membership analysis tracks individual provinces' spatial association classifications over time.

Average z-scores are calculated across the full study period to identify persistently high-performing and low-performing provinces (Equation 7):

$$\bar{z}_i = \left(\frac{1}{T}\right) \sum_t z_{it} \quad (7)$$

where T represents the number of study years (22) and z_{it} denotes annual standardized physician density for province i in year t.

Software Implementation

Analysis used Python with NumPy (1.23.0) for calculations, Matplotlib (3.6.0) for visualizations, and Shapely for geographic data processing.

Methodological Limitations

Provincial-level data may mask local variations. The analysis excludes other health workers and demographic variables.

Results

Global Spatial Autocorrelation

The Global Moran's I statistic reveals significant positive spatial autocorrelation in Turkish physician distribution ($I = 0.235$, $P = .003$). This value indicates moderate spatial clustering, where provinces with similar physician densities are located near each other more frequently than random chance would predict. The permutation-based P value of .003 provides strong statistical evidence against the null hypothesis of spatial randomness (Table 1).

Table 1. Global Moran's I Statistics

Statistic	Value
Global Moran's I statistic	0.235356
Expected value (under H_0)	−0.012500
Variance (under permutation)	0.003966
Z-score (under permutation)	3.949737
Permutation *P* value	.003000
Number of permutations	999

The observed Moran's I value of 0.235 suggests that approximately 23.5% of the maximum possible positive spatial autocorrelation exists in the data. This moderate clustering indicates systematic geographic patterns in physician distribution while allowing for substantial local variation across provinces.

Local Indicators of Spatial Association

The LISA analysis identifies distinct spatial clustering patterns across the 81 Turkish provinces (Table 2). The decomposition reveals 4 spatial association categories with varying prevalence:

Low-Low Clusters

Twenty-nine provinces (35.8%) exhibit low physician density surrounded by provinces with similarly low density.

High-High Clusters

Twenty-five provinces (30.9%) demonstrate high physician density surrounded by provinces with similarly high density.

Low-High Outliers

Fifteen provinces (18.5%) show low physician density despite location among high-density neighbors.

High-Low Outliers

Twelve provinces (14.8%) exhibit high physician density while surrounded by low-density neighbors.

Figure 1 displays the choropleth map showing LISA cluster classifications for all 81 Turkish provinces, with distinct colors representing High-High, Low-Low, High-Low, and Low-High spatial associations, and hatching indicating statistically significant clusters.

Statistical significance testing reveals 12 provinces with significant LISA statistics ($P < .05$). The significant clusters comprise 2 High-High clusters and 10 Low-Low clusters, indicating that spatial clustering is most pronounced in areas of physician shortage rather than abundance.

Provincial Physician Density Rankings

Analysis of average z-scores across the 2002-2023 period identifies substantial disparities in provincial physician distribution. The standardized scores range from −1.90 to 5.12, spanning 7.02 standard deviations and demonstrating extreme inequality in physician access. This overall range reflects annual extremes across the full period, while the long-run average gap between provinces is 5.38 SD (Table 3).

Top-Performing Provinces

Ankara leads all provinces with an average z-score of 3.97, indicating physician density nearly 4 standard deviations above the national mean. Edirne ranks second with a z-score of 2.54, followed by Isparta (2.06), İzmir (2.03), and Kırıkkale (1.47). These 5 provinces consistently maintain physician densities well above national averages throughout the study period (Figure 2).

Bottom-Performing Provinces

Şırnak exhibits the lowest physician density with an average z-score of −1.41, representing density 1.41 standard deviations below the national mean. Ağrı (−1.39), Muş (−1.26), Hakkari (−1.23), and Mardin (−1.21) complete the bottom 5 provinces. These eastern and southeastern provinces demonstrate persistent physician shortages across the 22-year study period (Figure 3).

The gap between the highest-performing province (Ankara: 3.97) and the lowest performing province (Şırnak: −1.41) spans 5.38 standard deviations, illustrating the magnitude of geographic inequality in physician distribution.

Temporal Patterns and Stability

The 22-year temporal analysis encompasses physician distribution patterns from 2002 to 2023, revealing both persistent inequalities and gradual changes in spatial clustering (Table 4). Inspection of distributional dynamics reveals 3 notable periods. First, during 2006-2010, kurtosis reached its highest values (5.6-7.2), indicating heavy-tailed distributions, with strong right-skew (1.98-2.21) and relatively few provinces below −1 SD. This reflects a concentration of extreme high-performing provinces. Second, in 2014-2017, kurtosis (0.6-1.0) and skewness (0.82-1.02) approached values closer to a normal distribution, suggesting more symmetry and a balanced pattern of extreme performers. Finally, in 2018-2023, both skewness and kurtosis began to rise again, reflecting a return to more right-skewed distributions and an increasing number of extreme low performers. Z-score calculations demonstrate that relative provincial rankings remain stable (Figure 4).

Ankara's physician density ranges from 3.20 to 5.12 standard deviations above the national mean across individual years, demonstrating consistent exceptional performance.

Some eastern and southeastern provinces exhibit persistent deficits throughout the study period. The Low-Low cluster pattern in this region shows remarkable stability, with provinces maintaining below-average physician densities across all study years.

Table 2. LISA Cluster Classification Summary

Cluster Type	Count	Percentage (%)	Significant ($P < .05$)	Significant (%)	Avg Local I
High-High (HH)	25	30.9	2	8.0	0.3755
Low-Low (LL)	29	35.8	10	34.5	0.5060
High-Low (HL)	12	14.8	0	0.0	−0.1585
Low-High (LH)	15	18.5	0	0.0	−0.2064
Total	**81**	**100.0**	**12**	**14.8**	**0.2354**

Detailed Significance Level Breakdown

Cluster Type	$P < .01$	(%)	$P < .05$	(%)	$P < .1$	(%)
High-High (HH)	1	4.0	2	8.0	7	28.0
Low-Low (LL)	1	3.4	10	34.5	10	34.5
High-Low (HL)	0	0.0	0	0.0	0	0.0
Low-High (LH)	0	0.0	0	0.0	1	6.7

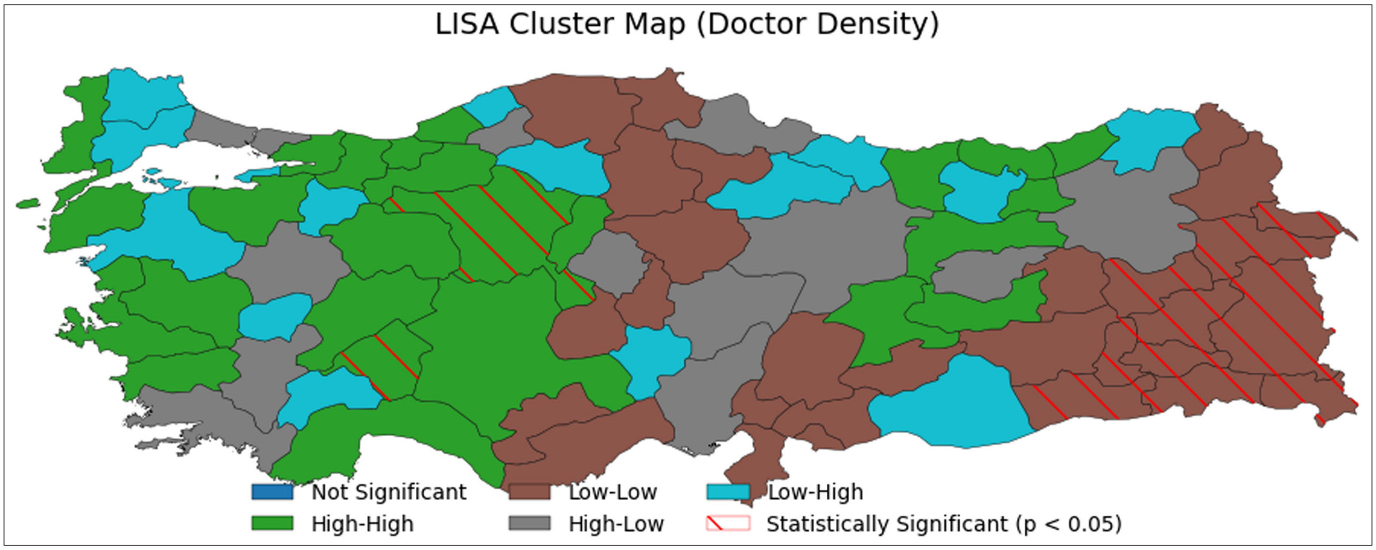

Figure 1. LISA cluster map (physician sensity). Choropleth map showing LISA cluster classifications for all 81 Turkish provinces, with distinct colors representing High-High (green), Low-Low (red), High-Low (gray), and Low-High (blue) spatial associations. Hatching indicates statistically significant clusters ($P < .05$). Data based on TÜİK provincial statistics and author's calculations.

Policy-Relevant Findings

The analysis identifies specific provinces requiring targeted policy intervention. The 10 provinces with significant Low-Low LISA statistics represent priority areas for health workforce recruitment initiatives. These provinces exhibit both individual physician shortages and location within broader regions of physician scarcity.

High-Low outlier provinces present opportunities for understanding successful physician recruitment within challenging regional contexts. These provinces may provide models for effective local policies that could be replicated in neighboring areas.

The persistence of spatial clustering patterns across 22 years suggests that market-oriented physician allocation mechanisms appear insufficient to correct geographic inequalities. The stability of Low-Low clusters indicates that passive policy approaches are insufficient to address systematic regional disadvantages in physician recruitment and retention.

Table 3. Top and Bottom 10 Provinces by Average Z-Score

Category	Province	Average Z-Score
Top 10	Ankara	3.969
Top 10	Edirne	2.545
Top 10	Isparta	2.058
Top 10	İzmir	2.028
Top 10	Kırıkkale	1.473
Top 10	Trabzon	1.439
Top 10	Eskişehir	1.434
Top 10	Bolu	1.372
Top 10	İstanbul	1.296
Top 10	Elazığ	1.16
Bottom 10	Bingöl	−0.92
Bottom 10	Siirt	−0.933
Bottom 10	Bitlis	−0.983
Bottom 10	Şanlıurfa	−1
Bottom 10	Iğdır	−1.046
Bottom 10	Mardin	−1.208
Bottom 10	Hakkari	−1.233
Bottom 10	Muş	−1.264
Bottom 10	Ağrı	−1.393
Bottom 10	Şırnak	−1.405

Discussion

Interpretation of Spatial Patterns

The significant positive spatial autocorrelation ($I = 0.235$, $P = .003$) confirms systematic geographic clustering in Turkish physician distribution. The concentration of significant clustering in Low-Low areas (10 of 12 significant clusters) demonstrates that physician shortage regions exhibit stronger spatial dependencies than physician abundance regions. Ankara's exceptional performance (z-score = 3.97) reflects its unique status as national capital with concentrated medical education and research infrastructure. The southeastern Low-Low cluster persistence indicates structural barriers that transcend individual provincial characteristics, requiring regional rather than province-specific policy approaches.

Policy Implications

Results identify specific targets for workforce interventions. The 10 provinces with significant Low-Low clustering require immediate attention through coordinated regional strategies. High-Low outlier provinces (12 provinces) demonstrate successful physician recruitment within challenging regional contexts and merit investigation as policy models.

The 5.38 standard deviation gap between highest and lowest performing provinces indicates extreme inequality requiring targeted redistribution mechanisms. Market-oriented physician allocation mechanisms appear insufficient to address geographic disparities.

Methodological Considerations and Limitations

The k-nearest neighbors approach ($k = 5$) provides balanced neighborhood structures while avoiding isolation of peripheral provinces. Z-score standardization enables temporal comparisons while controlling for national physician supply changes. Monte Carlo permutation testing ensures robust significance assessment.

This study has certain limitations. First, the use of provincial-level aggregation may mask intra-provincial inequalities in physician

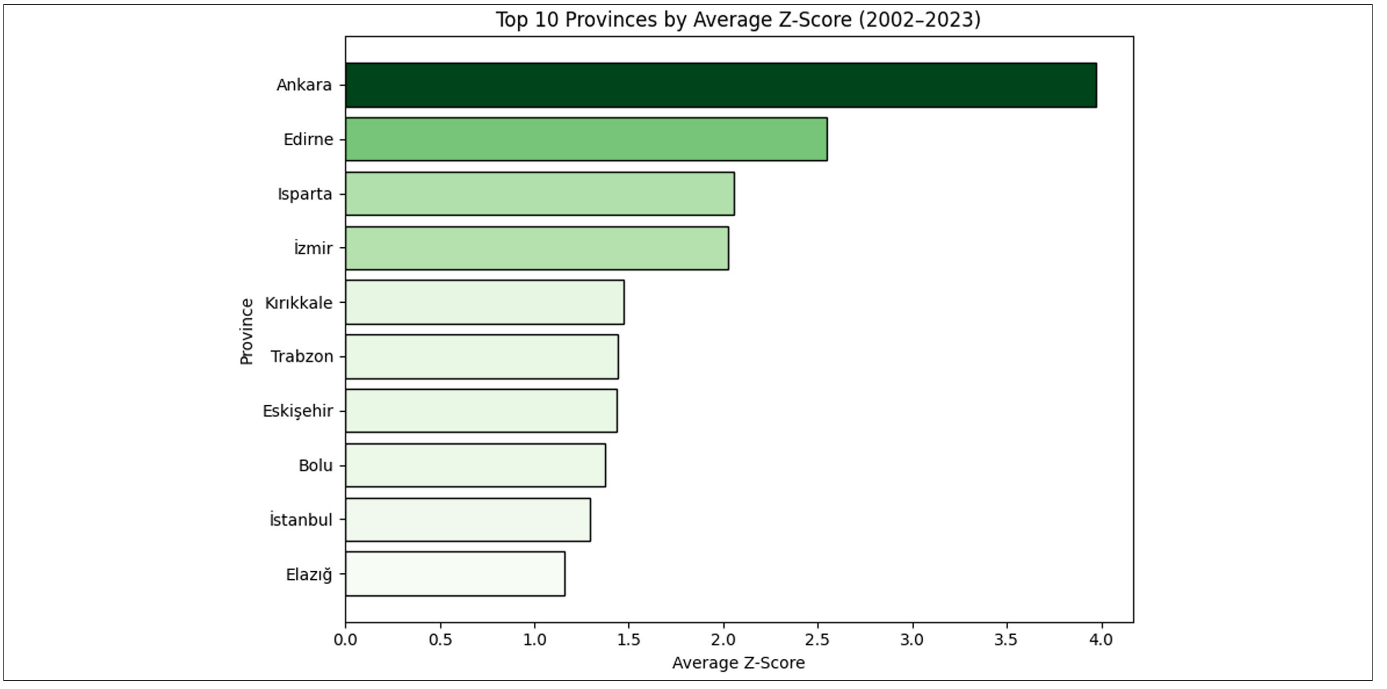

Figure 2. Top 10 provinces by average z-score (2002-2023). Horizontal bar chart displaying the highest-performing provinces ranked by average standardized physician density scores. Ankara shows exceptional performance with a z-score of 3.97. Data based on TÜİK provincial statistics and author's calculations.

distribution. Second, the analysis is limited to physicians and does not include other categories of health workers or sociodemographic determinants. Third, while annual data provide valuable longitudinal coverage, the temporal analysis does not explicitly model serial correlation. Despite these constraints, the study's strengths include comprehensive national scope, a 22-year time span, robust spatial methods, and direct policy relevance.

Future Research Directions

Future research could extend this analysis by distinguishing between generalist and specialist physicians, exploring sub-provincial (district- or municipality-level) data, and linking spatial workforce patterns with health outcomes such as mortality or service utilization. In addition, applying space-time panel models could help clarify the causal influence of policy reforms on workforce distribution dynamics.

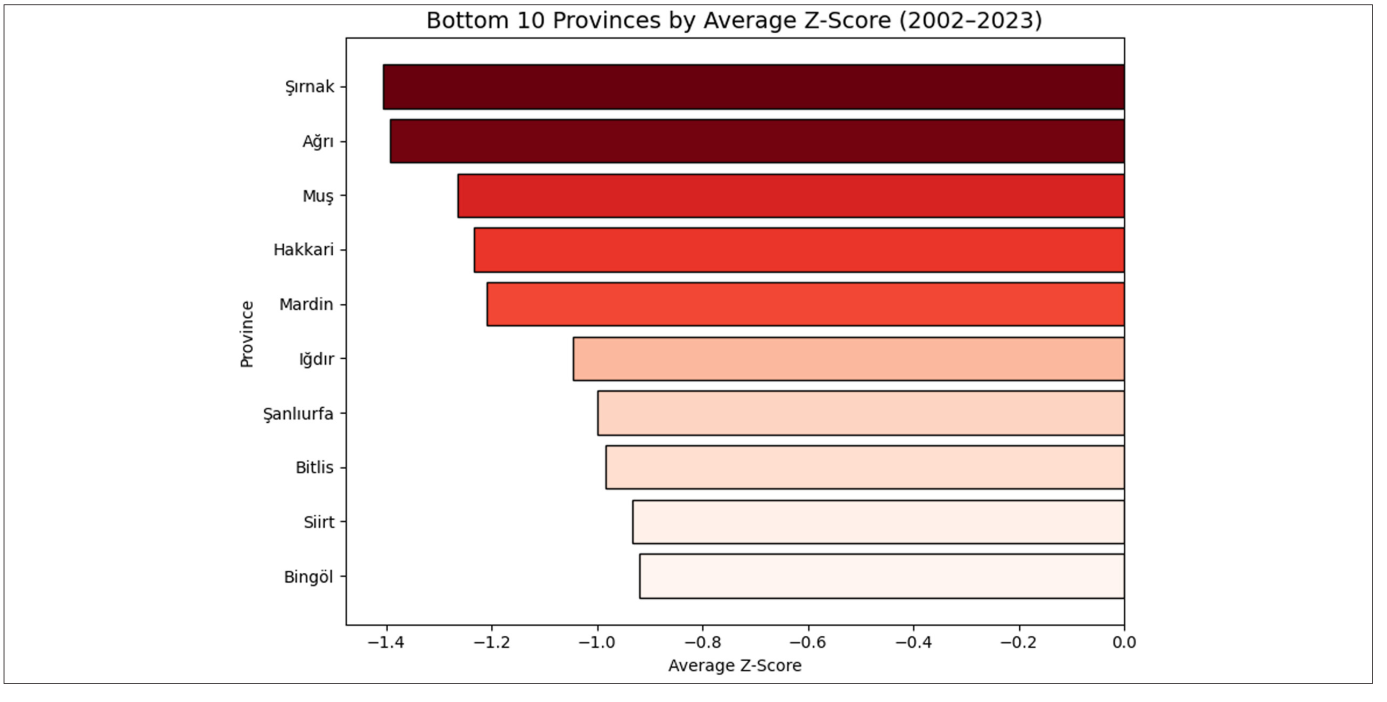

Figure 3. Bottom 10 provinces by average z-score (2002-2023). Horizontal bar chart showing the lowest performing provinces ranked by average standardized physician density scores. Şırnak exhibits the lowest density with z-score of −1.41. Data based on TÜİK provincial statistics and author's calculations.

Table 4. Distributional Statistics of Z-Scores by Year

Year	Provinces >+1 SD	Provinces <−1 SD	Minimum Z-Score	Maximum Z-Score	Skewness	Kurtosis
2002	12	12	−1.896	3.839	0.943	1.672
2003	12	11	−1.691	4.017	0.982	2.118
2004	12	10	−1.797	3.848	0.948	1.720
2005	13	11	−1.690	3.590	0.889	1.082
2006	11	2	−1.264	5.122	2.202	7.133
2007	10	2	−1.149	5.042	2.204	6.846
2008	12	5	−1.079	5.109	2.212	7.182
2009	10	7	−1.221	4.821	2.011	5.751
2010	12	4	−1.156	4.797	1.983	5.642
2011	14	8	−1.326	3.900	1.502	2.491
2012	14	8	−1.515	3.760	1.249	1.683
2013	12	8	−1.301	3.802	1.270	1.663
2014	13	13	−1.674	3.524	0.995	0.938
2015	14	6	−1.798	3.442	0.911	0.778
2016	15	6	−1.668	3.564	1.016	0.995
2017	14	9	−1.855	3.349	0.820	0.635
2018	12	12	−1.542	3.202	0.954	0.856
2019	13	10	−1.583	3.331	1.074	1.098
2020	11	12	−1.492	3.581	1.125	1.450
2021	11	8	−1.363	3.665	1.215	1.619
2022	11	6	−1.508	3.943	1.360	2.447
2023	10	12	−1.565	4.078	1.351	2.808

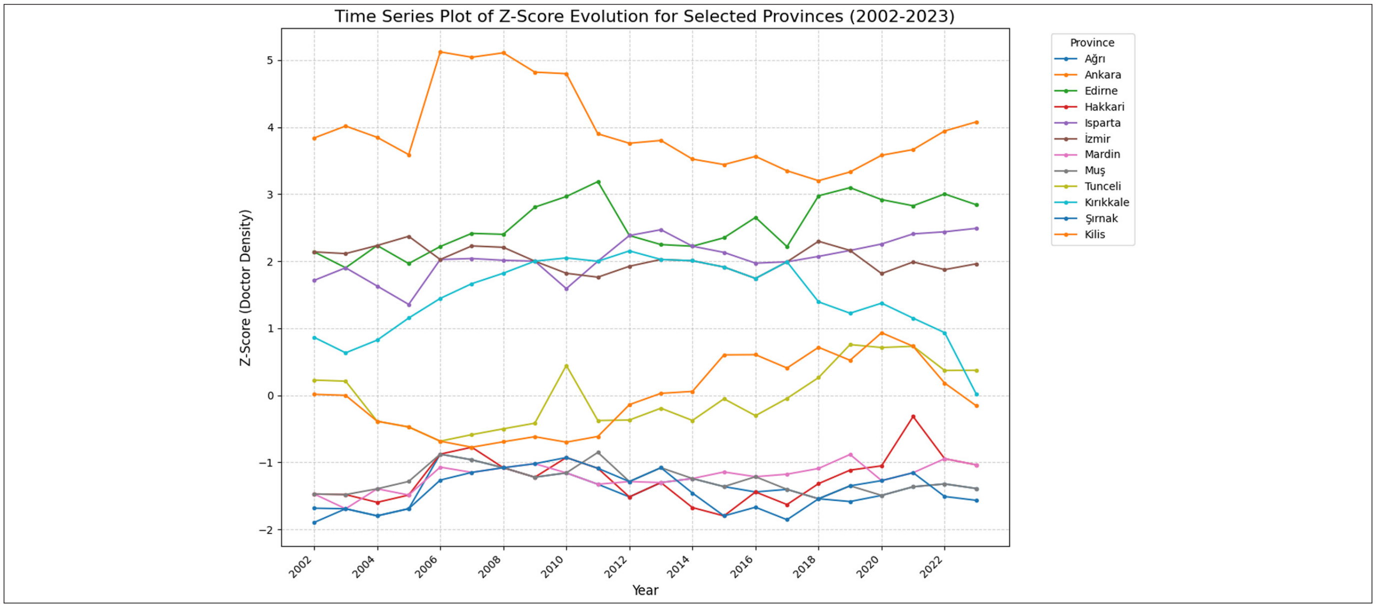

Figure 4. Time series plot of z-score evolution for selected provinces (2002-2023). Multi-line plot showing temporal trends in standardized physician density for representative provinces across performance categories. Lines demonstrate persistent ranking stability over the 22-year study period. Data based on TÜİK provincial statistics and author's calculations.

Integration of specialist physician categories and demographic variables would provide comprehensive workforce analysis. Multiscale analysis incorporating sub-provincial units would refine spatial clustering identification. Longitudinal modeling of clustering evolution could identify policy intervention effects and predict future spatial patterns.

Conclusion

Turkish physician distribution exhibits significant spatial autocorrelation with persistent Low-Low clustering in southeastern provinces and High-High clustering in western regions. Spatial autocorrelation methods effectively identify geographic inequalities and priority areas for policy intervention. The 22-year persistence of spatial patterns demonstrates that active policy approaches are needed to address systematic regional disadvantages in physician distribution. Targeted interventions in the 10 provinces with significant Low-Low clustering represent the highest priority for improving geographic equity in healthcare access.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: Ethics committee approval was not required for this study because it used only secondary, publicly available, aggregated data and did not involve human participants or identifiable personal information.

Informed Consent: Informed consent was not required because the study was based exclusively on secondary public data and involved no direct interaction with human subjects.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – İ.K.Ş.; Design – İ.K.Ş.; Supervision – İ.K.Ş.; Resources – İ.K.Ş.; Materials – İ.K.Ş.; Data Collection and/or Processing – İ.K.Ş.; Analysis and/or Interpretation – İ.K.Ş.; Literature Search – İ.K.Ş.; Writing Manuscript – İ.K.Ş.; Critical Review – İ.K.Ş.; Other – İ.K.Ş.

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References

1. McGrail MR, Humphreys JS. Measuring spatial accessibility to primary care in rural areas: improving the effectiveness of the two-step floating catchment area method. *Health Serv Res*. 2009;44(3):1044-1063. [CrossRef]
2. Rosenthal MB, Zaslavsky A, Newhouse JP. The geographic distribution of physicians revisited. *Health Serv Res*. 2005;40(6 Pt 1):1931-1952. [CrossRef]
3. Mollahaliloglu S, Yardım M, Telatar TG, Uner S. Change in the geographic distribution of human resources for health in Turkey, 2002-2016. *Rural Remote Health*. 2021;21(2):6478. [CrossRef]
4. Yardım MS, Üner S. *Geographical Disparities in the Distribution of Physicians in Turkey*. Published Online 2013.
5. Ünal E. How the government intervention affects the distribution of physicians in Turkey between 1965 and 2000. *Int J Equity Health*. 2015;14:1. [CrossRef]
6. Vujicic M, Sparkes S, Mollahaliloglu S. *Health Workforce Policy in Turkey, Recent Reforms and Issues for the Future*. Washington DC: The International Bank for Reconstruction and Development/World Bank; 2009. [CrossRef]
7. Moran PAP. Notes on continuous stochastic phenomena. *Biometrika*. 1950;37(1-2):17-23. [CrossRef]
8. Anselin L. Local indicators of spatial association—LISA. *Geogr Anal*. 1995;27(2):93-115. [CrossRef]
9. Cliff AD, Ord JK. *Spatial Processes: Models and Applications*. Pion Limited; 1981.
10. Matsumoto M, Inoue K, Kajii E. Characteristics of medical students with rural origin: implications for selective admission policies. *Health Policy (New York)*. 2008;87(2):194-202. [CrossRef]
11. Getis A, Ord JK. The analysis of spatial association by use of distance statistics. *Geogr Anal*. 1992;24(3):189-206. [CrossRef]
12. Akdağ R. *Turkey Health Transformation Program Evaluation Report (2003-2011)*. Ministry of Health; 2012.
13. Önal FG. Physician migration through the lens of patient and physician rights: A qualitative evaluation from the Turkish Parliament. *Health Sci Q*. 2023;3(4):269-282. [CrossRef]
14. Pekdemir D. Alternative financing models in public facilities: the case study of Medical Campuses, Healthcare PPP Program in Turkey. In: *European Real Estate Society (ERES)*. European Real Estate Society; 2017. [CrossRef]
15. Türkiye Istatistik Kurumu, *İstatistik Veri Portalı*. Available at: https://data.tuik.gov.tr. Accessed June 25, 2025.
16. Jacquez GM, Kaufmann A, Meliker J, Goovaerts P, AvRuskin G, Nriagu J. Global, local and focused geographic clustering for case-control data with residential histories. *Environ Health*. 2005;4(1):4. [CrossRef]
17. Warin T. *Geospatial Data Analysis*. Preprint posted online 2025. Available at: https://warin.ca/geospatial/08-geospatial_data_analysis.html.