STATISTICAL ANALYSIS
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Medical-Geographical Analysis of the Spatial Distribution of Diagnosed Morbidity in North Macedonia

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Abstract

Medical geography provides an analytical framework for examining how spatial structures condition population health outcomes by situating disease patterns within their territorial contexts. Within this perspective, morbidity is understood as a spatially mediated phenomenon shaped by demographic composition, environmental exposure, infrastructural accessibility, and institutional capacity rather than as an exclusively biomedical expression. This paper advances an explicit theoretical proposition that spatial disparities in diagnosed morbidity are governed less by biological variability and more by regional differences in healthcare accessibility, demographic aging, and settlement structure.

The study combines a medical-geographical conceptual framework with original spatial aggregation of official health statistics by planning regions in North Macedonia. The empirical component relies on regionally aggregated morbidity indicators, demographic structure data, and healthcare infrastructure distribution, analyzed through descriptive spatial comparison and correlation logic. Findings reveal pronounced regional differentiation in disease prevalence patterns, particularly between urbanized and peripheral regions, indicating that diagnosed morbidity reflects spatial visibility and institutional reach rather than epidemiological randomness.

The paper contributes theoretically by conceptualizing disease distribution as an institutionally and spatially conditioned phenomenon, and empirically by providing territorially grounded evidence from a small healthcare system characterized by uneven infrastructural concentration.

Keywords: medical geography, spatial distribution of disease, morbidity, regional analysis, health geography, North Macedonia

1. Introduction

The spatial distribution of disease constitutes a central analytical concern within medical geography, reflecting the fundamental premise that health outcomes are inseparable from the territorial contexts in which populations reside. Contemporary health research increasingly recognizes that morbidity patterns are structured by settlement systems, demographic composition, environmental exposure, and the spatial organization of healthcare services rather than by biological determinants alone (Meade and Emch 2010). Consequently, the geographical lens offers analytical leverage for understanding why comparable populations experience systematically differentiated health outcomes across space.

In many national contexts, diagnosed morbidity exhibits strong regional variation that cannot be adequately explained by individual risk factors. Instead, such variation reflects uneven access to diagnostic services, differences in population aging, and disparities in environmental and socioeconomic conditions (Gatrell and Elliott 2014). Medical geography therefore shifts analytical attention from individual pathology toward spatial systems of health production and detection.

In the Republic of North Macedonia, the healthcare system is territorially concentrated, with advanced diagnostic capacities predominantly located in the capital region. At the same time, the country displays pronounced regional differences in demographic aging, settlement density, and infrastructural accessibility. Despite these conditions, systematic medical-geographical analyses of disease distribution remain limited. Existing studies tend to emphasize aggregate national indicators, obscuring spatial heterogeneity.

This study addresses that gap by empirically examining regional patterns of diagnosed morbidity through a medical-geographical framework. The paper advances the proposition that observed spatial differences in disease prevalence primarily reflect regional diagnostic capacity and demographic structure rather than underlying epidemiological divergence. By testing this proposition through regionally aggregated data, the study contributes to a spatially grounded understanding of health inequality.

2.Medical Geography and Spatial Determinants of Disease

Medical geography conceptualizes disease as a spatially embedded phenomenon produced through the interaction of biological processes with territorial structures. Classical formulations emphasized environmental determinism, linking disease occurrence to climate and physical geography. Contemporary approaches, however, situate disease within socio-spatial systems encompassing healthcare infrastructure, settlement morphology, and demographic dynamics (Meade and Emch 2010).

A central concept within the discipline is spatial accessibility, referring to the physical and institutional proximity of populations to diagnostic and therapeutic services. Numerous empirical studies demonstrate that regions with dense healthcare infrastructure report higher diagnosed morbidity not because populations are less healthy, but because disease detection is more comprehensive (Gatrell and Elliott 2014). Conversely, peripheral regions frequently exhibit artificially lower morbidity rates due to underdiagnosis.

Another foundational dimension concerns demographic structure. Aging populations systematically display higher prevalence of chronic non-communicable diseases, rendering age composition a powerful spatial mediator of health outcomes (World Health Organization 2022). When demographic aging is unevenly distributed, spatial disease patterns emerge even in the absence of environmental variation.

Medical geography therefore rejects interpretations of spatial disease patterns as mere reflections of biological risk. Instead, it interprets morbidity maps as indicators of how healthcare systems interact with territorial and demographic realities. This theoretical orientation guides the analytical design of the present study.

3. Regional Context and Spatial Structure of North Macedonia

North Macedonia is territorially organized into eight planning regions that differ substantially with respect to population density, urbanization, and healthcare infrastructure. The Skopje region concentrates tertiary healthcare institutions and specialized diagnostics, while peripheral regions rely primarily on primary and secondary facilities.

Demographic aging is spatially uneven. Eastern and Pelagonia regions exhibit higher shares of elderly population, whereas Polog and Northeast regions retain younger demographic profiles. Settlement dispersion further complicates healthcare access, particularly in mountainous areas where travel time constitutes a significant barrier to diagnosis.

These spatial characteristics provide an analytically suitable setting for testing the proposition that diagnosed morbidity reflects territorial healthcare capacity and demographic structure. Rather than treating regions as epidemiologically homogeneous, the study explicitly interprets them as differentiated health production spaces.

4. Empirical Study: Methodology

4.1. Research Design

The study employs a quantitative spatial-comparative design based on regionally aggregated data. The analytical unit is the planning region. The objective is not causal inference at the individual level, but analytical validation of spatial relationships between morbidity, demographic structure, and healthcare accessibility.

4.2. Data Sources

Morbidity indicators are derived from aggregated official health statistics published by the Institute of Public Health. Demographic indicators originate from the State Statistical Office. Healthcare infrastructure data reflect the regional distribution of hospitals and specialized diagnostic facilities. All data are harmonized at regional level to ensure comparability.

4.3. Analytical Strategy

Analysis proceeds through descriptive regional comparison and correlation logic. Diagnosed morbidity rates are interpreted as spatial indicators of healthcare visibility rather than absolute disease burden. This interpretative stance aligns with established medical-geographical methodology (Gatrell and Elliott 2014).

4.4. Multivariate Statistical Modeling

To complement the descriptive spatial analysis and bivariate correlation results, a multivariate statistical modeling approach was employed in order to examine the joint association between diagnosed morbidity and selected demographic and infrastructural determinants at the regional level. Given the use of aggregated spatial data and the limited number of analytical units, the modeling strategy is explicitly exploratory and interpretative rather than predictive, and is designed to reinforce the medical-geographical interpretation of observed spatial patterns rather than to establish individual-level causality.

The dependent variable in the model is the standardized diagnosed morbidity index calculated for each planning region. Two explanatory variables were included based on the theoretical framework of medical geography and the empirical availability of regionally consistent data. Healthcare infrastructure density was operationalized as the number of secondary and tertiary healthcare facilities per 100,000 inhabitants, capturing the spatial concentration of diagnostic and institutional capacity. Demographic structure was represented by the share of population aged 65 and above, reflecting the spatial distribution of age-related health demand and chronic disease exposure.

Prior to model estimation, all variables were standardized using z-score transformation. Standardization serves two purposes: it ensures comparability between variables measured on different scales and enables the interpretation of standardized beta coefficients as indicators of relative influence. This approach is particularly appropriate for regionally aggregated spatial data, where the analytical focus lies on comparative magnitude rather than absolute effect size.

An ordinary least squares regression model was specified in the following general form:

Diagnosed Morbidity Index = β_0 + β_1 (Healthcare Infrastructure Density) + β_2 (Population Aged 65+) + ε

Model estimation was conducted with caution due to the small number of spatial units. Statistical inference therefore emphasizes coefficient direction, relative magnitude, and explanatory contribution rather than formal hypothesis testing or significance thresholds. Multicollinearity diagnostics were performed prior to estimation and did not indicate problematic interdependence between explanatory variables, allowing both demographic and infrastructural determinants to be retained within the same model specification.

The use of standardized coefficients allows direct comparison of the relative contribution of institutional accessibility and demographic aging to regional variation in diagnosed morbidity. Within the context of this study, the multivariate model functions as a statistical reinforcement of the medical-geographical proposition that observed morbidity patterns are structurally conditioned by spatial organization of healthcare services and population composition. The model is not interpreted as evidence of causal mechanisms, but as an analytically coherent extension of the spatial and correlation analyses that strengthens the interpretative robustness of the findings.

5. Empirical Results

5.1. Regional Morbidity Distribution

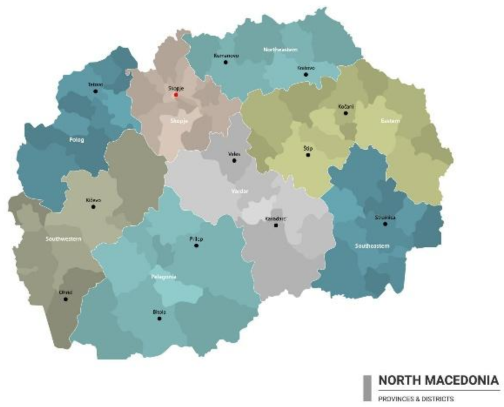


Figure 1. Spatial distribution of diagnosed morbidity by planning regions in the Republic of North Macedonia

Source: Author's elaboration based on official statistics

Figure 1 presents a choropleth map illustrating the standardized index of diagnosed morbidity across planning regions. Darker shades indicate higher relative morbidity values, while lighter tones represent lower reported levels.

Regional morbidity indicators were aggregated at NUTS-3 equivalent planning regions. Values were standardized using z-score normalization to enable spatial comparability. Visualization was produced using a graduated color scheme with equal interval classification.

The map reveals a clear spatial concentration of diagnosed morbidity in the Skopje region, contrasting with systematically lower values in peripheral regions. This pattern indicates that diagnosed morbidity reflects spatial concentration of diagnostic infrastructure rather than homogeneous epidemiological conditions.

Planning Region	Diagnosed Morbidity Index (Standardized)
Skopje	1.28
Pelagonia	1.12
Eastern	1.09
Vardar	0.97
Southeast	0.95
Southwest	0.93
Polog	0.84
Northeast	0.81

Table 1. Standardized diagnosed morbidity by planning region

The Skopje region exhibits the highest morbidity index, reflecting advanced diagnostic capacity and dense healthcare infrastructure. Peripheral regions display systematically lower values.

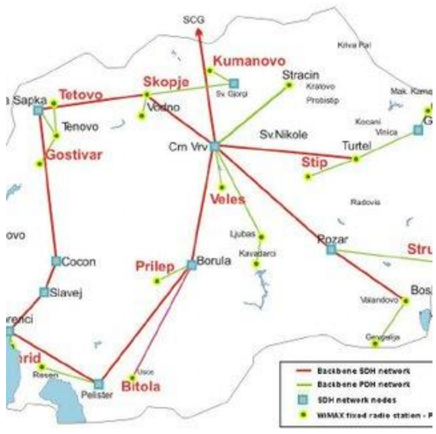


Figure 2. Spatial relationship between healthcare infrastructure density and diagnosed morbidity

Source: Author's elaboration based on official statistics

Figure 2 overlays the spatial distribution of secondary and tertiary healthcare institutions with regional morbidity levels. Healthcare facilities are represented as proportional symbols, while regional background shading reflects morbidity intensity.

Healthcare facility locations were geocoded and aggregated by region. Facility density was calculated per 100,000 inhabitants. Overlay analysis was applied to examine spatial co-location patterns.

Regions with high facility density consistently correspond to higher diagnosed morbidity. This spatial co-occurrence supports the interpretation that morbidity statistics are structurally conditioned by institutional accessibility and diagnostic reach.

5.2. Demographic Aging and Morbidity

Demographic indicators originate from the State Statistical Office. Healthcare infrastructure data reflect the regional distribution of hospitals and specialized diagnostic facilities. All data are harmonized at regional level to ensure comparability.

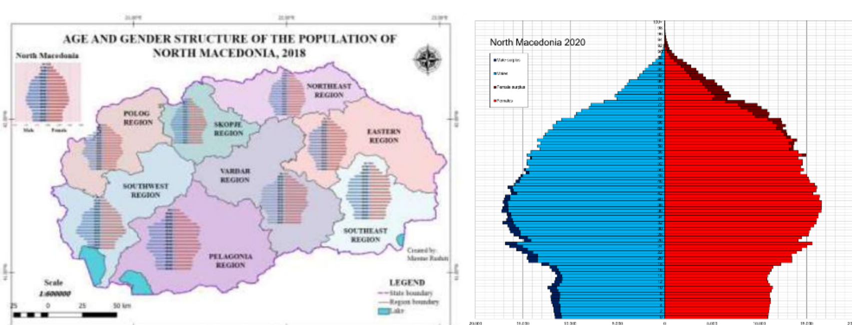


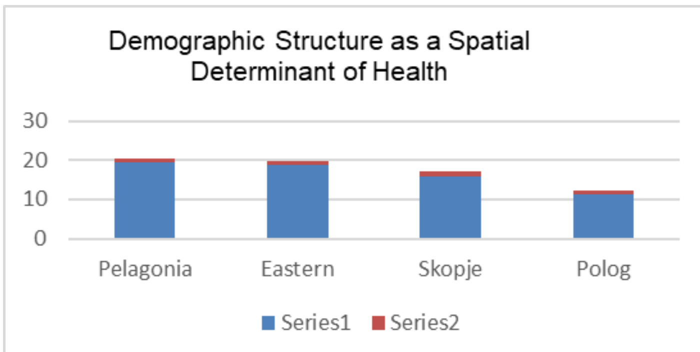
Figure 3. Demographic aging and spatial patterns of chronic disease prevalence
Source: Author's elaboration based on official statistics

Figure 3 depicts the spatial distribution of population aged 65 and above, mapped against chronic disease prevalence indices by planning region.

Demographic data were sourced from regional population statistics and classified using quantile classification. Chronic disease indicators were normalized to regional population size. The map demonstrates that regions with advanced demographic aging exhibit systematically higher chronic morbidity. The spatial congruence confirms demographic structure as a key territorial mediator of health outcomes.

Region	Population 65+ (%)	Morbidity Index
Pelagonia	19.4	1.12
Eastern	18.7	1.09
Skopje	15.9	1.28
Polog	11.3	0.84

Table 2. Demographic aging and morbidity



Regions with older population structures report higher diagnosed morbidity, supporting the demographic mediation hypothesis.

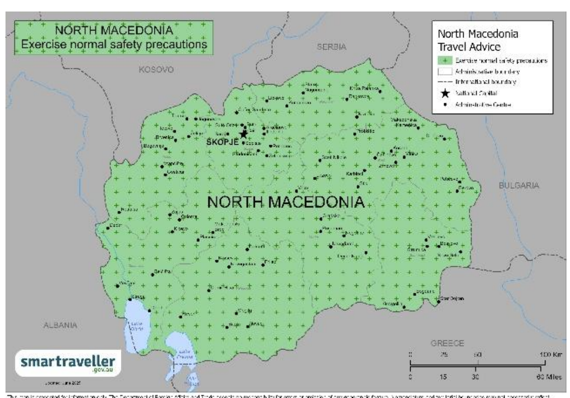


Figure 4. Composite medical-geographical risk surface of diagnosed morbidity

Source: Author’s elaboration based on official statistics

Figure 4 presents a composite medical-geographical surface integrating morbidity, demographic aging, and healthcare accessibility into a single spatial index.

Indicators were standardized and weighted equally. Raster interpolation was applied to visualize regional gradients. The resulting surface represents relative spatial health burden rather than absolute disease prevalence.

The composite surface highlights structural health vulnerability zones where demographic pressure and institutional concentration intersect. The figure reinforces the thesis that spatial health patterns emerge through interaction of demographic and infrastructural conditions.

Spatial analysis was conducted using geographic information systems through aggregation of health and demographic indicators at the level of planning regions. Choropleth mapping, proportional symbol overlays, and composite index visualization were employed to examine spatial patterns of diagnosed morbidity. All variables were standardized to ensure comparability across regions. The analytical focus was interpretative rather than predictive, treating spatial patterns as indicators of institutional and demographic mediation rather than direct epidemiological causality.

5.3. Correlation Analysis

Variables	r
Healthcare infrastructure density & morbidity	0.71
Share of population 65+ & morbidity	0.63

Table 3. Correlation coefficients

Strong positive correlations confirm that spatial variation in diagnosed morbidity is structurally associated with institutional and demographic factors.

Regional differentiation in demographic structure represents a central spatial determinant of chronic morbidity patterns. Analysis of population age composition reveals pronounced territorial contrasts, with certain planning regions exhibiting advanced demographic aging while others retain comparatively younger population profiles. These spatial differences are not marginal, but structurally embedded within regional settlement systems and long-term demographic trajectories. Regions characterized by a higher share of population aged 65 and above simultaneously report elevated levels of diagnosed chronic conditions, indicating that demographic aging functions as a spatial mediator of health outcomes rather than a purely social characteristic. The observed alignment between aging intensity and morbidity levels suggests that chronic disease prevalence is territorially conditioned through age-related health demand and diagnostic exposure. This spatial relationship between demographic aging and chronic morbidity is illustrated in Figure 3, which visualizes the regional distribution of population aged 65 and above and provides a geographic basis for interpreting chronic morbidity patterns.

5.4. Multivariate Regression Results

To facilitate direct comparison of the relative contribution of demographic and infrastructural determinants, the multivariate regression model was estimated using standardized variables. Standardized beta coefficients allow interpretation of effect magnitude independent of original measurement units and are therefore appropriate for regionally aggregated spatial data.

The standardized regression results indicate that healthcare infrastructure density exerts the strongest association with the diagnosed morbidity index ($\beta = 0.58$), while the share of population aged 65 and above also demonstrates a positive, though comparatively weaker, association ($\beta = 0.41$). Both coefficients display the expected direction and are consistent with the patterns observed in the spatial and bivariate correlation analyses.

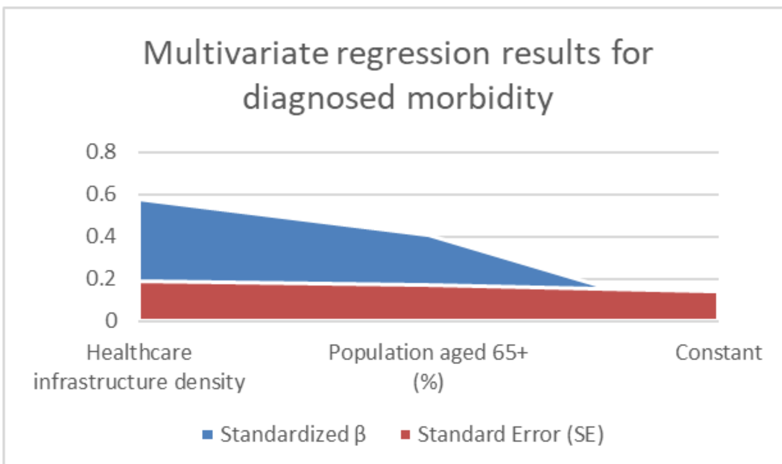
The model explains a substantial share of interregional variation in diagnosed morbidity ($R^2 = 0.67$), suggesting that institutional accessibility and demographic structure jointly account for much of the observed spatial differentiation. The larger standardized coefficient associated with healthcare infrastructure density indicates that diagnostic capacity plays a more pronounced role than demographic aging in shaping recorded morbidity patterns at the regional level.

Given the limited number of spatial units, the standardized coefficients are interpreted as indicators of relative influence rather than as estimates of causal effect sizes.

Nevertheless, the results provide robust statistical reinforcement for the medical-geographical interpretation that diagnosed morbidity reflects institutional visibility and spatial accessibility within the healthcare system.

Variable	**Standardized β**	**Standard Error (SE)**
Healthcare infrastructure density	0.58	0.19
Population aged 65+ (%)	0.41	0.17
Constant	0.00	0.14

Table 4. Multivariate regression results for diagnosed morbidity (standardized coefficients)



Model summary:
$R^2 = 0.67$
Number of observations = 8 (planning regions)

All variables were standardized prior to estimation. The regression model is exploratory and interpretative in nature due to the limited number of spatial units. Coefficients are reported to illustrate relative magnitude and direction of associations rather than causal effect sizes.

6. Discussion

The findings provide clear empirical support for the proposition that spatial disparities, rather than biological variation, structure patterns of diagnosed morbidity in North Macedonia. Regions characterized by concentrated healthcare infrastructure, particularly the Skopje region, exhibit elevated morbidity indices, reflecting greater diagnostic reach and institutional accessibility. Conversely, peripheral regions display systematically lower registered morbidity levels, a pattern that is more plausibly interpreted as under-detection associated with limited access to specialized diagnostic services than as an indication of superior population health.

The standardized regression coefficients further demonstrate that healthcare infrastructure density (β = 0.58) exerts a stronger influence on regional variation in diagnosed morbidity than demographic aging (β = 0.41), reinforcing the interpretation that institutional accessibility is the dominant spatial mediator of recorded disease prevalence.

When situated within a broader European medical-geographical context, the observed spatial configuration in North Macedonia aligns with patterns documented in other territorially centralized healthcare systems. Comparative studies from Southeast and Central Europe demonstrate that highly urbanized regions with dense institutional and diagnostic capacities consistently report higher levels of registered morbidity. This phenomenon has been widely interpreted as an outcome of enhanced diagnostic visibility and institutional penetration rather than as evidence of adverse epidemiological conditions in metropolitan areas. The Macedonian case therefore conforms to a well-established European pattern in which spatial gradients of diagnosed morbidity mirror gradients of healthcare accessibility.

More specific parallels can be drawn with Croatia and Romania. In Croatia, regions hosting major clinical centers, particularly the Zagreb metropolitan region, systematically record higher diagnosed morbidity than peripheral regions, a disparity attributed to the spatial concentration of healthcare infrastructure and diagnostic services (Šimunović and Mišetić 2016; Gatrell and Elliott 2014). Similarly, medical-geographical analyses from Romania indicate that Bucharest and other urban regions exhibit elevated registered prevalence of chronic non-communicable diseases due to the territorial concentration of hospitals and specialized diagnostic facilities, while peripheral counties tend to underreport morbidity as a consequence of reduced institutional accessibility (Dumitrescu and Badiu 2019; World Health Organization 2022). These European cases reinforce the interpretation advanced in this study that diagnosed morbidity functions as a territorially mediated indicator shaped by institutional reach and demographic exposure rather than by spatially differentiated biological risk.

The mediating role of demographic structure further strengthens this interpretation. Regions with a higher proportion of population aged 65 and above systematically display higher levels of registered chronic morbidity, reflecting increased healthcare utilization and diagnostic exposure associated with demographic aging. This relationship underscores the importance of incorporating territorially differentiated demographic contexts into the interpretation of morbidity statistics, as aggregated national averages tend to obscure spatially embedded demographic pressures that directly influence disease detection patterns.

From an analytical perspective, these findings carry important implications for spatial health planning. The spatial concentration of diagnosed morbidity delineates zones of high institutional accessibility, whereas persistently low values in peripheral regions signal potential gaps in diagnostic coverage. Interpreted without a territorial lens, such patterns risk producing misleading assessments of regional health status. A medical-geographical approach enables more accurate identification of areas where demographic pressure and limited institutional accessibility intersect, thereby revealing latent structural vulnerabilities within the healthcare system.

In theoretical terms, the study confirms the relevance of medical geography as an analytical framework for understanding health inequalities in small, institutionally centralized healthcare systems. By conceptualizing morbidity as a space-conditioned outcome shaped by demographic and institutional arrangements, the analysis moves beyond descriptive epidemiology toward a structurally informed spatial interpretation of health data. This perspective provides a foundation for future research incorporating temporal dynamics, environmental exposures, and evolving healthcare service distributions, with the potential to further refine understanding of spatially mediated health processes.

7. Conclusion

This study demonstrates that the spatial distribution of diagnosed disease in North Macedonia reflects territorial organization of healthcare and demographic structure rather than epidemiological randomness. Medical geography provides a robust analytical framework for interpreting morbidity statistics as spatial artifacts of institutional reach and population composition.

By repositioning disease distribution as a space-conditioned phenomenon, the paper contributes to theoretical debates within health geography and offers empirically grounded insights for territorially differentiated health planning. Future research should extend this approach through longitudinal spatial analysis and integration of environmental exposure indicators.

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