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Geographic maldistribution of the physician workforce in Romania: urban-rural divide and need for better planning and retention strategies

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The spatial allocation of medical resources is closely related to population health outcomes. Health workforce shortage and maldistribution represent significant challenges for health systems functioning in many countries. Romania registers the lowest physicians per patient ratio in the European Union (EU). Despite the increasing number of medical graduates, shortages have become more critical over the past two decades with both out-migration of health professionals and intra-country disparities between large cities and rural areas or between primary and speciality care. Considering these variances in health workforce supply, it is crucial to identify areas with particularly low human resources. This paper focuses on a critical determinant of geographic access to healthcare, namely the availability of health professionals. We identified and analysed the patterns of physicians' geographic distribution at the lowest spatial level, pointing out their imbalances and factors interrelated with territorial disparities. Gini coefficient calculation and Moran's *I* index provided strong evidence for increasing divergences in this distribution. Furthermore, the analysis of the physician/population ratio spatial patterns revealed two areas of opposite clusters on the west-east axis: one of positive spatial aggregation in the west and one negative in the east. Geographical imbalances in the health workforce distribution have adverse effects, particularly on the public healthcare sector. To address the issue of territorial imbalances, we considered that the maldistribution of physicians is contextually created and might cause several dysfunctions in the healthcare system: normative (the dilemma of dual practising in the public and private sector simultaneously), educational (specialized training, enrolment, and logistics), and social (emigration of physicians and retention policies). Therefore, for the effective functioning of its healthcare system,

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Romania still needs to implement policies to retain medical graduates and reduce physician outflows. Also, specific strategies regarding the size, structure and distribution of the physician workforce are required to alleviate issues related to access to care.

Key Words: ***physician workforce, geographic maldistribution, spatial distribution patterns, urban-rural divide, healthcare system, Romania.***

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Introduction

The distribution of healthcare resources is a traditional field of research in health geography and social health studies. The health workforce distribution engenders processes, influences the availability and accessibility of healthcare service delivery, and raises concerns in terms of equity and efficiency. Geographical space plays an undeniable role in the location and allocation of the health workforce and healthcare services. The spatial setting of geographical space and the flow of health professionals became inextricably linked due to the relational complexity of the healthcare system configuration and its spatial outcomes. In this case, spatial outcomes are mainly concerned with extended underserved areas, the significantly growing urban-rural divide in allocated health resources, and geographical imbalances in healthcare provision. Geographical imbalances of the health workforce are generally understood as reported shortages in shrinking urban or poor rural areas having adverse outcomes for the health system performance. Shortages of the health workforce are primarily analysed by visualising the distribution of patterns at local, regional, and global scales. On the one hand, the health workforce should be fairly distributed depending on population density and the characteristics of geographical areas. On the other hand, uneven distribution of the health workforce and healthcare resources shifts gaps between the population living in urban and rural areas. Usually, this distribution pattern is often associated with geographical imbalances and health inequities.

From the economic perspective, the distribution of the health workforce is assessed in terms of equity and productivity. While equity indicators, for example, are related to the analysis of flows of news graduates at health training institutions, the productivity indicators may reflect the intensity of work activities among healthcare providers (average number of hours worked per week, the attrition rate of health training institutions, training cost per students, etc.) (Diallo, et al. 2003).

Using a single-dimensional approach, studies (Kreng & Yang, 2011; Mollahaliloglu et al., 2021; Wu & Yang, 2019) have examined the distribution of human or physical medical resources (physicians, nurses, hospital beds, and hospital units). Conversely, other studies focused on a multidimensional perspective given the complexity of the spatial layout, the coordinated allocation

of health resources, and persisting territorial disparities (Wan et al., 2021; Lu & Zeng, 2018; Rosenthal et al., 2005).

Health workforce imbalances are diverse. Zurn et al. (2002) suggested a typology tailored by several criteria: profession/speciality imbalances, geographical imbalances related to disparities between urban and rural regions, institutional and services imbalances and gender imbalances. Geographical inequalities are usually associated with differential access of the population to healthcare providers and resources. Overall, when discussing the social health-related behaviour of consumers, it is a relation between spatial constraints or barriers and population location preferences. However, it is recognised that the relationship between healthcare supply and demand is consistent with spatial accessibility.

During the last two decades, studies of the geography of healthcare supply in the GIS environment proliferated, stressing various patterns in health professionals' (mal)distribution and trends (Luo & Qi, 2009; Cromley & McLafferty, 2012; Guagliardo, 2004; Luo, 2004; Meyer, 2010; Wu & Yang, 2019). Locational distribution of health services is compared to population group size, considering that a higher concentration of the population may reduce the availability of health services and generate territorial imbalances. In addition, Page et al. (2018) underlined that high demand levels in the proximity of services might undermine good geographical access to services and vice versa; in this case, the potential demand must be addressed.

Geographical imbalances in the supply of health professionals also significantly impact health system management and performance (Blumetithal, 1994; Gupta et al., 2003; Zurn et al., 2004; Pong & Pitblado, 2005; Pong & Pitblado, 2001) as well as the quantity and quality of educational training of health professionals and spatial differences between physicians and nurses or primary care and speciality care (Chapman et al., 2005). Previous studies highlighted various inequalities in population access to primary care services (PHCs) and geographic distribution of general practitioners and nurses while considering the increasing services needs of an ageing population (Guagliardo et al., 2004; Shah et al., 2017; Ariste, 2018). Healthcare professional distribution should be linked to medical care practices and the colocation of different healthcare resources (Yan et al., 2022).

The uneven distribution of the healthcare workforce delineated differences in efficiency (high healthcare workforce density is associated with increased utilisation of medical services) and equity (high healthcare workforce density is associated with better medical outcomes, higher average income, and lower need for healthcare). In addition, multidimensional indices to assess the imbalances and reduce physician distribution were developed, such as PUD (Physicians Uneven Distribution) and HRSA (Health Professional Shortage Area) (Department of Health, 1998; Takayama & Poudyal, 2021). However, a study using OECD data from 19 countries to assess the relationship between physician supply and healthcare outcomes suggests that more physicians will not necessarily translate into better healthcare outcomes (Watson & McGrail, 2009).

Physician workforce: essential role in healthcare delivery

A solid physician workforce is considered essential to ensure optimised patient care. Therefore, an adequate size, structure and distribution of the physician workforce are necessary to improve quality and expand access to healthcare. Physicians play a critical role in healthcare delivery and remain crucial within shifted inequalities in their regional distribution (Dussault & Franceschini, 2006; Correia & Veiga, 2010). Inequalities in health work distributions paid attention to scholars. Maldistribution refers to the mismatch between the spatial distribution of inhabitants and health care providers. An unbalanced distribution of the physician workforce may trigger several outcomes, such as low care utilisation patterns, access barriers and a high degree in physician demand. Significant issues related to the physician workforce concern the low level of recruitment of physicians into non-primary care specialities, inadequate funding for training, the ageing physician population (Dellinger et al., 2017; Kuhn & Ochsen, 2019), attrition, and diversity-related workforce disparities (Silver et al., 2019). Cross-sectional studies identified trends in workforce entry and reduction among rural and urban speciality physicians. For example, Gettel et al. (2022) demonstrated that the attrition of emergency physicians affected vulnerable rural areas and caused a potential overestimation of future clinicians.

Health inequalities in the health workforce distribution by plotting the Lorenz curve and calculating Gini and Theil coefficients were conducted by several authors (Rój et al., 2020; Mantzavinis et al., 2003; Theodorakis & Mantzavinis, 2005; Khammarnia et al., 2021; Wiseman et al., 2017, Hazarika, 2013). In Poland, Rój et al. (2020) evaluated the distribution of human healthcare resources across the region from 2010-2017. Using the Gini coefficient and Theil indexes, the author founds a range value from 0.25-0.32 for main groups of human healthcare resources and 0.25-0.43 for the case of different types of specialists. In Sweden, Mantzavinis et al. (2003) depicted trends in the inequalities of the distribution of general practitioners. Inequalities in the distribution of rural primary care physicians were explored by Theodorakis et al. (2006) for the special case of two remote districts in Greece and Albania. The value of PPR (population per physician ratio) was higher and unevenly distributed in the prefecture of Greece than in Albania. Khammarnia et al. (2021) analysed inequalities in the distribution of health workers in Iran, with Gini coefficient values of 0.675 and 0.589 in urban areas. The distribution of midwives and rural health workers was assessed at 0.216 and 0.278. Relevant studies also focused on spatial variations of physicians (Zhu et al., 2022, Lin et al., 2021; Stahlhut et al., 2021; You & Donnelly, 2022). Zhu et al. (2022) conducted a study to unravel the licensed doctor misdistribution. Using space-time scan statistics and Moran's *I* statistics, the authors explored the spatial variations in the temporal trends of licensed doctor density during 2012-2016. The authors compared the temporal trends, spatial variations in temporal trends, and changing spatial patterns of different subtypes of licensed doctors in China. Lin et al. (2021) analysed the improvement of the efficiency of medical and health

services using the spatial autocorrelation analysis and found obvious differences in regional efficiency.

Physicians play a critical role in healthcare management. As leaders and practitioners, they are engaged in direct patient care requiring high curricular competencies (Stahlhut et al., 2021). In addition, they have a central role in improving the population's access to healthcare and preventing and treating diseases. However, geographical space, healthcare settings and demographic compositions shape the relationship between physician provision, healthcare access disparities and population health outcomes at a spatial scale. For example, better access to healthcare services may indicate lower cause-specific mortality, while poor access may translate into increasing hospital admission or poor physical health. However, physician density represents a significant predictor of overall population health measured with life expectancy at birth (You & Donnelly, 2022).

The mismatch between the spatial distribution of healthcare professionals and population, geographical barriers, healthcare supply and demand, and the health policies debate shaped the policy priority agenda for EU countries. In 2020, the EU registered 1,75 million practising physicians, with the four largest countries (Germany, Italy, Spain, and France) cumulating 60% of the total number of practising physicians. In 2019, the number of physicians licensed to practice per 100,000 inhabitants recorded high ratios in Greece (619.5), Portugal (548.8) and Austria (534.7). This indicator registered a value of around 300 (333) in Romania, similar to Belgium, Ireland, Estonia and Croatia (Eurostat, 2020).

Winkelmann et al. (2020) examined changes over time in regional distributions of physicians in selected European countries, using yearly percentage change and Compound Annual Growth Rate (CAGR) to assess the relative growth of the profession's representativeness. Findings showed an increase in physician density in all countries between 2005-2017, from 314.7 practising physicians per 100,000 populations in 2005 to 370.7 in 2017 and an increase of CAGR of 1.27%. Romania was placed among the countries with initially low physician density but registered the highest growth rate of CAGR - 2.83%.

However, statistics show significant differences in the distribution of physicians across countries and substantial variations in physician coverage within countries, with high imbalances between regions or rural and urban areas. The increase in physicians' number does not match the improvement in geographic imbalances over time. The uneven geographic distribution of physicians and difficulties recruiting and retaining them in remote and sparsely populated areas constitute challenges in many European countries (Pál et al., 2021).

National and international reports emphasised that physicians tend to be concentrated in urban regions, metropolitan regions, and larger cities (OECD, 2020). The geographic distribution of physicians in the EU revealed a core-periphery pattern. The more advanced NUTS (Common classification of territorial units for statistics) regions benefitted from a better supply of physicians. From 2006 to 2018, physician density (the number of physicians per 100,000

population) increased at the EU level, from 320.4 to 368.8 physicians per 100,000 population. Romania registered a growth rate at the NUTS 2 level, with Portugal, Spain, and Cyprus (Pál et al., 2021). However, rural areas are disadvantaged and register shortages in health personnel. Therefore, task shifting in primary health care is recommended as a strategy to cope with imbalances in primary care in underserved and remote areas.

Many countries are implementing reforms to shift patient care tasks from physicians to nurse practitioners to meet increasing demands for high-quality and affordable care (OECD, 2021). Also, in different countries, medical students are encouraged to practise in underserved areas after graduation, receiving a monthly stipend during their education and training. Shortages of health professionals may exacerbate territorial imbalances. Given that population ageing is a significant global challenge, the European Commission initiated actions to help member states tackle this challenge by improving workforce planning and forecasting, such as the EU4 Health programme.

Staff shortages for medical specialities also affect EU member states since over a third of all physicians are 55 years. Romania provides a typical example of a country facing challenges in the geographical distribution of the health workforce, particularly among physicians. Despite a relative increase of licensed physicians of 20.4% (2015 compared to 2020) and a high relative proportion of young physicians (34% under 35 years), significant differences in the distribution of physicians at the national and regional levels persist.

This paper explores the geographic distribution of physicians, highlights spatial patterns of physicians' density, and examines potential factors in addressing dysfunctions of the healthcare system. To address the issue of territorial imbalances, we consider that the maldistribution of physicians is contextually situated and might render several dysfunctions on the healthcare system: normative (the dual practice dilemma of practising both in the public and private sector), educative (specialised training, enrolment, and logistics), and social (emigration of physicians and retention policies).

Romania tackles several underlying issues, from disparities in regional economic development, ageing population challenges (Dumitrache et al., 2016; Matei et al., 2018), administrative constraints, decentralisation, legislative reforms, low expenditures, and investments in health. The Romanian health system has undergone incremental changes over the last three decades, including social health insurance reform, reorganisation, decentralisation, and private sector development (Dumitrache, 2014; Nae, 2014; Dumitrache et al., 2020). However, the shortage of health professionals is one of the main ongoing challenges for health authorities. This is largely due to the significant emigration of physicians after Romania's EU accession in 2007.

According to NIS (2022), the health workforce relies on 65,740 physicians, out of which over 70% are practising in the public sector, and 152,686 nurses, meaning 307 inhabitants per physician and 127 inhabitants per nurse, which is below the European average (Table 1).

Table 1. Health workforce structure in Romania (2020)

Medical personnel	Total	Urban areas	Rural areas	Inhabitants/ Medical personnel	
				Urban	Rural
Physicians	65,740	60,154	5,586	174	1,588
Out of which: GPs	12,424	8,098	4,326	1,291	2,051
Pharmacists	19,470	16,047	3,423	652	2,592
Stomatologists	18,491	16,330	2,161	640	4,106
Nurses	152,686	136,363	16,323	-	-

Source: National Institute of Statistics, 2022

However, a positive aspect is that in 2021, the number of physicians increased with 3,020 new practitioners, from which 2,080 were residents. While the number of specialist physicians is increasing, general practitioners decreased from 14,509 in 2010 to 12,424 in 2020. This decrease in GPs' number affected mainly rural areas, from 4,553 to 4,326, resulting in over 200 rural localities remaining without physicians in this period. As a result, the geographic distribution of the health workforce is uneven across the country, with rural areas being disadvantaged (NIS, 2022).

Romania registered 63,314 health units (51,713 in the urban areas and 11,601 in the rural areas). The number of hospitals continuously increased, from 467 in 2011 to 535 in 2020 (NIPH, 2020). This results from the development of the private healthcare sector with hospital chains or new private hospital units established, particularly in large cities. Thus, the health network is consistent with the urban network configuration (90.9% of the total number of hospitals and units assimilated into hospitals, 93.1% of the total number of outpatient clinics, and over 90% of other medical units (medical offices, clinics, and specialised medical centres).

The rural area sees a deficient coverage of medical units, with 54 hospitals, 4,267 GP offices, and a reduced number of pharmacies and stomatology units (Table 2). Thus, rural areas incorporate 40% of GP offices, only 20% of pharmacies and 15% of stomatology offices. Deficiencies appear mostly at the primary care level; the average number of patients per GP office increased to 1,638 in urban and 2,079 in rural (NIPH, 2020).

In 2020, the urban healthcare network concentrated on 60,154 physicians (91.0% of total numbers), 16,330 dentists (87.6%), and 16,047 pharmacists (81.8%). On the other hand, the rural area was poorly represented, with only 9.0% of physicians, 12.4% of dentists, and 18.2% of pharmacists (% of total health personnel). The urban and rural divide is consistent in healthcare personnel and health units' territorial distribution, maintaining significant discrepancies. At the territorial level, the Bucharest-Ilfov region leads the other regions (63,000 health workers), followed by the Northeast region (51,000 health workers). Southwest Oltenia and West regions (33,000 health workers each) are less represented.

Table 2. Health network structure in Romania (2020)

Healthcare units	Total	Urban areas	Rural areas
Hospitals	535	481	54
GPs offices	10,652	6,385	4,267
Pharmacies	8,045	5,392	2,653
General medicine offices	746	648	98
Stomatology offices	15,650	13,374	2,276

Source: National Institute of Statistics, 2022

Methods

Good access to medical care requires sufficient physicians, a proper mix of generalists and specialists, and an appropriate geographic distribution to meet the population's needs. The unbalanced geographical distribution of health personnel can lead to inequalities in access to care. This paper focuses on the geographical distribution of the physician workforce and broad speciality categories, highlighting concentration/clusters and underserved areas within Romania. However, assessing healthcare professionals' current supply and demand is limited by the low reliability of data collected by different institutions and sources. Although many studies highlight the shortage of physicians in several regions of Romania, there is no concrete evaluation of the number of health professionals required to meet the population's needs, nor the projected physician supply and demand and their implications for the healthcare system. While statistics show that the number of physicians is continuously increasing in recent years, in many regions, the underserved areas are expanding. This suggests a growing shortfall of physicians over time as an expanding ageing population drives demand for healthcare services.

In this study, we considered all declared physicians according to the definition of NIS (National Institute of Statistics). The health personnel consist of all the staff with medical education or training (physicians, nurses, and auxiliary medical personnel) working in healthcare units and administrative or scientific research units in the medical field, both in the public and private sectors. According to NIS (National Institute for Statistics, 2020), this also includes the medical personnel from the social protection units providing both medical care and social care (residential units for the elderly or people with disabilities) as well as the medical staff active in public administration units within the health system (the Houses of Health Insurance, Public Health Directorates) or carry out research activities in institutes and medical institutions without beds (NIPH, 2020).

This approach could lead to an overestimation of the physician workforce. The Romanian College of Physicians considers only practising physicians as doctors providing direct patient care. Therefore, according to the law, all practising physicians, including resident physicians, must register as RCP members. These differences in appreciation could explain the significant difference between the total number of physicians counted by NIS (60,585)

compared to RCP (48,461) in 2018. These include primary care, medical specialities, surgical specialities, and *other*. There is no data regarding the distribution of physicians by speciality except for the county level; only GPs (family physicians) are considered at the lowest territorial level. The number and structure of physicians are changing annually, as is the number of speciality physicians and trainees. The deficits in the knowledge base present opportunities for ongoing research on the workforce implications on the healthcare system functioning and underscore the need for timely updates to projections. That is why in this study, we only considered the changes in the distribution of physicians at the national level from 2013 to 2020.

To analyse the geographic distribution of physicians, we calculated the ratio of physicians (all types of physicians) at the lowest administrative levels. We provided evidence only for a year (2020). The physician density is the dependent variable, defined as the ratio of physicians to population size, conventionally calculated as the total number of physicians per 1,000 populations. A cross-sectional study was performed using the national statistical database of NIS (www.Tempo-online) and published healthcare-related data from 2013 to 2020. The geographical units of analysis were the current population distributed at LAU2s (local administrative unit level 2). The LAU2s classify areas in the 27 EU according to the population distribution, these corresponding to communes, towns, and cities at the national level (Eurostat, 2011).

The spatial dataset was changed during the last 30 years, from 2,948 LAU2s in 1991 to 2,946 in 1994 and 3,181 in 2016. The geographical distribution of physicians among the population of each local administrative unit was evaluated using the Lorenz curve and the Gini coefficient. Since health data are generally scarce, we could compute the imbalanced distribution of physicians at the national level for only one year. Comparing the Gini coefficient over several years would have been useful. However, the data are unreliable and do not allow an accurate analysis at the micro-spatial level. Furthermore, healthcare resources and service providers are not uniformly distributed across the geographical space, and imbalances and inequities in accessibility may occur. Also, we used global and local spatial autocorrelation using Moran's *I* index to observe spatial autocorrelation trends.

Global and local spatial autocorrelation methods in ArcGIS and GeoDa are almost the same, but the visual representation of the gained results is slightly different. Detecting clusters of geographic units in which parameters under observation deviate from the expected values represents a key element in analysing spatial patterns. Local indices of spatial autocorrelation (LISA) are also included to identify the location of clusters of high and low values in aggregate data. GeoDa software provides more detailed statistical information and visual distribution of the values produced in scatter plot graphs, offering spatial distribution of the values (in our case, physician to population ratio), indicating possible locations of the clustering values in geographical areas. ArcGIS and GeoDa outputs provide the same information on the process and the differences in the amount of information and statistical quality. In that case, we can see the

visual representations of the possible clusters and outliers' values occurring in the geographical areas.

We used the Gini coefficient to measure the equity of physician distribution among hospital units (all categories of hospitals). First, we sorted all LAU2s in ascending order according to the physician (HP)-to-population ratio. Then, the cumulative percentage of the proportion of physicians (HP) was plotted against that of the population in each LAU2 to construct a Lorenz curve. If there is complete equality, the cumulative curve has a diagonal of 45° (Figure 1).

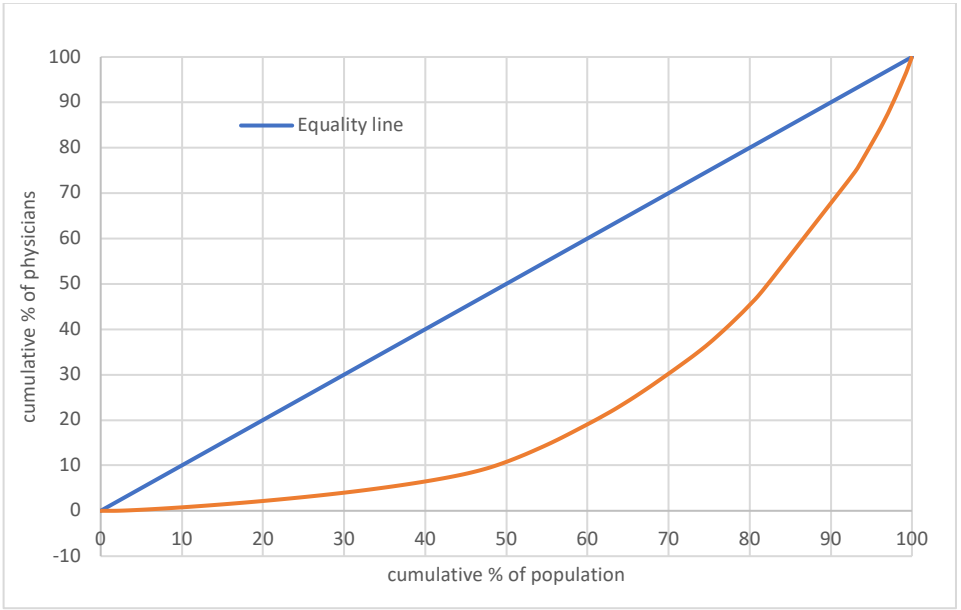

Figure 1. Lorenz curve and Gini coefficient of physicians against the population in each LAU2s

The Gini coefficient is a numerical measure of concentration and is defined as the ratio of the area bounded by the diagonal. At the same time, the Lorenz curve is visualised as the area below the diagonal line. The values of the coefficient range from 0 to 1, with higher values showing more significant territorial imbalances (Shinjo & Aramaki, 2012; Cromley, 2019). More inequality in physicians' distributions implies more convexity in the Lorenz Curve shape. The Gini values could indicate different degrees of equality, going from ≤ 0.2 to 0.3 (relative – reasonably equality) to > 0.5 - 0.6 values (large gap) (Zhang et al., 2017; Lu & Zheng, 2018). The geographic distribution of physicians in hospitals, clinics and other medical units is represented as the Lorenz curve in Figure 1. The value of the Gini coefficient was 0.673.

Results and discussion

The supply and demand of human resources for healthcare usually illustrate spatial disparities between regions. In the last decades, the spatial mismatch in

human resources for healthcare has become a policy issue across many countries (OECD, 2016; Ono et al., 2014). The health workforce is unequally distributed across Romania. Geographic imbalances are registered between eastern and western regions, especially between urban and rural areas. Large urban areas with a high concentration of health providers alternate with significantly undersupplied rural areas.

At the national level, the number of physicians per 1,000 inhabitants (without dentists) recorded variations from 1.83 – 2.04/1,000 inhabitants (1990 - 2000) to 2.16 in 2003 and 2.44 in 2010. However, since 2010, the indicator/index has exceeded the value of 2.5 and reached 3.11 in 2018 and 3.2 in 2020. Also, the number of general practitioners (GPs) per 1,000 inhabitants was around 0.52 in the period 2000-2010, with an increase to 0.69 in 2012 and, respectively, a slight decrease of 0.62 in 2018. The supply of physicians, expressed in physician density or physician-to-population ratio, displays various inequalities at a spatial level. The density of physicians is significantly greater in urban regions because of the high concentration of tertiary services and specialist clinics.

The number of physicians per 1,000 inhabitants (physician-to-population ratio) was one of the lowest in the European Union, 3.2, compared to the 3.9 EU average. Romania also registered 5.5 nurses per 1,000 inhabitants, whereas the EU average is 8.4. The physicians-to-population ratio value placed Romania in the lower middle group of EU countries, with 3.2 alongside Slovenia, Hungary, and Belgium, with values between 3.30 and 3.21 (SGI, 2022).

Physicians and nurses remain well below EU averages despite increased health employees over the past decade. Even if the medical education system produced the fifth-highest number of medical graduates (4,967) and the third-highest number of nursing graduates (17,549) in absolute terms in the EU, the emigration of medical personnel has created/caused a reduced number of health professionals working in Romania, which affects access to healthcare (OECD, 2021).

The distribution of these values at the national level shows significant differences. For example, as many as 373 localities have no physicians, meaning 11.55% of total localities. This doubled the value from 2010 when only 5% of localities had no physician (Figure 2).

The general reduction in GPs could explain this overall distribution. The decrease affects mainly rural areas from mountainous regions, the Danube Delta, and the south and eastern part of Romania. Additionally, 40.35% of localities registered low values, ranging from 0.1-1 physician/1,000 inhabitants, reflecting over 3,000 patients for a physician. 12.87% of localities reported a density between 1-3.5. Only 103 localities meaning 3.18% of the total, recorded values over 3.5 physicians/1,000 inhabitants, suggesting a concentration of health professionals in large urban centres such as Bucharest, Iași in the eastern part of the country, Cluj-Napoca in the central part of the country and Arad, Timișoara, in the western part of the country.

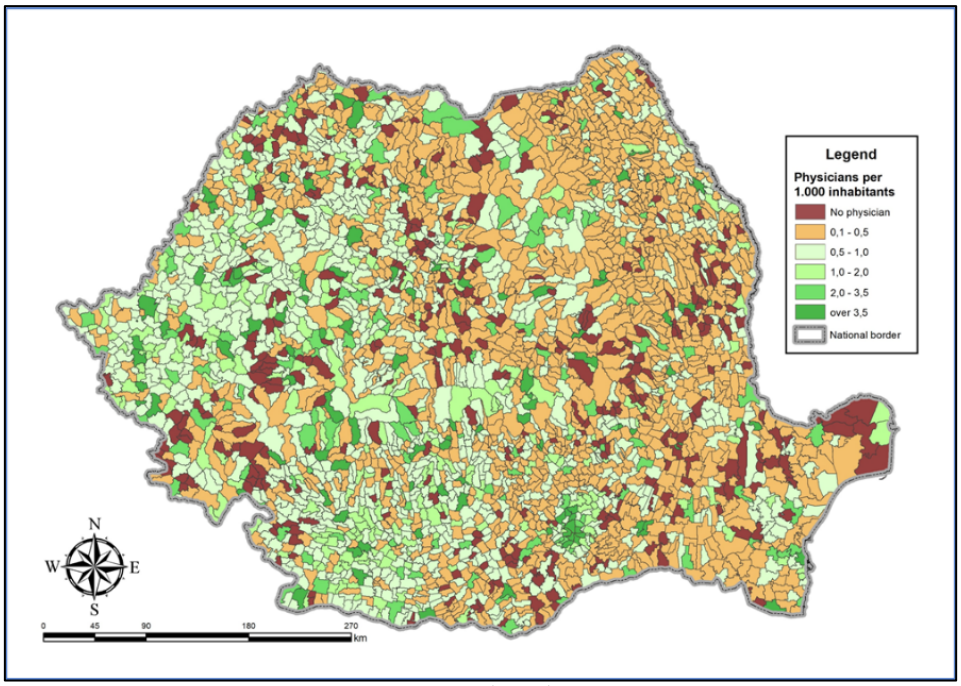

Figure 2. Degree of coverage with physicians (2020)

Spatial patterns of physician distribution

The essence of spatial analysis is that *space matters* and what happens in one area is related to neighbouring areas. The issue of spatial autocorrelation is complicated as it may go in any direction. Spatial autocorrelation involves the evaluation of relation intensity and the proximity of places and their degree of similitude (resemblance). This spatial autocorrelation can be measured by spatial proximity and the statistic indicator Moran's *I* (low cluster, high cluster). Spatial clustering is said to occur with positive spatial autocorrelation (Anselin et al., 2010). LISA is a class of statistics that provides location-specific information (by administrative-territorial units, in this case). It estimates the extent of spatial autocorrelation between the value of a given variable (in our case, physicians) in a particular location and the values of the same variable in locations around it.

To describe the spatial distribution of physicians, we applied a global and local spatial autocorrelation using Moran's *I* index. The Global Moran's *I* index evaluates the entire degree of spatial autocorrelation. In contrast, the local Moran's *I* index provides estimations of the local autocorrelation at each specific location and the atypical localisations. The data was processed by spatial analysis software GeoDa 1.8.16 (University of Chicago). To further observe whether, at the national level, there are inequalities like spatial patterns or trends of spatial aggregation at the LAU2s level, we used several simulations at different spatial weight matrices. First, the Moran Scatter plot allows us to calculate Moran's *I*. Since Moran's *I* value is greater than zero, it implies a positive autocorrelation for

the variable in question, meaning that spatial units with relatively high or low physician ratios are localised close to other units with relatively high or low physician ratios. The value range of global Moran's *I* is [−1,1]. When $I > 0$, it means there is a positive spatial correlation in the distribution of physicians. We could say that cities with higher (or lower) physicians in geographical areas tend to be spatially more concentrated. When $I < 0$, it means that there is a negative spatial correlation. When $I = 0$, it indicates that there is no spatial correlation in the distribution of physicians (random distribution in space). To measure whether the global Moran's *I* is significant, a standardized Z-statistic test method is applied.

We used the Queen contiguity weight method to calculate the Global Moran's *I* and Local Indicators of Spatial Association (LISA) cluster map (Anselin, 2010). To check the index's robustness, we used four spatial weights based on the Queen contiguity and k-nearest neighbours' structure from the first to the fourth spatial lag order (Table 3).

The value of p was set as 0.05 (the 999-permutation test to delineate the statistically significant spatial units). The Moran's *I* index values were higher than zero and were positive (positive spatial autocorrelation). The values of Moran's *I* index were higher using Queen contiguity weight (0.045) than the K-nearest (k=2) (0.020) (Figure 3).

Table 3. Moran's *I* Global spatial autocorrelation (calculations using GeoDa software)

Ln Physician ratio			
K-nearest (K=1)	0.017	Queen first	0.022
K-nearest (K=2)	0.020	Queen second	0.045
K-nearest (K=3)	0.008	Queen third	0.046
K-nearest (K=4)	0.019	Queen fourth	0.034

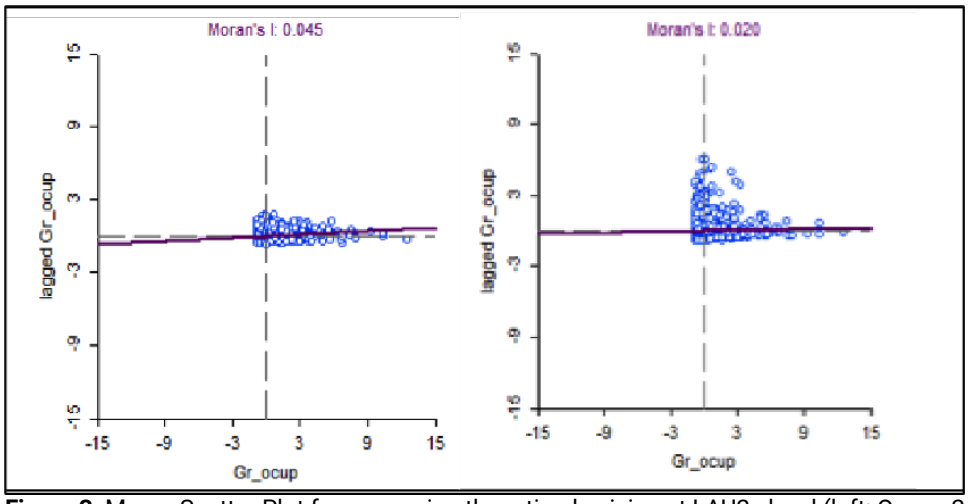

Figure 3. Moran Scatter Plot for measuring the ratio physician at LAU2s level (left: Queen 2 contiguity weight; right: K2 – nearest neighbour weight

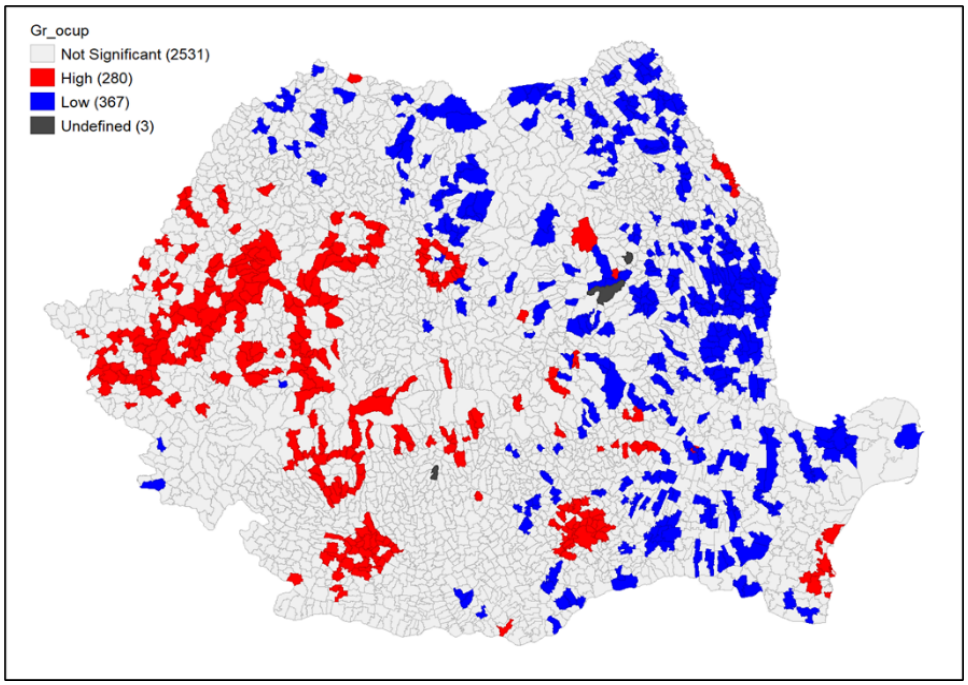

Figure 4. Cluster map for physician ratio, using Gi* statistic (Queen contiguity 2)

The analysis of the spatial patterns of the physician ratio reveals two areas of opposite clusters on the west-east axis, one of positive spatial aggregation in the west and one negative in the east (Figure 4).

In addition, the data show, at a 5% significant level, that significant local clusters of high values are located in metropolitan zone areas in the southern part of the country, southern and north-western parts of Transylvania, and the Black Sea region.The higher populated cities stand out as leading medical centres with universities, medical schools, and research institutes: Bucharest, the capital, Craiova, Constanța, Târgu-Mureș, Timișoara, Oradea. Local clusters with low values (typically large rural areas) reached significant parts in the northern and southern parts of the Moldova region and eastern and southern-eastern areas of the country.

The LISA map (obtained by applying Queen 2 contiguity weight based on the shared borders of spatial units) shows sections of spatial outliers or atypical localisations. For example, the physician ratio is spatially different, with the low-low clusters found in the eastern and southwestern parts of the country. In contrast, the high-high clusters are concentrated in the surroundings of large urban areas (Bucharest, Craiova, Timișoara, Cluj - Napoca and Iași). The spatial units with polarised spatial structures (high-low type) are defined by values significantly above the national average (2.5), while their neighbouring areas registered values significantly below the national average. A fragmented spatial structure is characterised by the distribution of spatial units with their neighbours with a physician ratio significantly below the national average (Figure 5).

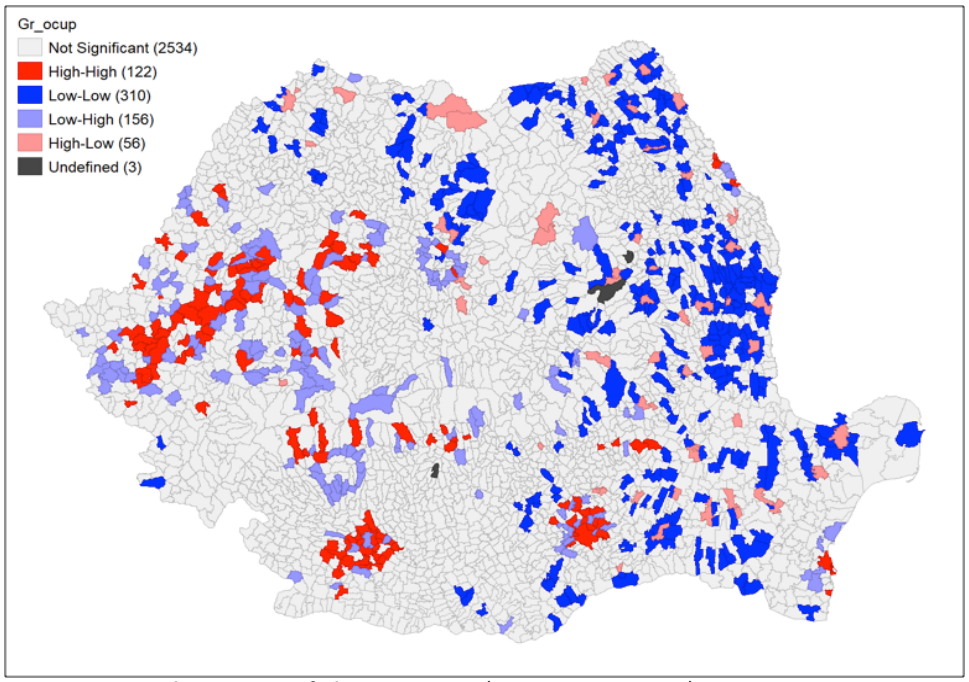

Figure 5. LISA cluster map of physician ratio (Queen contiguity 2)

The maps presented above mostly translate the spatial inequalities of the physician ratio at the national level, with significant social and economic effects in the medium and long term. Spatial analysis of the physician/population ratio could provide useful information in proposing and promoting effective public physician retention policies. Spatial autocorrelations via Moran's *I* have advantages, but there are also limitations. Global Moran's *I* index does not give us information in differentiating between random spatial patterns and those with significant variation. Also, Moran's *I* index is particularly sensitive to spatial weights matrix *wij* and MAUP (modifiable areal unit problem) (Fotheringham, 2000). The degree of spatial association depends on the level of aggregation of spatial units.

Low-low clusters are distributed in the eastern and southwestern parts of the country, consistent with their poor economic development at the NUTS 2 level, where seven Romanian regions registered a share of GDP per capita between 18 - 23%. The Northeast and South Muntenia regions registered the lowest share of GDP per capita in 2000, while the Northeast region reached a constantly lower value (29), despite slight improvements in 2009. The growing inequalities in income and wealth are also observed at the county level (NUTS 3), with significant differences in GDP per capita below 30 in the south and east (Benedek & Csilla, 2013).

Regions with economic prosperity are considered attractive for physicians and health resources. Therefore, high-high clusters surround large urban areas and metropolitan areas, considered to be leading regions for economic growth and welfare, advanced medical technology, and academic medical research

(Bucharest-Ilfov region, West region with polarised cities such as Timisoara, Oradea, Centre region with Brasov, Sibiu, and Northwest region, with Cluj – Napoca, as a polarised city). However, the relationship between GDPs per capita and the human development index revealed strong evidence of widening imbalances. The market does not lead to the optimal distribution of physicians. They are concentrated in high-income urban regions with social and cultural amenities.

The economic development is spatially differentiated, where regional divergences are associated with highly polarised spatial (high-low) clusters. Parts in the eastern and southern regions are less developed, with strong differences between core areas and periphery. A spatial polarisation and spatial autocorrelation of economic development were found in core regions (Bucharest-Ilfov), while eastern parts of Transylvania, Moldova and Northern Muntenia are lagging (Benedek, 2016).

Potential factors interrelated with physician shortages

A physician shortage has long-lasting effects and produces significant barriers to patient care access. The supply of physicians is highly dependent on the regional character and the age structure of the local population. Demographic and environmental factors, location, average income, and distance to central cities are important in explaining the geographical distribution of physicians (Vogt, 2016). Solutions and actions to mitigate the outcomes of the physician shortages were taken, such as postponing the retirement of current physicians and recruiting more from abroad. Findings suggest that the average age for actual and expected retirement was reported to be between 60 and 69 years, respectively (Silver et al., 2016).

To address the issue of territorial imbalances, we consider that the maldistribution of physicians is contextually situated and might render several dysfunctions on the healthcare system: normative (the dual practice dilemma of practising both in the public and private sector), educative (specialised training, enrolment, and logistics), and social (emigration of physicians and retention policies).

Romania provides a typical example of a discrepancy between the physician workforce and the number of medical graduates. Member states registered a lack of supply at the EU level concerning the expected number of physicians. For 2020, medical doctors graduating was estimated at 15.9 for every 100,000 inhabitants. Romania recorded the highest ratio (26.3 per 100,000 inhabitants), Malta (26) and Ireland (25.4). A comparison between 2010 and 2020 revealed that the most significant increases were registered in Latvia, Bulgaria, Romania, and Malta, while decreasing ratios were recorded in Austria, Estonia, Germany, and Finland (Eurostat, 2020).

In Romania, the number of medical graduates increased, especially after 2005, from over 5,500/year, with a boom to over 7,000 (2008-2009), falling slightly below 5,500/year in 2014-2015 and 4,967/year in 2018/2019 (CSFM, 2019). The

medical education cycle lasts six years, and undergraduate medical education is offered by public medical schools, usually in main university centres: Bucharest, Cluj-Napoca, Iaşi, Timişoara, Craiova, and Târgu-Mureş.

Medical graduates must complete in general medicine or speciality to attain a license to practice. Usually, specialisations start after graduation, and hospitals and large university clinics ask for extensive clinical experience (3-5 years for general medicine, plus 6-7 years in speciality training have often resulted in a post-graduate medical education of 10 or more years). Romania registered a high enrolment rate in medical schools with 13 medical faculties, with 5,000 medical graduates per year. The capacity of the medical program is extensive, targeting international medical students. Universities also offered a BA program in Medicine in English or French. Although Romania has become an international medical hub (Ungureanu & Dietrich, 2019), working in the national health system is not considered attractive for most international medical graduates. Therefore, medical schools have attempted to address health workforce shortages by recruiting and training more students.

Territorial imbalances in the distribution of physicians' workforce are rendered by emigration, as health professionals were considered the fourth wave of migration after 1990. However, official data is scarce, dealing with a sensitive indicator called the 'intention to emigrate' by the Romanian College of Physicians (RCPs). Based on data from the Romanian College of Physicians and the applications for current professional certificates, the number of emigrated physicians increased mainly after 2007, when Romania joined the EU, and reached a boom in 2011 (approximately 1,800). After 2018, the number decreased (Apostu and Vasile, 2020). However, Romanian medical students consider emigration an alternative to professional training started in the country (Suciu et al., 2017).

In addition, the deficit of human resources in the Romanian health system must be considered, especially from the costs involved in medical education and training. Economists consider the emigration of Romanian physicians as a negative externality, with the investments in a physician's education reaching 11,300 Euros, including the expenses for general training and medical specialization. For the training and specialisation of a physician for over 6-11 years (6 years of university and 3-5 years of residency), Romania spends approximately 20,000 Euros (Astărăstoaie et al. 2014).

Solutions to reduce the physician's out-migration are complex, involving concrete measures to reorganise the health system and allocate considerable financial resources. Most physicians and other healthcare workers are considered public employees; they work in public hospitals, clinics or health facilities but may also practise in the private sector.

Practising medicine in the private healthcare system is not necessarily considered an alternative to the emigration of physicians, which suggests the need to implement clear retention strategies and the promotion of ethical recruitment of medical personnel to protect the health workforce. Incentives to attract physicians and retention policies such as bonus payments and income guarantees

were implemented. Recently, in Romania, the wages of medical staff increased significantly as a retention policy. Retaining medical staff also requires improving working conditions and investing in modern infrastructure and equipment (Dornescu & Manea, 2013). Despite the increase in the number of graduates and the increase in the expenses of the educational system, retention policies and training programs are insufficient or need to be adjusted to current challenges. Governments have implemented public policies to increase the diffusion of physicians across underserved areas. For example, supply-side incentive policies were applied in France and Germany to locate physicians in rural and less populated regions (Mugeot & Naegalen, 2018).

Conclusions

This paper should be considered a preliminary study of geographic imbalances in the density of workforce physicians in Romania. Our results provide strong evidence for increasing divergence in the distribution of physicians at national, regional, and local scales. Even though we do not focus on spatial-temporal divergences in the distribution of physicians, we underpinned that the physician ratio has been uneven for at least one year. Despite the improvements in health allocation resources, an increasing gap was observed in the degree of inequality between the distribution of physicians and the population, with a larger Gini coefficient. The divergent distribution of physicians and population is underscored by a low level of Moran's *I* statistic.

High-high clusters are concentrated around large urban areas and metropolitan areas, in leading regions in terms of economic growth and welfare, advanced medical technology, and academic medical research (Bucharest-Ilfov region, West region with polarised cities such as Timisoara, Oradea, Centre region with Brasov, Sibiu and Northwest region with Cluj - Napoca). In contrast, low-low clusters are distributed in the eastern and southwestern parts of the country. Regions with economic prosperity are considered attractive for physicians and health resources. The main concern was the growing shortage of physicians, particularly general practitioners in rural areas.

Locating and measuring supply and demand for medical provision and healthcare is a challenge for policymakers when deciding on the equitable allocation of health resources. Despite the vast array of policies for the equitable allocation of human resources for health, integrated approaches still need to be addressed. These findings have significant implications for healthcare and policymakers. Evaluating imbalances in healthcare requires considering the different types of healthcare resources. More policy concerns are needed to address the maldistribution of physicians. Considerable efforts were made to enhance primary care by providing considerable financial support to primary care facilities. However, Romania registers the lowest health expenditure among the EU countries, with 1,310 Euros compared to 3,523 Euros, adjusted for differences in purchasing power in 2019. Physicians are attracted to urban

amenities, medical technologies, and good infrastructure. The concentration of healthcare demand is consistent with top-tier hospitals, while secondary hospitals and primary care units registered low bed utilisation rates.

Limitations

The findings should be interpreted in light of some limitations. Firstly, obtaining comprehensive data for all physicians at the lowest administrative levels was impossible, and evidence was provided only for a year (2020). Secondly, unreliable data does not provide comparative trends by years and differences between speciality physicians and trainees. Thirdly, medical faculties are also unevenly distributed at the territorial level, resulting in an imbalance between the population of each region and the number of medical graduates. Finally, the number of medical graduates remains high in the most prominent university centres, with traditions in medical education, such as Bucharest, Cluj-Napoca and Iaşi.

To find driving forces affecting the uneven distribution of physicians, spatial regression models provide more accurate explanations of patterns observed in developed urban regions, with strong financial capacity, medical technology and administrative advantages that can attract physicians compared to less developed or rural regions. Other essential healthcare resources and their maldistribution deserve attention, such as shortages of nurses.

However, assessing healthcare professionals' current supply and demand is limited by the low reliability of data collected by different institutions and sources. Although there are numerous studies in which the shortage of health workforce is highlighted, there is no concrete evaluation of them, nor that of projected future physician supply and demand and their implications at the health system level. Historical data regarding other healthcare indicators at the regional and local levels are unavailable. Everything suggested a growing shortfall of physicians as a growing ageing population drives demand for healthcare services. Addressing health workforce shortage, maldistribution, and performance challenges is essential for progress towards all health-related goals, including universal health coverage. Policies aimed at redistributing physicians need to acknowledge cost-benefit results.

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