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HEALTH GEOGRAPHY OF COVID-19. AN EXPLORATORY ANALYSIS OF THE PANDEMIC DURING ITS FIRST PHASE IN THE COMPACT CITIES OF BARCELONA AND MADRID

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1. Introduction

COVID-19 has affected every aspect of life around the globe. In the first part of the pandemic, five months after the outbreak appeared, countries were unable to test a large number of people, and did not have reliable data on the prevalence of the virus in the general population. To understand the spread of disease and how it works as accurately as possible, it is essential to record the disease location, and all characteristics associated with the place, space and population; as in the cholera maps in the first epidemiological study, by the physician Dr. John Snow, which was the first use of a spot-map in epidemiology (Snow, 1855). It examined the cholera outbreak which occurred in London from the 19th of August to the 30th of September in 1854, and the Broad Street pump. After contamination with sewage from a nearby pipe the outbreak caused 500 cholera deaths within the space of ten days. Another recent example is the case of the Diamond Princess Cruise, which departed from Yokohama (Tokyo) on January 20, 2020 and was scheduled to return on February 4, on a 14-day round trip itinerary. There were 2,666 guests and 1,045 crew onboard and 11.78% of the cruise population tested positive for COVID-19. This situation is very interesting, because two key factors became evident: an entire, closed population was tested, and those with positive results were separated and sent to hospitals. The case fatality rate was 1.0%, in a largely elderly population, in which the death rate from COVID-19 was otherwise much higher. Globally, some 3.4% of reported COVID-19 cases died; in comparison, seasonal flu generally kills far less than 1% of those infected (WHO, 2020).

Henry Mayhew, journalist and social investigator (1812-1887) (Neuburg, 1985), studied the conditions of London's urban life, and wrote that the precarious living conditions, density and gases in the atmosphere had resulted in a cholera outbreak, and that the prevalence of such conditions made a poor woman say that "Neither I nor my children know what health is" (Duarte Nunes, 2012, p. 3). Historical texts such as this one, and many other studies, later indicated the important variables of contagion. The background of this chapter is based in history and the epidemiologist literature reporting the relevant variables. They are based on grounded studies supporting the explanation of the dependent variable.

This exploratory study presents factors that are hypothesized as the most causative in the COVID-19 outbreak in compact cities such as Barcelona and Madrid. Contemporary global cities such as these are characterized by complexity and diversity, and therefore, the objective is to determine which variable affects contagion by COVID-19 the most. Are both cities affected by the same variables? Are there differences between the cities? Why? Specifically, the set of relevant variables presented involve: (a) the socioeconomic conditions of the population, including family income, housing area, and population density; (b) an ageing population, as estimated by nursing home capacity and population over 65 years old; and (c) neighborhood conditions, as estimated by urban greenery. At the beginning of March 2020, the coronavirus crisis accelerated, with contagions across all Spain. Barcelona and Madrid were hit heavily by the outbreak and different policies and resorts resulted in similar or different results.

The goal of finding explanations for the epidemic outbreak can lead to more grounded policies to solve future unexpected episodes. Data sources used in this study barely begin to reflect the outcomes of pandemics in Spain. Proper quantitative research requires very controlled conditions and often lacks the depth or precision that qualitative studies can provide (Communications for Research, 2021). This vulnerability is noted in order to underline that the compilation of data in this quantitative study will likely encounter some problems. Fortunately, there are ways to work around them, as long as we are aware of the risks in the research process and respond accordingly.

A comprehensive methodology approach would treat all factors as part of a system, each of them contributing to explain their effect in the contamination of the disease. Databases are being created from official sources in Barcelona and Madrid. The Global and Local Moran's I tools for spatial autocorrelation analysis are used, as well as econometric modeling to control for spatial dependence by means of spatial autoregressive models (SAR). The results would explain the degree to which the number of tested positives per 10,000 inhabitants -the dependent variable- is related to independent variables.

1. Health and society as a system

Health and society can be conceived as a system in that every society produces its own vulnerabilities and resiliencies (Snowden, 2019), according to political priority and social culture strategy. In the end, the success or failure of health strategies/systems depend on their ability to catalyze changes. Proficiencies suggest that social inequalities and pandemics have been studied very carefully for at least for at least 150 years (Farmer, 2001; Scheidel, 2017; Virchow, 1848). One of the most critical issues to be addressed by social sciences is "the fact that society's poor and otherwise less privileged members live in worse health and die much younger than the wealthy and more privileged ones." (Link & Phelan, 1995, p. 105).

The existence of social inequalities in health has been demonstrated in many studies. In the earliest research, it was easy to see the causal links, from low income, through poor housing and sanitation, inadequate diets and hazardous jobs, to poor health such as infectious diseases, injuries and accidents. It is clear that there are complex chains of exposure between income and health across the life course. For example, employment will be influenced by education, which in turn is influenced by childhood health and circumstances, which will have been influenced by the income and wealth of parents.

2.1. Why social inequalities explain health

Academic research into the effect of social inequality on population health and mortality is compelling. In Western nations, mortality risks have been sharply reduced in the last fifty years, although chronic diseases have increased, but the improvement has not been shared equally among socioeconomic groups (Pappas et al., 1993). It continues to be true that the greatest risk of death or contagion is among the poorest groups (usually measured by occupation, education, and/or income) rather than the general population. Differentials in mortality according to socioeconomic and demographic characteristics suggest disparities between social class position and risk of death (Kitagawa & Hauser, 1973). The question is how social inequality is conceptualized, and which variables it is important to analyze. Factors might differ for different diseases, and they could play diverse role in health and disease and in mediating or moderating their effects, according to people's social position. For instance, culture, social networks, social support, care-taking, differentials of social and economic origin, and the universal availability of public health and medical care could explain the causes of social inequalities (Moss, 1995).

Some research suggests that income inequality is a health risk in rich and poorer countries (Deaton, 2003). Marmot (2005) underlines the differences of life expectancy between and among countries, and the possibility of increasing life expectancy by narrowing these differences:

> "The gross inequalities in health that we see within and between countries present a challenge to the world. That there should be a spread of life expectancy of 48 years among countries and 20 years or more within countries is not inevitable." p. 1099.

In order to reduce inequalities in health across the world something other than the development of health systems and the relief of poverty is needed. Action is required on the social determinants of health, and this means improving the circumstances in which people live and work. Research has found evidence that income inequality alone is not a major determinant of population health differences (Lynch et al., 2004), although reducing income inequality by raising the incomes of the most disadvantaged will improve their health, and also improve the health of the population in general (Lynch et al., 2004). Studies looking at wealth inequality –wealth being defined as an abundance of valuable possessions or money- suggest that wealth is far more unequally distributed than income, and it is associated with less health in poorer populations (Nowatzki, 2012). According to economics, health can be viewed as a durable capital stock (Grossman, 2000). The relationship between inequalities in national health and national wealth is thus important (Jumbri et al., 2019); and that health stock is a vital component in measuring health inequality and health-related sustainable development.

Broadening the study of the causes of health inequalities, medical sociologists and social epidemiologists include social conditions and personal risk factors associated with diet and exercise, as fundamental causes of disease (Link & Phelan, 1995). The fundamental cause theory (FCT) of health disparities (Link & Phelan, 1995) - which is based on the association between socioeconomic status and health disparities - bases its evidence on income and education, and focuses on the relationship between socioeconomic status, health outcomes, and life expectancy. FCT suggests that the disparities in health and mortality will persist, despite changes in the mechanisms created to fight diseases, such as vaccines. In a study of health policy, health economics and population, Evans and Stoddar (1990) emphasized the role of health in adding well-being to the population, and that the inclusion of social and physical environments and individual behaviors might be determinants of health. While it is obvious that the effect of a low socioeconomic position on health is mediated by health-related behaviors, changing behavior will only be possible if other determinants of health-damaging behavior (psychosocial stressors, financial problems, social norms, geographical barriers to healthy behavior, social cohesion) are addressed (Mackenbach, 2006; Wilkinson, 1997).

2.2. The interrelationship of density, longevity, socioeconomics, biodiversity and contagion

Evidence for the association between high density, longevity and contagion has been established in direct statistical data reported in the literature. Recent studies of the COVID-19 pandemic have analyzed the underlying built environment, economic activities, and public service status. A spatial regression analysis for Wuhan, China showed that population density, proportion of construction land area, value-added tertiary industry per unit of land area, total retail sales of consumer goods per unit of land area, public green space density, and aged population density were associated with an increased COVID-19 morbidity rate (You et al., 2020). The role of socioeconomic factors, including public health measures that encourage social distancing and weather characteristics are used as explanatory variables for COVID-19 morbidity in China. They found that the stringent quarantines, city lockdowns, and local public health measures imposed in late January 2020 significantly decreased the virus transmission rate. Local public health measures, such as the closed management of communities and family outdoor restrictions could have further reduced the number of infections. Cross border travel restrictions were also imposed in order to reduce the risk of case importation (Qiu et al., 2020). Epidemiologic research in a large retrospective cohort study, with data from Wuhan, since December, 2019, among patients with COVID-19 (SARS-CoV-2) who have experienced a definite outcome, found that pneumonia in older age, pre-existing cardiovascular diseases, and a greater severity of coronary heart disease have created social vulnerability and health risk factors (Zhou et al., 2020).

Inequity is often highlighted in emergency conditions, such as the disproportionate effects of COVID-19 in African American communities in Chicago, USA; which are a reflection of the racial inequality and social exclusion that existed before the COVID-19 crisis (Kim & Bostwick, 2020), which has led some research to point out that COVID-19 is socially constructed (Burton et al., 2018; Cutter, 1996; Pelling, 2003). Social vulnerability highlights social, economic, demographic, and geographic characteristics that determine not only risk exposure but also low socio-economic status. Economically disadvantaged people are more likely to live in overcrowded accommodation, financially poorer people are often employed in occupations that do not provide opportunities to work from home, and those in low socioeconomic groups are more likely to have unstable work conditions and incomes, conditions exacerbated by the responses to COVID-19 and its aftermath. Such financial uncertainty disproportionately harms the mental health of those in low socioeconomic status groups and exacerbates their stress (Patel, 2020). Life course effects are fundamental to an understanding of the origins of health inequality. To the extent that health inequalities in adult life are partly determined by early life circumstances, their elimination cannot be left to individual choice alone (Kawachi & Subramanian, 2002).

Longitudinal study investigated the effects of density on the spread and mortality rates of COVID-19 in metropolitan counties in the United States using multilevel linear modeling, and found that large metropolitan size (measured in terms of population) led to significantly higher COVID-19 infection rates and higher mortality rates (Hamidi, Ewing and Sabouri, 2020). However, county density led to significantly lower infection rates and lower death rates, controlling for metropolitan size.

Some studies show that pollution, public green space density and compact dense urban agglomerations increase the perception of density in a neighborhood, and might contribute to closer contact between people (Knittel & Ozaltun, 2020). Pollution in COVID-19 deaths has received significant attention in the popular press, but contrary to past work, recent results in the USA did not find a correlation between pollution and death rates, and in Wuhan the density of public green space was associated with an increased COVID-19 morbidity rate (You et al., 2020).

2. **Barcelona and Madrid, compact and dense cities with different contagion patterns: Data, methodology and results**

Madrid and Barcelona are compact Mediterranean cities with some differences in organizational type and density, as well as in their governance and funding (Figure 1). Madrid covers 604.3 square kilometers, and has 3.33 million inhabitants, reaching a population density of 5.405 inhabitants per square kilometer. Barcelona's area is 101.9 square kilometers, with 1.64 million inhabitants and a population density of 16.062 inhabitants per square kilometer (INE, 2019) (Figure 2). There are similarities in socioeconomic variables, where average gross household income in Madrid is €50.872 and Barcelona €48.394 (INE, 2017) (Figure 3). The average house in Madrid is 87.37m2 in area (Madrid City Council, 2019) and in Barcelona is 70.99 m2 (Barcelona City Council, 2019). An age pyramid shows that there are 661,890 people over 65 years old in Madrid, and in Barcelona, there are 350,065 people (20 and 21% of the total population, respectively) (INE, 2019) (Figure 4). Madrid has a nursing home capacity of 19,017 places and Barcelona has 12,202 places (5.82 and 7.45 places per 1,000 inhabitants, respectively) (Figure 5). Both cities have similar patterns of greenery and climate. Urban green spaces in Madrid cover 77 square kilometers, and in Barcelona they cover 18 square kilometers (13% and 18% of the total area, respectively) (Copernicus, 2018). Madrid's annual average temperature is around 16ºC, with minimum average annual temperature of 11.1ºC and maximum of 20.9ºC, while in Barcelona, the annual average temperature is around 17.6ºC, reaching minimum and maximum average annual temperatures of 14.4ºC and 20.8ºC, respectively (AEMET (2020).

Figure 1. Barcelona and Madrid, neighborhoods

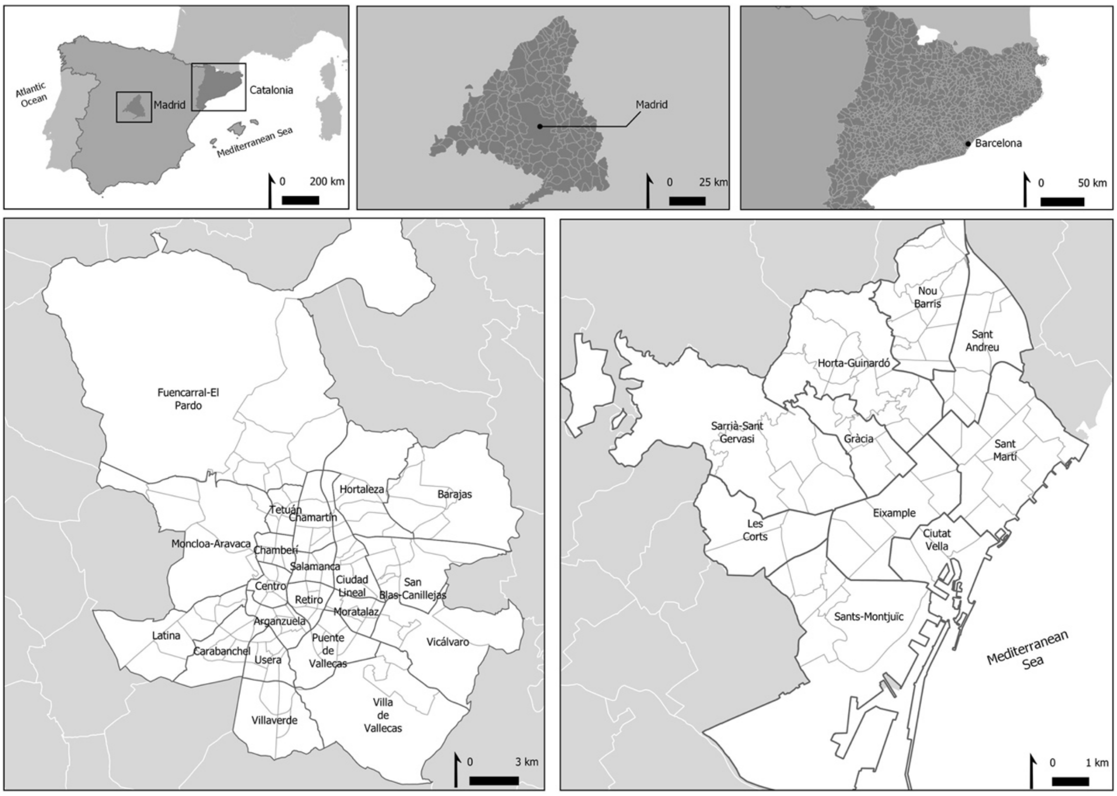


Figure 2. Population density in Barcelona and Madrid

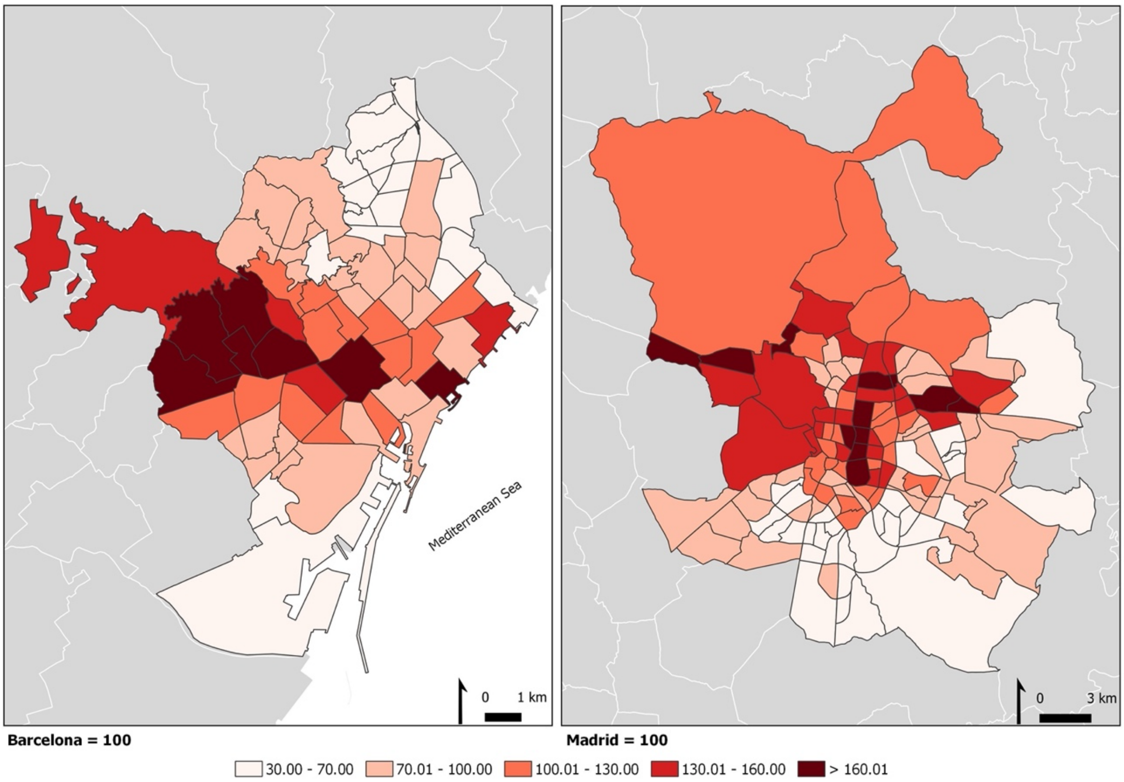


Figure 3. Family income by neighborhood, Barcelona and Madrid

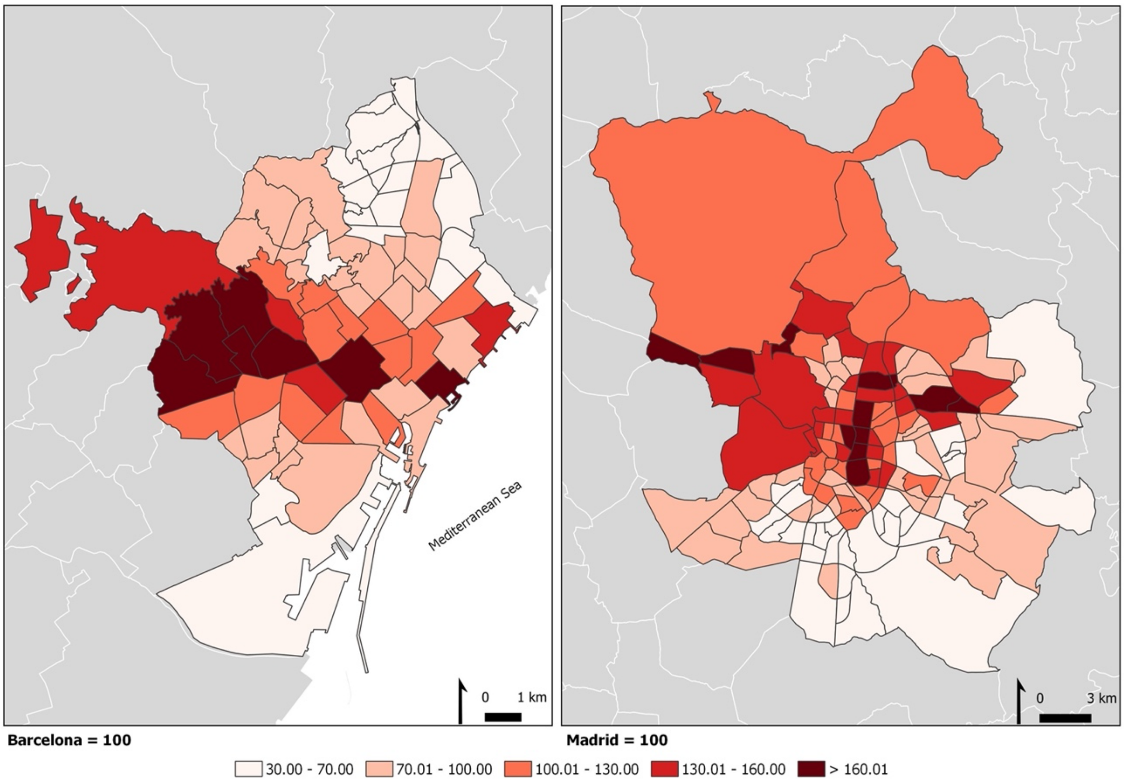


Figure 4. People >65 years old

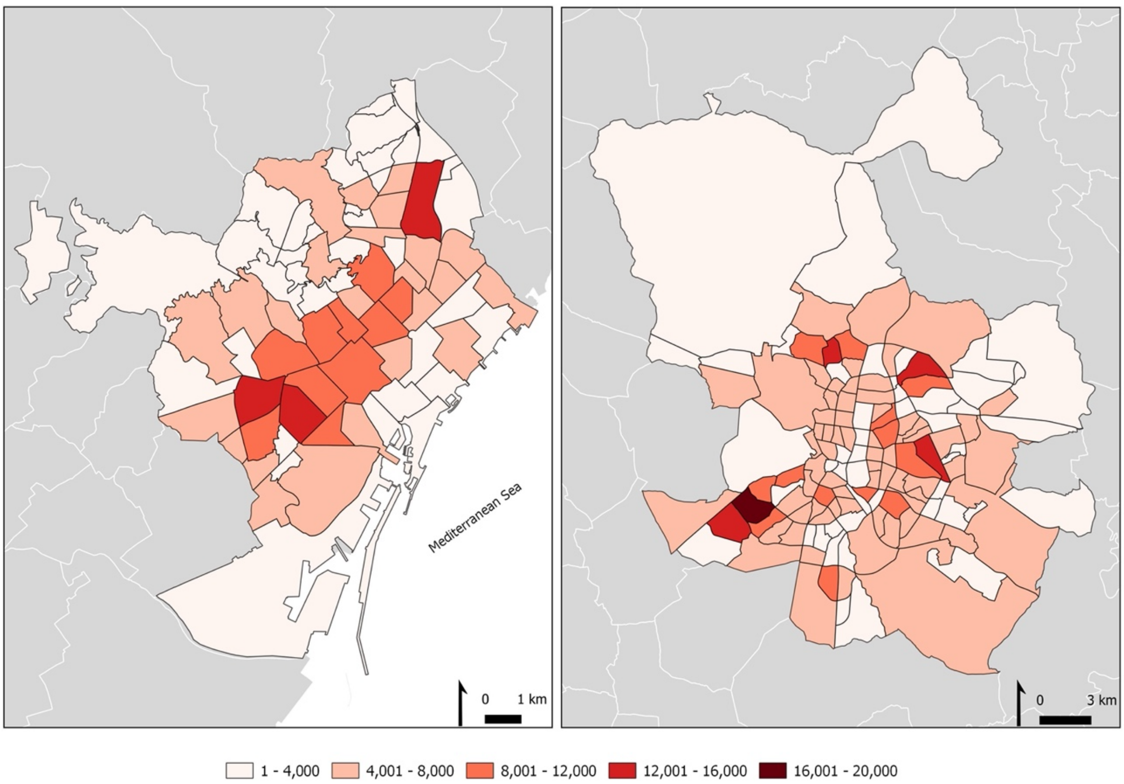
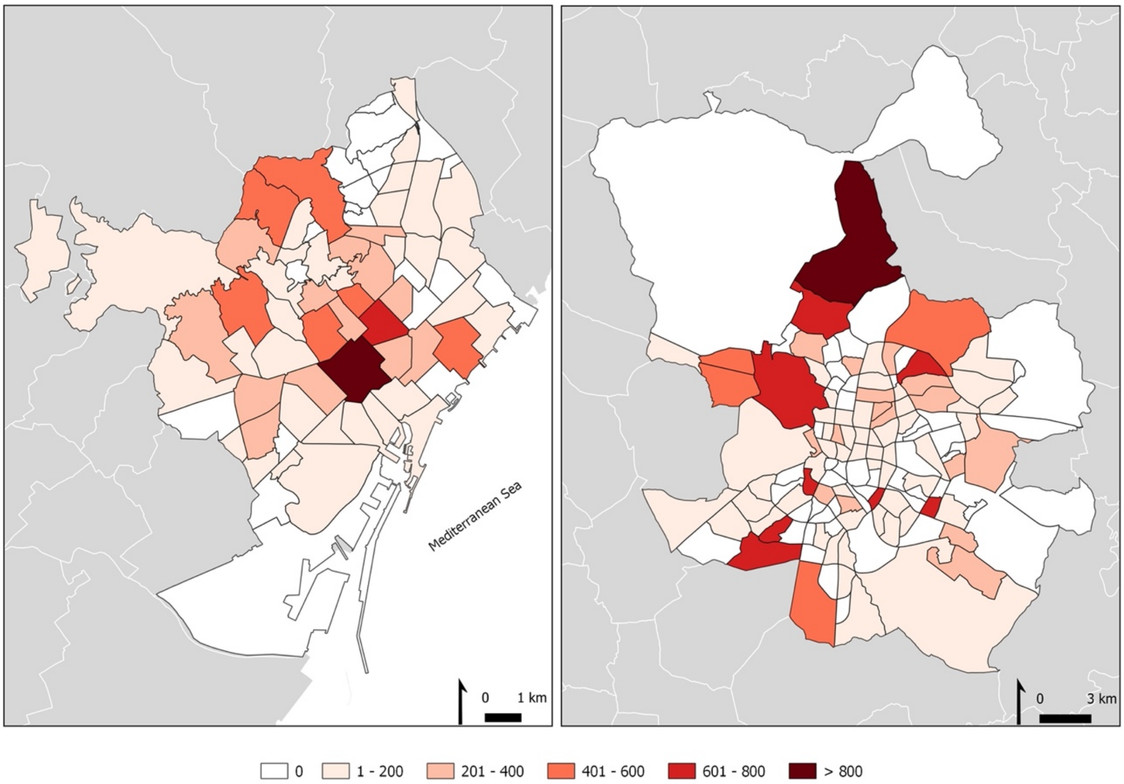


Figure 5. Nursing home capacity



3.1. Data and data sources

The study employs a proxy variable for contagions based on the existing understanding of the total number of positive COVID-19 cases (Test PCR) per 10,000 inhabitants, from 31st March 2020 to the 16th May 2020. This variable is different from some previous studies, where the concepts of morbidity and mortality are used as dependent variables, which can lead to a different interpretation of results. Socioeconomic conditions are constructed from population density, family income and housing area (in m2; this variable in Barcelona is calculated from rented housing). The neighborhood condition proxy is greenery, and ageing population variables are nursing home capacity and percentage people >65 years old. The data was obtained from official sources at neighborhood scale (Table 1). The number of PCR COVID-19 tested positives, however, which was originally drawn from basic health zones, was calculated by neighborhood using ArcGIS© and QGIS software.

Table 1. Data sources

	Variables	City	Source	Period of time
Dependent variable	Number of PCR COVID-19 tested positives per 10,000 inhabitants	Barcelona	Catalan Department of Health	31.03.2020 - 16.05.2020
		Madrid	Epidemiological Surveillance Network of the Community of Madrid	
Independent variables	Population density	Barcelona and Madrid	Statistics National Institute	2019
	>65 years old population	Barcelona and Madrid	Statistics National Institute	2019
	Housing area	Barcelona	Barcelona Government	2019
		Madrid	Madrid Local Government	2019
	Greenery	Barcelona and Madrid	Copernicus Urban Atlas	2018
	Average family income	Barcelona	Barcelona Government	2017
		Madrid	Madrid Local Government	2015
	Nursing homes capacity	Barcelona	Barcelona Local Government	2020
		Madrid	Madrid Regional Government	2020

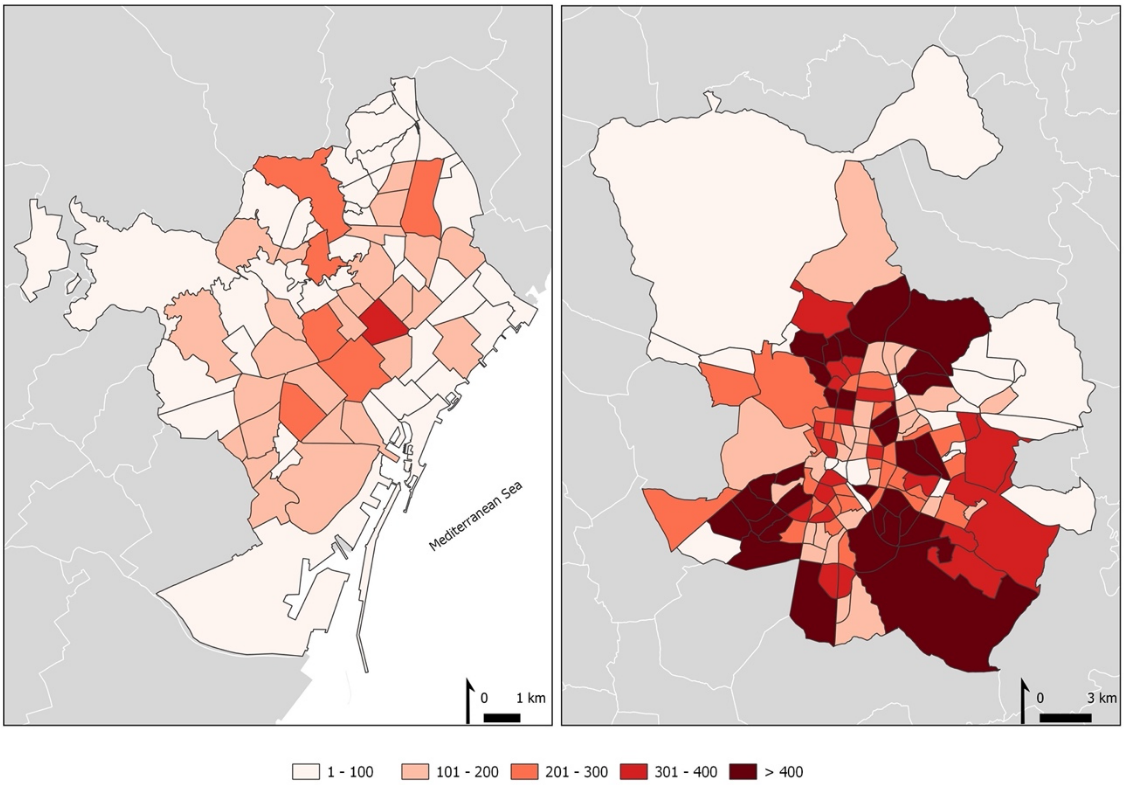
3.2. Methodology and results

3.2.1. Cluster analysis: How clustered are the neighborhoods with highest contagions of COVID-19 cases?

When aggregated at the neighborhood level, the total number of positive COVID-19 cases distribution seems to follow different patterns in Barcelona and Madrid (Figure 6).

We used Global and Local Moran indicators in order to understand the spatial pattern of contagion. The former describes the degree of the concentration of positives in each city, and the latter measure indicates whether neighborhoods with high proportions of contagion are located next to other neighborhoods with high proportions of contagion ("hotspots") (Moran, 1950). Where neighbors with high degrees of contagion are clustered together, it means that the observations are not independent (Glen, 2016). The Global Moran I is a measure that identifies the spatial autocorrelation due to the clustering of high-high values, but also low-low values. Barcelona (0.57) and Madrid (0.27) therefore show spatial autocorrelation (significance 0.05) between neighborhoods (Figure 7). Local indicator of spatial association (LISA) maps were used to identify local clusters of highest contagion (see Figure 7).

Figure 6. Total number of positive COVID-19 cases in Barcelona and Madrid (Test PCR), by neighborhood, 31/03/2020-16/05/2020



Source: Source: own elaboration based on Generalitat Catalunya and Comunidad Madrid.

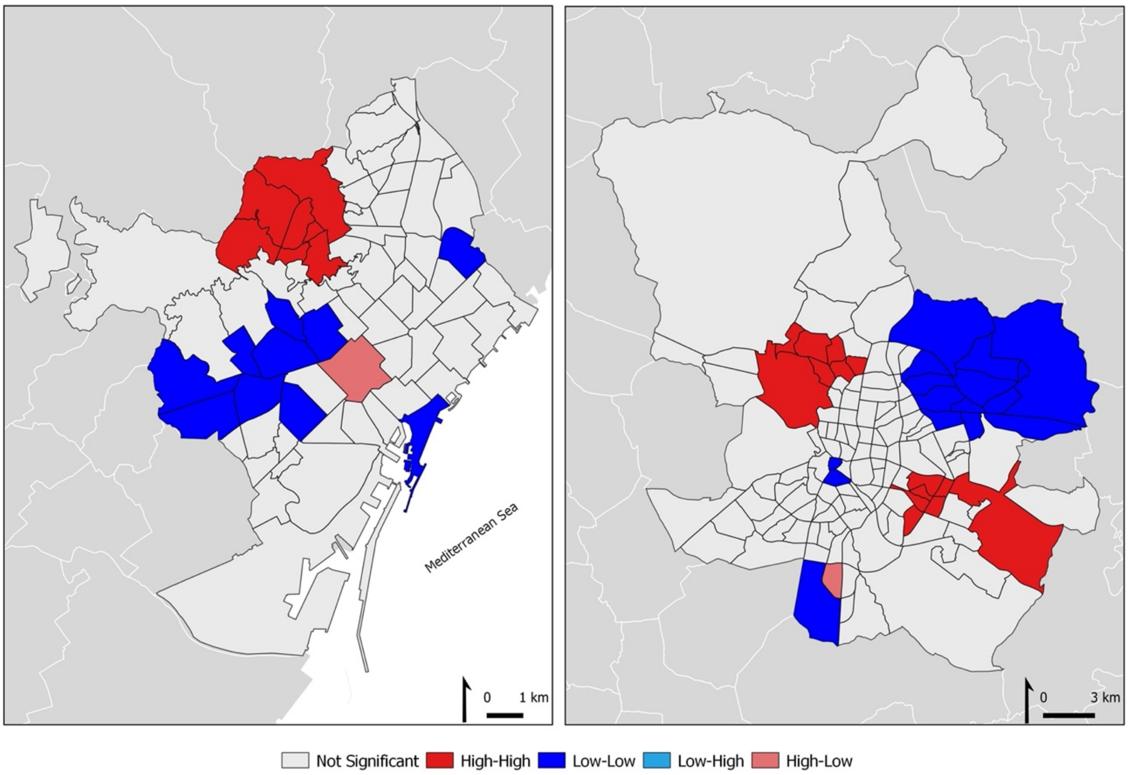


Figure 7. Degree of clustering in the number of positive cases of COVID-19 per 10,000 inhabitants, Barcelona; Global Moran's I index: 0.57 and Madrid; Global Moran's I index: 0.27

In Barcelona, high-high values are concentrated in the north of the city (Figure 7). In Madrid high-high values are located in three clusters in the northwest and southwest parts of the city. These results are explained further in the following spatial autoregressive models.

3.2.2. Spatial AutoRegressive Analysis

Multivariate analysis, including spatial dependence, explains the degree to which the number of tested positives - dependent variable - is conditioned by independent variables. Given that the results obtained suggest the existence of spatial dependence among neighborhoods in the number of people infected by COVID-19 per 10,000 inhabitants, we use an econometric model that incorporates this spatial autocorrelation (the SAR model, and particularly the spatial lag model) when establishing the relationship between this variable and other factors that, according to the literature, may be conditioning our variable of interest. Using data from neighborhoods in the cities of Barcelona and Madrid, we define two sets of SAR models, one for each city, in the following matrix form (following the notation proposed by LeSage & Pace, 2009):

$$y_i = \rho_i W_i y_i + X_i \beta_i + \varepsilon_i, \quad \varepsilon_i \sim \mathrm{N}(0, \sigma_i^2 I_{\mathrm{n}(i)}), \; i = \{\text{Barcelona, Madrid}\}$$

Where y_i is a vector of size n(i) x 1 that represents the dependent variable in each neighborhood in city i, where $n(i)$ is the number of neighborhoods in city i. In our case, the dependent variable is the number of COVID-19 positive cases per 10,000 inhabitants. W_{i} is the matrix of spatial weights of the neighborhoods for each city i; X_i is a matrix including the set of independent variables (population density, average housing area, average family income, the weight of people over 65 years old over the total neighborhood population, the weight of the number of nursing home places over the total area of each neighborhood and the weight of urban green areas over the total are of each neighborhood) plus a constant term; ρ_i is the spatial lag parameter; β_i is a vector of the parameters of the independent variables; and ε_i is the error term.

Given the definition and the timing of the variables, the results of the models only allow correlations to be identified. Due to the complex relationships among the variables of a phenomenon that has not yet ended and requires a broader perspective, we point out that our approximation of these relationships is not necessarily causal. That is, we do not imply to the reader that changing one of the independent variables in our model would change contagion rates, we can only say how the contagion rates and the variables analyzed move together. We stress this carefully throughout. While causal relationships are often needed in order to formulate policy, the correlations we identify may help policy makers identify variables potentially causally related to COVID-19 contagion rates, and adopt appropriate policies when the causal relationship is understood. It is also important to note the potential gap between true COVID-19 contagion and the contagion data that is available and thus used in this study. This gap, which is a result of a city's ability to capture or miss cases, probably varies between each city as well, depending on different testing capacities. As a result, some of the estimates we present may reject correlations between the variables in our model and reporting errors (Knittel & Ozaltun, 2020, p. 1).

In spite of this limitation, the multiple regression framework used in our analysis does allow researchers and policy makers to better focus their attention on potential causal mechanisms that might be driving the estimates we show. The way to interpret the estimates is as the correlations between contagion rates and a particular independent variable, such as the share of population density by neighborhood, *after controlling for the other independent variables in the model*. So, for example, if we find a positive relationship between population density and contagion rates, we can determine that this relationship is not driven by either family income or house area disparities, because we control for family income and house area in the model. Moreover, the causal mechanism may come from other factor that is not already in our statistical model. Our framework therefore not only says what is and what is not correlated with contagion rates, but also allows policy makers to eliminate potential channels driving these important correlations (Knittel & Ozaltun, 2020, p. 1).

3.3. How socioeconomic, neighborhood and ageing population conditions are related to cases of COVID-19 in Barcelona and Madrid

Table 2 shows the estimates of the parameters using the SAR models. In both cities, Model 1 includes four variables (including the spatial lag variable with its parameter ρ), which are regressed on the variable of interest (contagion rate), while in Model 2, seven variables (including the spatial lag variable) are regressed.

Table 2. Estimates of the SAR models for Barcelona and Madrid

	Barcelona		Madrid	
	Model 1	Model 2	Model 1	Model 2
Population density	-0.00030*	-0.00040***	0.00020	0.00002
Average housing area	-0.23	-0.30	0.22**	0.28**
Average family income	-0.02	-0.05	-0.25***	-0.35***
% Nursing home places / neighborhood	-	0.04***	-	0.01
% people > 65 / neighborhood population	-	52.23	-	137.34***
% Urban greenery /neighborhood	-	2.56	-	8.04
Constant	36.75**	34.34*	51.03***	34.11**
ρ	0.79***	0.71***	0.56***	0.52***
Log-likelihood	-317.17	-307.42	-612.34	-605.28
Observations	73	73	131	131

Notes: * Significant at 10% level, ** Significant at 5% level, *** Significant at 1% level.

ρ = spatial lag parameter.

According to the results of Model 1 for Barcelona, the number of infected people increases in neighborhoods with lower density (all other controlled characteristics equal). This seems to be a counterintuitive result (not significant in the case of Madrid), but it is in line with evidence found in others studies (Hamidi, Ewing, Sabourib, 2020, Teller, 2021). We elaborate on this important question in the conclusion. In any case, in Model 2 the estimated nursing home places in the neighborhoods of Barcelona can be interpreted in terms of the higher rates of contagion affecting elderly people (Knittel and Ozaltun, 2020), and reinforced by the scarcity of PCR diagnosis tests during the first wave of the pandemic, something that obliged diagnosis of the more vulnerable groups at that time to be prioritized. A first conclusion regarding Model 1 for Madrid involves the negative relationship of household income level with the spread of COVID-19, for which the previous literature has indeed reported strong evidence (Deaton, 2003). A higher average housing area in neighborhoods also has a positive association with contagion rates. Similar conclusions were obtained from the Model 2 results for Madrid, where there is also a clear positive relationship with the concentration of people of above 65 years old living in the neighborhoods. This is in line with most evidence about the effect of population health conditions, and especially comorbidities and diabetes in these groups of individuals (Sands et al., 2016).

4. Conclusions and concluding remarks

The presentation of spatial variation in risk is one of the most important functions of spatial analysis, and in this chapter it is used to find why contagions of COVID-19 are different by neighborhoods, given relevant variables related to housing conditions, neighborhood conditions, and an ageing population. Specifically the research questions ask which variables are more significantly related to the contagion of COVID-19, whether both cities have a similar relationship with a common set of independent variables, and identify whether there are differences in the cities and discuss such differences (if any).

This chapter introduces neighborhoods and compact cities as novel variables in COVID-19 in the literature, although the results include some unexpected findings which we will try to explain. Most epidemiological studies examine cities and regions, however, cities are not homogeneous, and geographical scale is important. For example, there are rich and poor neighborhoods; nursing homes can be randomly distributed; green spaces are sparsely distributed; density varies within a city; some areas are considered less desirable than others; and in a free market, most of these are reflected in housing prices, school quality and in neighborhoods being defined as “good” and “bad”. Analysis by neighborhood is therefore an added value in this chapter, and the results obtained corroborate that geographical scale should be considered in any study if the results are to be based on facts, and moreover, if they are to help policy makers to improve the quality of life.

In this study and based on the most relevant literature about health factors, socioeconomic, housing, neighborhood and age factors have been hypothesized as those most involved in spreading COVID-19 in Barcelona and Madrid. Methodologically, the spatial dependence of variables was tested as one of the most important pre-conditions for the contagion. The spatial autocorrelation is a process affecting most phenomena in space. For instance, it is common knowledge that being physically close to a neighbor or a friend could increase the probability of a virus being transmitted. Physical proximity can be a good thing, and improve wellbeing and communication, but it an also transmit disease. In this research the dependent variable has therefore been clustered and tested using Global Moran's I, with significantly positive results in both cities. The LISA results indicate the clustering of neighborhoods with high levels of contagion in Barcelona and Madrid. The results obtained therefore suggest the existence of spatial dependence in neighborhoods as regards the number of people infected by COVID-19 per 10,000 inhabitants. We then used spatial regression models that incorporate this autocorrelation when establishing the relationship between variables.

Under the pre-condition that COVID-19 is a highly contagious disease, one would expect density to be the main driver, however, research in Wuhan (You et al., 2020) and the USA (Hamidi, Ewing, Sabouri, 2020; Hamidi, Sabouri, Ewing, 2020) seems to have resulted in different interpretations. In Wuhan, density was associated with an increased COVID-19 morbidity rate, whereas in the USA the larger metropolitan areas had higher infection and higher mortality rates, but after controlling for metropolitan populations, county density was not significantly related to the infection rate. This is possibly due to greater adherence to social distancing guidelines. In the USA, dense areas lead to more face-to-face interaction among residents, which made them potential hotspots for the rapid spread of pandemics. On the other hand, dense areas may have better access to health care facilities and a greater implementation of social distancing policies and practices. Counties in the USA with higher densities had significantly lower virus-related mortality rates than counties with lower densities, possibly due to superior health care systems.

When we analyze compact cities such as Barcelona and Madrid, the results are different. Population density is significant (10% level) in Barcelona with a negative sign, suggesting that as density decreases contagion increases. In Madrid density is not significant, and density does not demonstrate the effect we expected. This could be explained in other ways, such as urban people in the USA being more aware of the adoption of specific measures to prevent COVID-19, such as social distancing, and because it is close to health facilities. Alternatively, there could have been a misinterpretation in the process of gathering values for the independent variable. A population moves easily in compact spaces, and PCR tests might be taken in an area that is part of another neighborhood. This result is relevant for further analysis: compactness can create misleading results because a population moves easily across neighborhoods.

In Barcelona and Madrid, the COVID-19 pandemic has reshaped perceptions of how older people live. High levels of deaths in nursing homes has alerted society to the precarious conditions of the ageing population, and national and regional authorities have had to react promptly to avoid the collapse of healthy provision systems. Our results showed (through the use of nursing homes and weights of people above 65 years old) that the ageing population in Barcelona and Madrid had a significant relationship with the contagion rate. Recommendations can be made to help policy makers design inclusive urban planning, urban management and governance for COVID-19 territories (or similar pandemics). This is an excellent opportunity for planners and policy makers to take transformative actions towards creating “new” cities. Global society is in a vulnerable position, as is planning and governance today. Sustainable living standards for the older population are neglected, inequalities are part of the planning strategy, and society and health are part of a system that should be treated as a whole. Further research should lead to discussions about how to analyze infections on an urban scale in compact cities, and compare them with other less compact territories. Socio-economic factors, and household and neighborhood conditions are important to explain the spread of COVID-19 based on social contact or distance. Population movements within compact territories might produce a distortion in research results if not accounted for. Overall, existing knowledge of COVID-19 factors shows that resilience and sustainability are more than fashionable concepts, they are the foundations of a new paradigm for society, its living conditions and health.

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