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Francisco Aguilera Benavente
Mirian Checa Romero
Marta Catalá Bustos

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Essential knowledge and skills tests of in the Community of Madrid: a spatial analysis of the results

Las pruebas CDI en la Comunidad de Madrid: un análisis espacial de los resultados

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Francisco Aguilera Benavente
Mirian Checa Romero
Marta Catalá Bustos
Universidad de Alcalá

Abstract

Educational assessment has experimented an important boom in the last decades, exposing educational systems to increasingly exacting demands. As a consequence, movements as school effectiveness and accountability have flourished. Within this context, the analysis of the results of academic performance have been object of many studies, especially in those Spanish Regions where assessment instruments have been developed for a longer period of time. However, rarely the analysis of these results is made from a spatial perspective. The present study analysed the results of CDI tests made in Community of Madrid in 6 grade of Primary School including the spatial dimension. Because of that, through the usage of thematic maps and local indexes of spatial autocorrelation (LISA), the results obtain for the public, state-subsidised and Private schools were analysed in CDI test in and 2013/2014. The results revealed the existence of spatial clusters where schools present a high spatial correlation on high values (high academic performance) as well as low values which socio-demographic factors that motivate these spatial patterns. Positive and negative anomalies were also detected, including schools with higher and lower values than expected in regards to their neighbourhood. All these findings can be useful for a better understanding of explicative factors explaining academic results, as well as for revealing schools whose

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internal characteristics may help to improve academic results within their spatial context.

Keywords: CDI Tests, spatial autocorrelation, spatial analysis, academic performance; Community of Madrid.

Resumen

En las últimas décadas se ha producido un auge de la evaluación educativa, lo que supone que los sistemas educativos sean sometidos a demandas cada vez más exigentes. Esto deriva en fenómenos como la rendición de cuentas o la persecución de escuelas eficaces para satisfacer esas necesidades. En este contexto, el análisis de los resultados de rendimiento académico ha sido objeto de múltiples estudios, especialmente en aquellas comunidades autónomas donde se realizan pruebas de rendimiento en etapa primaria desde hace más tiempo. No obstante, en muy pocas ocasiones el análisis de dichos resultados se realiza desde una perspectiva espacial. El presente trabajo realiza un análisis de los resultados de las pruebas CDI realizadas en 6º de primaria en la Comunidad de Madrid incorporando la dimensión espacial. Para ello, mediante el empleo de mapas temáticos e índices de autocorrelación espacial locales (LISA), se analizaron los resultados obtenidos por los centros educativos de carácter público y concertado/privado en las pruebas CDI para el curso 2013/2014. Los resultados revelaron la existencia de agrupamientos espaciales donde los centros presentan una alta autocorrelación espacial tanto de valores altos (rendimientos académicos elevados) como bajos (rendimientos bajos) lo que muestra la existencia de factores sociodemográficos de carácter espacial que motivan dichos resultados. No obstante, también se reveló la presencia de anomalías positivas y negativas, entendidas como centros con valores más altos o bajos de lo que cabría esperar según su entorno, donde esos mismos factores no ejercen una influencia tan determinante. Estos resultados son de utilidad para ayudar a entender los factores explicativos del rendimiento escolar en la Comunidad de Madrid, así como para identificar aquellos centros cuyas circunstancias internas o variables intraescuela favorecen la presencia de resultados elevados en su contexto.

Palabras clave: Pruebas CDI, autocorrelación espacial, análisis espacial, rendimiento académico, Comunidad de Madrid

Introduction

There is no need here to emphasise the strategic value of education and training in modern societies for optimising the «productive capacities» of individuals, in order to maximise the productivity of different countries (Ruiz, 2011). Recent decades have seen a boom in educational evaluation, considered in terms of a tool for social change, economic development and the production of knowledge which means that education systems are subjected to increasingly exacting demands. Taken as a whole, these systems must respond to the demands that citizens and societies make of them, according to the phenomenon known as *accountability* (e.g.: Baker, 2009; Escudero, 2006). Various approaches have developed within this context of evaluation, including studies of effective schools (e.g.: Murillo, 2000; Ruiz de Miguel, 2009), which are considered to be those that achieve good results for their pupils (Muñoz-Repiso, 1997) and evidence-based management (EBM) (e.g. Oakley, 2002; Slavin, 2002), considered to be the need to adopt the best available evidence in order to make the best decisions (e.g. García del Junco, 2004; Pfeffer and Sutton, 2006).

Different international means of assessment of knowledge have been developed within these approaches. One of the most well-known is the PISA report, which has had unsatisfactory results for students in general, and for Spanish students in particular (OECD, 2013a and 2013b). In the specific case of the Community of Madrid, the negative results were also highlighted by the Madrid Educational Inspectorate, which found that in year 6 of primary education, 6.6% of the students had to repeat the year in the 2003-2004 academic year; 16.1% failed Spanish Language and 17.2% failed Mathematics. This meant that a significant percentage of students began their compulsory secondary education with learning difficulties in core subjects. These figures led to the approval of Order 5420-01/2005 of 18 October, regulating the General Plan for the Improvement of Essential Skills.

To comply with this order, the Ministry of Education of the Community of Madrid has carried out the Essential Knowledge and Skills Tests (CDI Tests) for students in the sixth year of Primary Education and the third year of Secondary Education since the 2004-2005 academic year, with a twofold objective: to monitor the degree to which the knowledge and skills considered essential for each stage of education are acquired, and to provide families with information about schools' educational performance in order to foster free choice between them (Ministry of Education, Culture and Sport, 2006). The census-based nature of the test means that all students enrolled in both public and private schools have to take it.

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During the period of over ten years in which the CDI tests have been carried out, various studies have analysed different aspects directly related to the test results. Some have analysed the influence of economic factors on the results (Trillo, Pérez and Crespo, 2007); others have focused on the intensity of competition between schools and its effects on academic achievement (Molina, 2015); meanwhile, others have considered the influence of the parents' level of education (e.g. Doncel, Sainz and Sanz, 2012; Ruiz, 2011); the impact of bilingualism on academic achievement (Sotoca, 2014), etc.

Some of the variables analysed in previous studies have also traditionally been used in studies of school performance, both in Spain and internationally. Some studies have focused on the influence of the socioeconomic and cultural environment (e.g. Cordero, Pedraja and Simancas, 2015; Elosua, 2013; Martins and Veiga, 2010; Moreno, Estévez, Murgui and Musitu, 2009), the characteristics of the schools (e.g. Cordero, Crespo and Pedraja, 2013; Donkers and Robert, 2008), the effects of immigration (Salinas and Santín, 2012); the students' personal characteristics (e.g. Martin and Marsh, 2006; Turner, 2006), the changes experienced in the transition from primary to secondary school (Gaviria, Biencinto and Navarro, 2009) and their social and academic contexts (e.g. Fredriksson, Öckert, and Oosterbeek, 2013; Van Ewijk and Sleegers, 2010).

Many if not all of these influential variables clearly have a spatial expression (e.g. income distribution, family socioeconomic status, etc.). However, very few studies have attempted to explore the relationship between the spatial location of the schools and their academic results, although there have been some studies in this area, both in Spain (e.g. Escolano, Ruiz and Climent, 2005; Moreno and López, 1989) and internationally (e.g. Gordon and Monastiriotis, 2006; Thrupp and Lupton, 2006).

This study aims to use an exploratory spatial data analysis (Anselin, 1995) to study the spatial distribution of the mean scores of the schools in the Community of Madrid in the Essential Knowledge and Skills Tests (CDI Tests) for Spanish Language and Mathematics for the sixth year of Primary school during the 2013-2014 academic year. This analysis will identify schools that are close to each other and have similar CDI test results (spatial clustering) and statistically significant anomalies in sets of public and subsidised and private schools. These anomalies are represented by schools with higher scores in the CDI tests than would be expected according to a spatial context of low results (positive anomalies), and schools with lower results than would be expected in a spatial context of high results (negative anomalies).

As the results of this study, we will therefore expect to be able to identify the geographical sectors or areas with high or low results in the CDI tests. These results will be useful for designing appropriate planning scenarios to facilitate the implementation of policies and decision-making processes aimed at improving academic results in the Community of Madrid.

This article is structured as follows: section 2 presents a detailed description of the CDI tests and the data collection used in the study. Section 3 presents the spatial analysis methodology for the data using QGIS and GeoDA, and the Moran's Local Indices using the LISA Test. The results are presented in section 4. Section 5 presents the discussion and conclusions.

The CDI tests

The Ministry of Education of the Community of Madrid launched a series of external performance evaluation tests in the 2004-2005 school year. These include the annual Essential Knowledge and Skills Test (CDI Tests) for all students (census-based tests) in the sixth year of primary education, in the third year of compulsory secondary education and in the first year of the Curricular Diversification Programme at any school in the Community of Madrid.

The aim of the specific test for the sixth year of Primary Education, the results of which are analysed in this study, is to determine whether a student's level of skills and knowledge at the end of their primary school education ensures that they are able to successfully complete the next compulsory stage in their schooling.

The test is taken using paper and pencil, and is divided into two parts of 45 minutes each. It consists of «closed» questions as well as more open-ended questions to which more elaborate answers are needed. The Spanish Language test consists of a dictation and a text that has to be read, followed by answering a series of questions, as well as other questions on general knowledge. The Mathematics test has two sections: one in which ten basic arithmetic questions are solved, and one with five problems.

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The test is designed based on a set of learning standards or essential skills defined by the competent Ministry, and these are grouped into four sections in the area of Spanish Language and Literature: oral communication, reading, writing and grammar and language analysis. The mathematics area is also grouped into four sections: numbers and operations, units of measurement, spatial orientation and geometry and organisation of information. These standards are listed in Appendices I and II of the General Plan for the Improvement of Essential Skills, approved by Order 5420-01/2005 of 18 October (http://www.madrid.org/ bvirtual/BVCM001649.pdf). The tests are corrected and graded by committees of teachers appointed by each of the Territorial Area Offices, which are supervised by the Educational Inspection Service, based on the correction criteria prepared by the competent Ministry every year. Each question has only three possible grades (literally «good», «bad» or «fair»), with the highest score for the total test being 10 points, and the lowest being 0.

The test is no barrier to moving on to the next stage of education, as it is for educational and guidance purposes. Teachers, schools, families, students and the Government are informed of the results, in order to develop possible improvement plans.

Other tests are also being applied at the same level of education, at both national and autonomous regional level. At the national level, there are the *Final assessment tests* for the sixth year of Primary Education, as stipulated in Royal Decree 1058/2015 of 20 November 2015, which were applied for the first time in May 2016. These tests also aim to check the level of acquisition of skills in linguistic communication, mathematics and basic competences in science and technology. At an autonomous regional level, the Autonomous Community of the Murcia Region also performs *Basic skills tests* for students in the sixth year of primary education, which are also structured in the same way as the CDI tests, with a language section and a mathematics section.

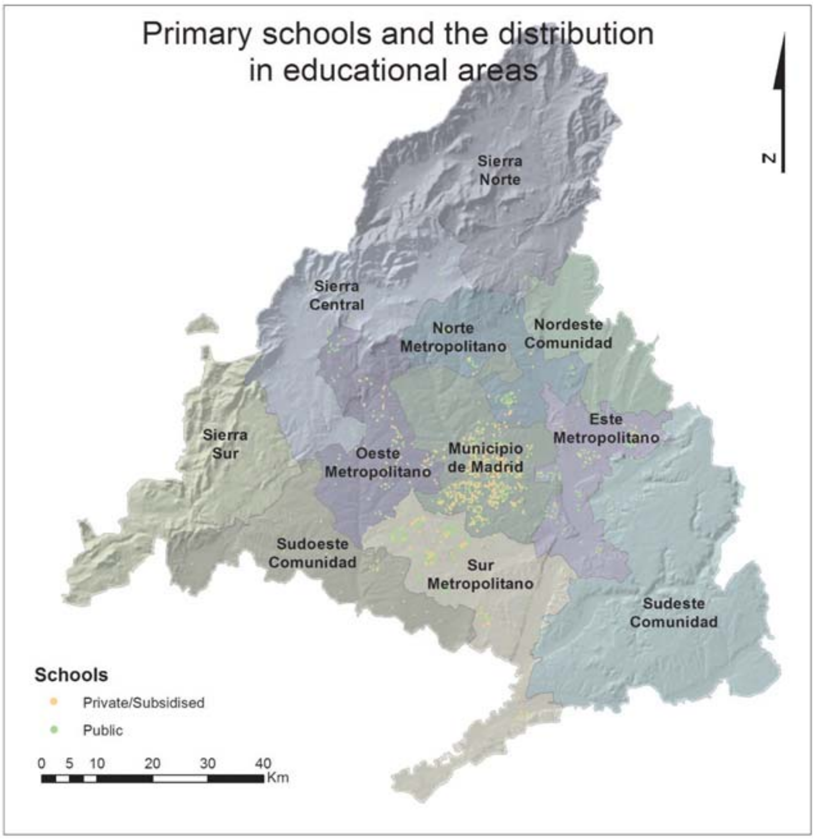
Methodology

Initial data

Information as regards the name of the school and its designation code was first gathered from primary schools in the Community of Madrid

(CoM). To do this, we used the information available in the National Register of non-university education centres of the Ministry of Education (https://www.educacion.gob.es/centros/home.do), which gave us a list with a total of 1,322 schools, 787 of which were public schools and 535 were private or subsidised schools.

FIGURE I. Spatial database with schools in the Community of Madrid.



Source: Compiled by the authors

Subsequently, in order to be able to spatially represent the data for the CDI tests obtained for each school, we downloaded the geographical information on the location of all public and private/subsidised schools in the CoM. To that end, we accessed the dissemination tool of the «*CoM Statistics Institute Territorial Information System*« known as NOMECALLES (http://www.madrid.org/nomecalles/) from which the relevant geographic information layers can be downloaded. The result of this download was a file with the spatial location of public schools in the CoM, which contained 789 public primary schools and 530 private/subsidised schools. The discrepancy between the two databases was minimal (a difference of 2 public schools and 5 private/subsidised schools), and was resolved by removing the schools that were not in both databases. The combination of the two data sets using the school code subsequently enabled us to obtain the geographical location for each school and its name and school code, thereby constituting a genuine spatial database (see Figure I).

TABLE I. Sources for the generation of the spatial database of CDI test results in the CoM.

Data	Description	Source	Number of valid schools
Community of Madrid primary schools	List of all schools by autonomous region, including their name, public/private status and code	Ministry of Education https://www.educacion.gob.es/centros/home.do	787 public and 535 private/subsidised schools.
Geographical location (point) of the schools	Spatial location of schools in the Community of Madrid, including the school's code.	CoM Statistics Institute Territorial Information System http://www.madrid.org/nomecalles/	789 public and 530 private/subsidised schools.
CDI test results for each school	CDI test results for each school for the 2013/2014 academic year.	CoM school search engine http://www.madrid.org/wpad_pub/run/j/MostrarConsultaGeneral.icm	747 public and 459 private/subsidised schools.

Source: Compiled by the authors

Finally, we made queries for the CDI test scores for each of these schools for the 2013/2014 academic year, the last academic year available when this study was being written, in the schools search engine on the website http://www.madrid.org/wpad_pub/run/j/MostrarConsultaGeneral.icm, and compiled information on the mean CDI test score. However, not all the 787 public schools and 530 private/subsidised schools in the spatial database had results for the CDI tests, as some of them (especially among the subsidised and private schools) had only recently been established and had not yet participated in the tests.

We therefore only kept the schools with results available for the CDI tests in the database, which amounted to a total of 747 public schools and 459 private/subsidised schools, and this constituted the starting point for conducting our analysis. Table I summarises the various sources used in the construction of the database, as well as its main characteristics.

Methods

The working methodology, presented in summary form in Figure II, is based on the following analysis:

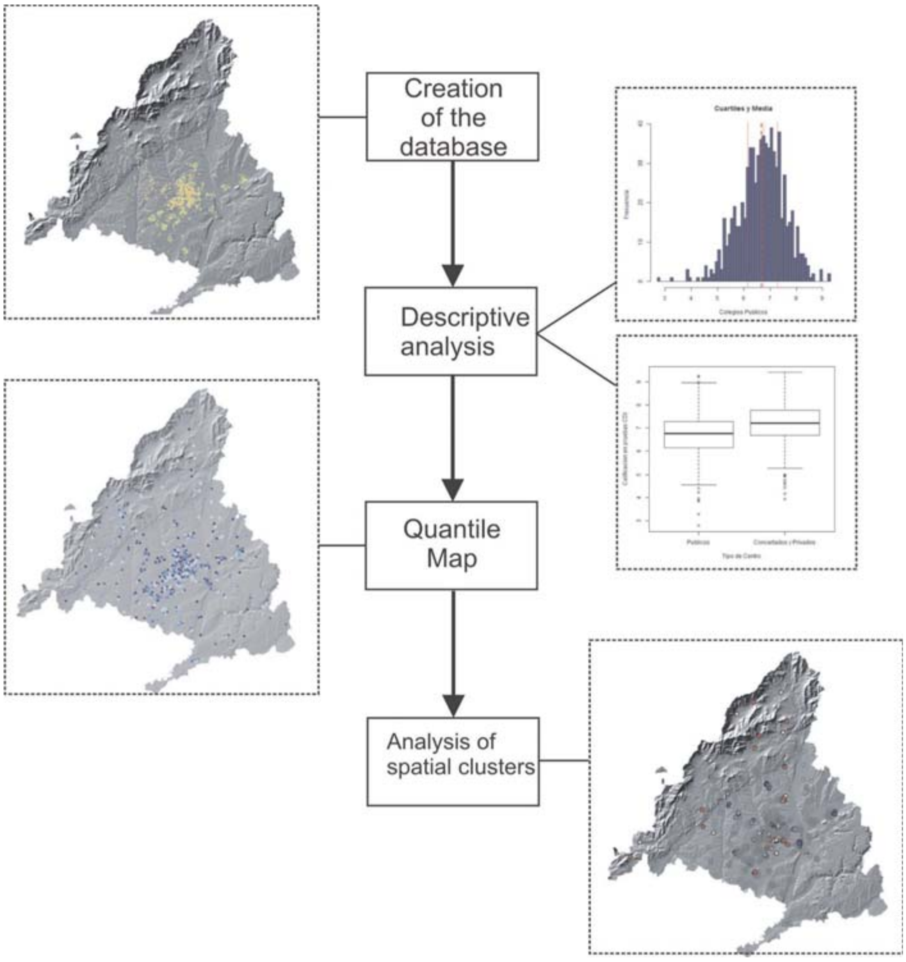
i) A descriptive analysis of the results for public and private/subsidised schools using the histogram of the results for the 2013/2014 academic year, and the boxplot graphs of the results for both types of schools.

ii) An exploratory spatial data analysis to identify the schools in each of the four intervals (called Q1 to Q4) sorted from highest to lowest CDI test score, in which the school population can be divided by defining the three quartiles, in both public and private/subsidised schools. We were thereby able to create a map with the location of the schools in the first, second, third and fourth interval according to their CDI test results.

iii) A spatial autocorrelation analysis using the Local Moran's Index (LISA) (Anselin, 1995), which identified spatial clusters of schools close together with similar high or low values in the CDI tests, and statistically significant spatial outliers, which were schools with results higher than would be expected for their neighbourhood, and schools with lower results than would be expected according to the values for their neighbourhood.

This analysis was performed using the following free software: the statistical package R (https://www.r-project.org/), the geographical information system QGIS (http://www.qgis.org/es/site/), and the spatial data analysis software GEODA (https://geodacenter.asu.edu/software/downloads).

FIGURE II. Diagram of the methodology



Source: Compiled by the authors

Descriptive and exploratory data analysis: the quantile map

These two analyses aim to show on the one hand, using a descriptive analysis using the R statistical package, the frequency distribution of the average CDI test results for public and private/subsidised schools in the 2013/2014 academic year, and the average values, quantiles and standard deviation obtained for each one, which were compared using a Box Plot. Moreover, the public and private/subsidised schools in the first, second, third and fourth interval (Q1 to Q4) of the frequency histogram delimited by the three quartiles were mapped by drawing a quantiles map for those average results using QGIS software. We were thereby able to determine the location of the schools with the best CDI test results (those in Q1), helping to interpret and infer the existence of spatial patterns in their distribution. These maps were completed with the preparation of Table II, comparing the percentage of schools in each statistical area of the CoM, and the percentage of schools in Q1 and Q4 in each of those areas.

Local spatial autocorrelation analysis: Identification of spatial clusters using the Local Moran Index

This analysis aims to identify the presence of statistically significant spatial clusters of schools with high or low results by means of a spatial autocorrelation analysis. Spatial autocorrelation can be understood as a measure of the degree to which the different values of a spatially distributed variable become more similar as the distance between them decreases. Various indices can be used to determine the existence of spatial autocorrelation, which may be global or local (Anselin, 1995), and one of the primary indices is the Moran global index (Goodchild, 1986). This can be defined as (Equation 1):

Equation 1: Moran Index

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} z_i z_j}{\sum_{i=1}^{n} z_i^2}$$

Where z_i is the deviation of an element from the mean, *wij* is the weight as a function of the distance between i and j, n is the number of elements, and S_0 is the sum of all the weights w_{ij}.

However, the global indices are limited to analysing spatial autocorrelation in the region as a whole, and do not allow us to determine

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whether the autocorrelation pattern observed in the region as a whole is also maintained at the local level, i.e. in different places in the region, or whether the absence of an overall correlation conceals some areas where this correlation does exist.

It is therefore possible to calculate the spatial autocorrelation in a particular subset of spatial units, and the instrument most commonly used to do this is the LISA test (Anselin, 2005). This test uses the local Moran indexes calculated for all the spatial units analysed (primary schools in this study) and determines whether the neighbouring schools have similar values for the variable or if instead the similarity is what will be expected due to the effect of chance (usually with a confidence interval of 95%). If the values in a set of nearby items have a strong positive correlation (low values near low values, or high values near high values) or a strong negative correlation (positive and negative anomalies) greater than the correlation which would be expected as a result of chance, those items are assigned to a spatial cluster. Otherwise they are not assigned to any cluster.

However, a fundamental aspect for calculating these correlation indices is to determine the items that are nearby, or in other words, the vicinity of each item. In the case of the selective data that concerns us here, this facility can be selected by establishing a threshold distance (all items included within 1,000 m, 2,000 m, etc.) or by specifying a fixed group of neighbours established by the user (4 neighbours, 5 neighbours, etc.).

Given the uneven distribution of the schools (a high density of schools in the municipality of Madrid and a low density in the municipalities furthest from the capital), we decided to use the method of selecting a number of neighbours, because selection using the threshold distance led to the allocation of few or no neighbours to the most isolated schools, and too many neighbours to schools in the areas of highest density.

This method requires a prior identification of the number of neighbours to carry out the analysis. To that end, Global Moran Index tests were performed for different numbers of neighbours (Gordon and Monastiriotis, 2006), ranging from 3 to 12 neighbours, for both public and private/subsidised schools separately, and for all the primary schools as a whole. In view of the results, the number of neighbours which gave the highest spatial correlation values was selected (see section 4.3). We then performed the LISA test to identify spatial clusters of public and private schools, and all the schools (section 4.4)

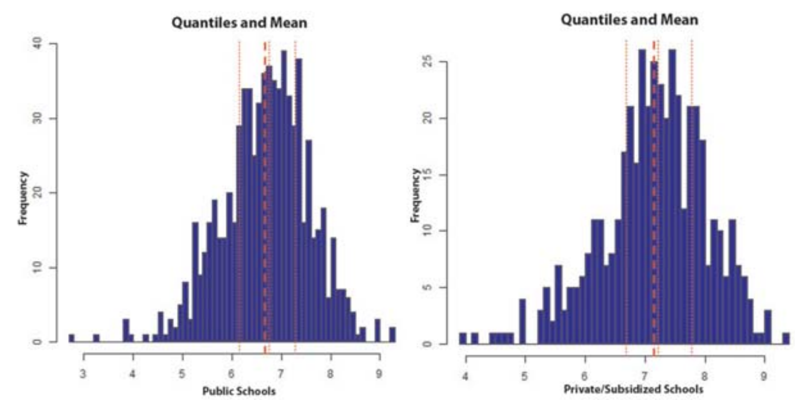
The analysis thereby identifies spatial clusters of nearby schools with similar results, and a greater explanatory load can be assigned to the spatial variables determining performance (income, unemployment rate, parents' education level, etc.). Based on the different clusters identified, this would facilitate detailed further study of the determinant variables for the school performance of each one. This would provide more accurate results if all the schools were studied, taking into account what could be the most influential variables in some places (e.g. spatial variables), while they could be others in other places, without such a clear spatial expression (e.g. good teaching practices).

Results

Results of the descriptive analysis of the CDI test results

An initial descriptive analysis of the CDI test results in public schools and in private and subsidised schools for the 2013-2014 academic year (Figure III and Table II) shows a normal distribution of frequencies in each one, with a slight asymmetry to the left, at low values, for both.

FIGURE III. Histogram with three quartiles (dotted line) and mean (dashed line) of public schools (left) and private and subsidised schools (right) for the 2013/2014 academic year.



Source: Compiled by the authors

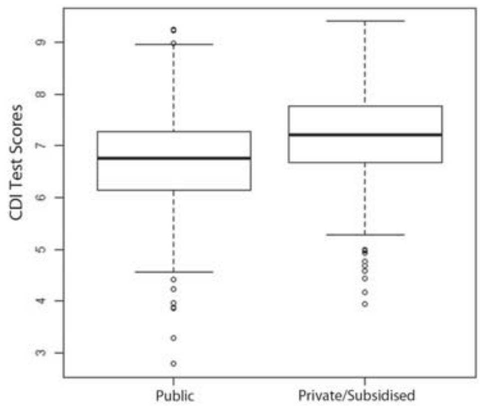
TABLE II. Descriptive statistics for the 2013/2014 academic year for all the schools, and for the public and private/subsidised schools separately.

	Mean	Deviation Standard	Min value	First Quartile	Median	Third Quartile	Max value
Total 2013/2014 academic year	**6.88**	0.99	2.79	6.30	6.93	7.48	9.24
Public 2013/2014	**6.69**	0.89	2.79	6.17	6.75	7.27	9.24
Private and subsidised 2013/2014	**7.19**	0.83	4.17	6.70	7.22	7.78	9.09

Source: Compiled by the authors

The mean values for private and subsidised schools are slightly higher than those for public schools, with the average for public schools slightly less than 7, while the mean values for subsidised and private schools are above 7 (figure IV). The number of extreme values or outliers is also higher in public schools, which also have very low values.

FIGURE IV. Boxplot of the CDI test results for public and private/subsidised schools.



Source: Compiled by the authors

Quantile map of the CDI test results

Spatial analysis of the quantiles enabled thematic spatial distribution maps to be produced for the CDI test results for both public and private/subsidised schools (figures V and VI), and Table III, which supplements the mapped information in an initial spatial approach. This table shows how some areas in the CoM have a concentration of schools in the Q1 that is higher than what would be expected according to the percentage of schools in the area, and this is accentuated in the case of private/subsidised schools. Examples include areas such as North Metropolitan (municipalities such as San Sebastián de los Reyes, Tres Cantos, etc.), with a concentration of private and subsidised schools in the Q1 which is twice the expected level, and West Metropolitan (Las Rozas, Pozuelo and Majadahonda) which also has a higher concentration of private schools, provide an initial idea of the existing spatial patterns.

TABLE III. Percentage of public and private/subsidised schools in each of the statistical areas of Madrid, and in the first and last quartiles.

	% Public schools	% Public schools in Q1	% Public schools in Q4	% Private/subsidised schools	% Private/subsidised schools in Q1	% Private/subsidised schools in Q4
Municipality of Madrid	31.05	34.65	38.99	66.4	62.38	74.58
North Metropolitan	7.23	7.09	5.65	3.9	8.26	0.84
East Metropolitan	13.25	14.09	10.17	5.22	8.26	5
South Metropolitan	26.10	24.41	22.60	12.85	8.26	13.56
West Metropolitan	7.09	7.87	5.08	10.45	12.84	2.54
Sierra Norte	1.74	1.57	3.39	0	0	0
North-east Community	1.74	1.57	3.95	0	0	0
South-east Community	3.34	0.79	1.69	0.43	0	0.85
South-west Community	3.21	3.15	3.39	0.65	0	2.54
Sierra Sur	1.61	0.79	3.39	0	0	0
Sierra Central	3.61	3.15	1.69	0	0	0

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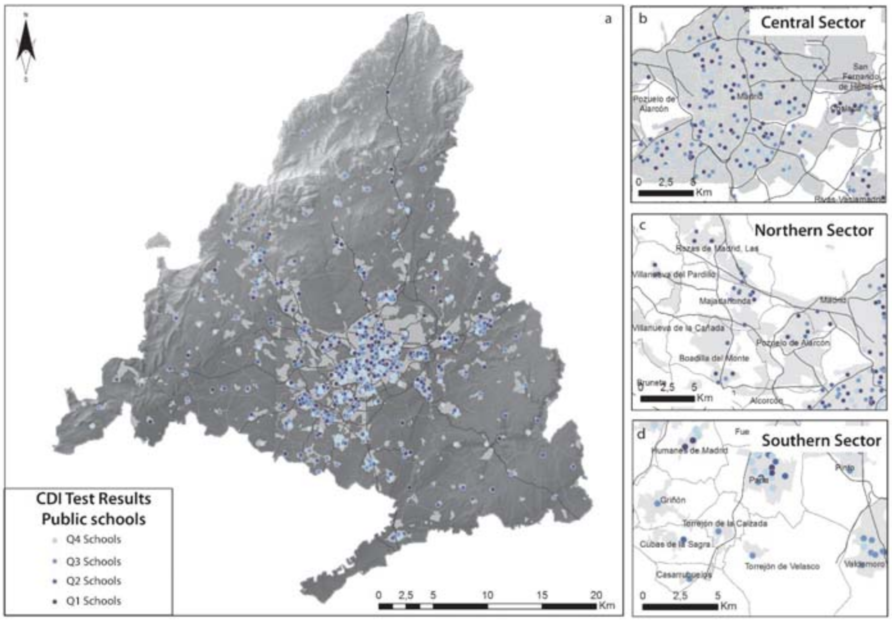
FIGURE V. Quantile map of public schools in the Community of Madrid.



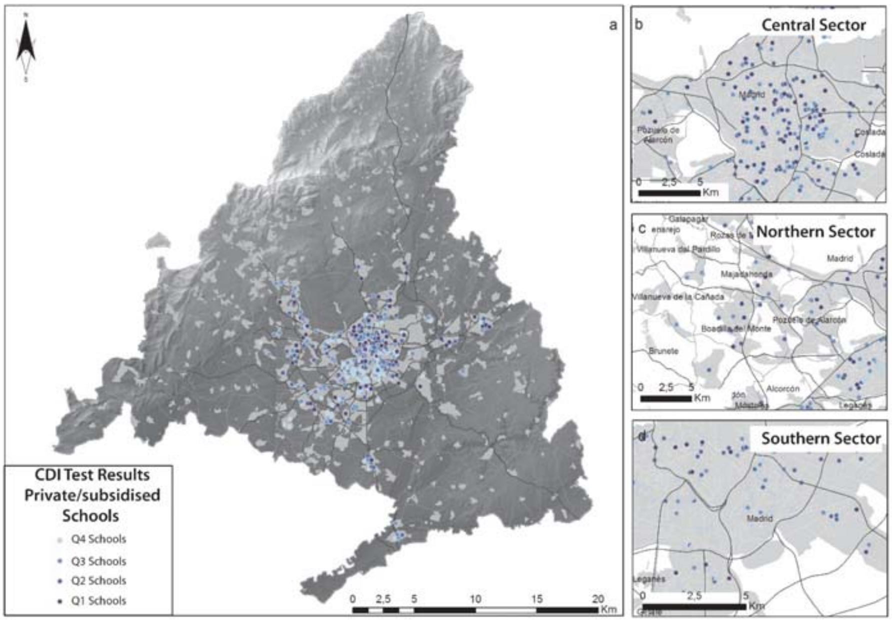
Source: Compiled by the authors

Figures V and VI enable better spatialisation of these spatial patterns, which are not entirely identified therein because they have a smaller scale than the areas listed in the table. The schools belonging to Q4 appear to be located mainly in the southern sector of the municipality of Madrid, in districts such as Puente de Vallecas, Villa de Vallecas, Carabanchel and Usera. This applies to both public schools and private and subsidised schools (see figure Vb and VId), while in the case of public schools, it particularly applies in the municipalities of Griñón, Parla, Humanes de Madrid, etc. (see figure Vd). We also found that a significant number of schools located in the Q3 are in municipalities far from the capital, such as Rascafría, Guadalix de la Sierra, Fuentidueña de Tajo, Nuevo Baztán, etc.

Meanwhile, the schools in Q1 appear to be more concentrated in the municipality of Madrid, particularly in the districts located within the M-30 orbital motorway (especially for private/subsidised schools; see figure

VIb), as well as in many of the municipalities located to the west and north-west of the municipality of Madrid (Pozuelo de Alarcón, Las Rozas de Madrid, Boadilla del Monte, etc.; see figures V and VIc). This is especially true of private/subsidised schools, as already shown in table III; although this is also the case in other municipalities such as Rivas-Vaciamadrid and Alcalá de Henares.

FIGURE VI. Quantile map of private/subsidised schools in the Community of Madrid.



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Results of the spatial autocorrelation analysis

The analysis of the overall spatial autocorrelation Moran indices obtained for different numbers of neighbours is shown in table III. The results are low (near zero), which would show a lack of spatial autocorrelation for

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the set of all schools in the CoM. However, as noted above, this lack of overall autocorrelation may conceal a spatial autocorrelation in some areas of the territory, and as such the local spatial autocorrelation analysis was performed using the LISA test, using the number of neighbours with the greatest overall autocorrelation. For public and private/subsidised schools separately, the best result is obtained with 4 neighbours for the calculation. However, when all the schools were considered together, the highest overall Moran values were obtained with a total of 9 neighbours, by selecting that value for the Local Autocorrelation analysis.

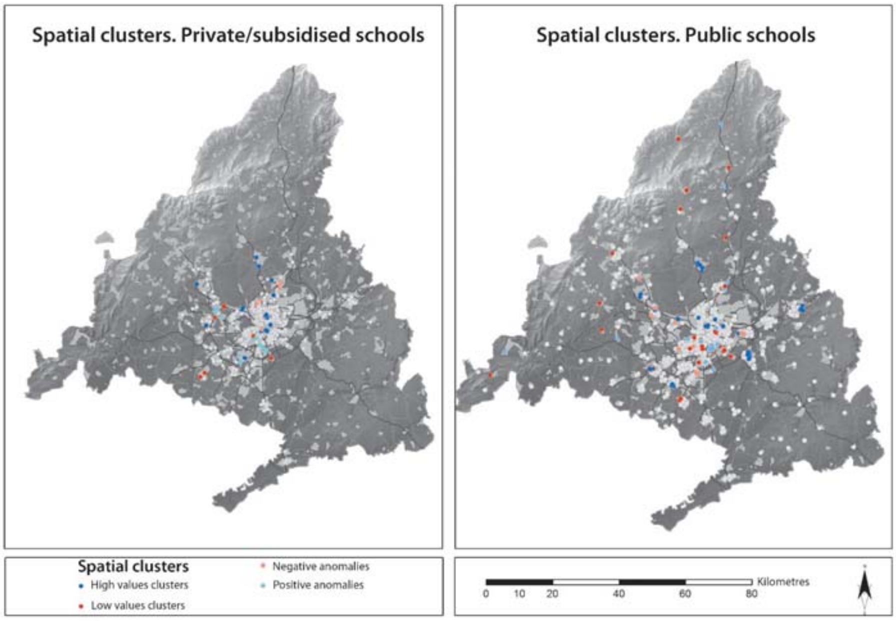
TABLE III. Spatial autocorrelation Moran indices calculated for different numbers of neighbours, for both public and private/subsidised schools

Number of neighbours	Public schools	Private/subsidised schools	All schools
3	0.107	0.141	0.066
4	**0.114**	**0.149**	0.071
5	0.098	0.145	0.130
6	0.086	0.141	0.127
7	0.088	0.141	0.127
8	0.084	0.141	0.132
9	0.080	0.142	**0.133**
10	0.068	0.141	0.123
11	0.062	0.140	0.120
12	0.065	0.139	0.121

Source: Compiled by the authors

Figures VII and VIII show the spatial cluster obtained by the LISA test (Local Moran) using nine neighbours for both public and private/subsidised schools separately (Figure VII), and for all the schools in the Community of Madrid (Figure VIII). Schools with *p values* below a significance level of á = 0.05 are included in the spatial clusters.

FIGURE VII. LISA for public schools and LISA for private schools. The spatial clusters are shown in colour and the non-significant schools in grey.



Source: Compiled by the authors

An analysis of the spatial clusters (Figure VII) of private/subsidised and public schools separately does not appear to show a clear clustering pattern. In any case, it is possible to identify a higher frequency of schools grouped in the high scores cluster in both the centre of Madrid and in some municipalities on the outskirts of the metropolitan area, such as Rivas-Vaciamadrid, Tres Cantos and Alcalá de Henares. By contrast, the schools associated with low score clusters generally appear to be located in the municipalities farthest from the municipality of Madrid, and in some districts south of the municipality. However, the analysis of the results of the clusters for all schools (Figure VIII) clearly shows the

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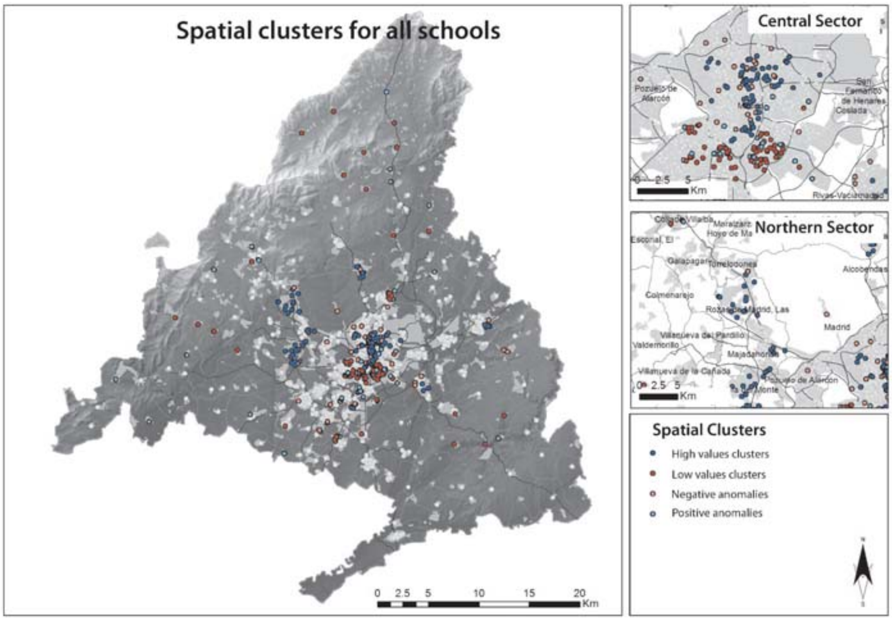
presence of spatial clusters that confirm the trend observed in the quantile maps, although probably with greater clarity.

FIGURE VIII. LISA clusters for all schools (2013/2014). The spatial clusters are shown in colour and the non-significant schools in grey.



Source: Compiled by the authors

As a result, there is a cluster of nearby schools with low CDI test scores in the Southern area of the municipality of Madrid (the districts of Puente de Vallecas, Usera and Carabanchel) and in the municipality of Parla, as well as two major clusters of schools with high scores in the centre of the municipality of Madrid (districts inside the M-30 orbital motorway and in Hortaleza, Chamartin and Ciudad Lineal) and in the municipalities of Las Rozas de Madrid, Majadahonda and Boadilla del Monte. Moreover, schools in more rural municipalities and those furthest from central Madrid, both to the North (Rascafría, Bustarviejo, etc.) and the West

(Fresnedillas de Oliva, Robledo de Chavela) and the East (Valdilecha, Perales de Tajuña) are generally also included in the low scores cluster, indicating lower scores than would be expected according to a random distribution of results.

Discussion and Conclusions

The results have revealed the influence of the spatial variable on CDI test results in a wide range of schools, by showing significant spatial clustering of both a positive and negative nature. These findings are consistent with the results obtained in other studies, such as the one performed in the United Kingdom by Gordon and Monastiriotis (2006) using similar methods.

The presence of these clusters appears to indicate the existence of a set of contextual variables operating around these clusters which significantly determined the results obtained in them, in either positive or negative terms. These clusters also seem to spatially match both: i) places with the highest incomes, with significant clusters of schools matching high scores in CDI tests in municipalities such as Las Rozas, Boadilla del Monte, etc., among those with the highest per capita income in the Community of Madrid (CoM Statistics Institute, 2012); ii) the most disadvantaged districts and municipalities in terms of income in the Community of Madrid, with these matching the most significant spatial clusters of poor results in the CoM. There is a significant overlap between these groups of low scores and districts classified as vulnerable in the Atlas of Urban Vulnerability (Ministry of Development, 2015), which include several districts in the Southern area of the city from Madrid. It should be noted that our intention is not to present the results as a list of «bad» or «good» schools, but instead this is an attempt to enhance knowledge of the aspects that influence school results - an area in which the spatial variable has traditionally been given little consideration, despite its influence (Lupton, 2006).

This finding is relevant, since it would be interesting to assess what kind of contextual variables are most closely associated with the CDI test results in the areas where these clusters are observed, and to extend this study using regression analysis to examine the possible relationship between these results and contextual variables with a clear spatial

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expression: income, families' educational level, unemployment, etc. These relationships have been examined in other studies for the Community of Madrid as a whole (Trillo, Pérez and Crespo, 2007; Ruiz, 2011) albeit without distinguishing between areas where the spatial variables have a great deal of weight (spatial clustering) and those where they do not.

However, another group of schools in the Community of Madrid has not been included in any of the spatial clusters, and has been listed as «not significant» as a result of the LISA Test. This suggests that unlike the schools included in the cluster, there is no spatial autocorrelation in the results at these schools, or at least no more of an autocorrelation than would be expected than if they were distributed randomly. This result appears to suggest that spatial contextual variables have a significant influence both in areas with higher income levels and in the most disadvantaged area, and are not relevant elsewhere. The hypothesis about the timeliness of this study and the need to identify schools that are strongly influenced by spatial variables is thereby reinforced. Otherwise, any study that analysed the relationship between contextual variables and academic performance would include both schools where spatial variables have a significant influence and those where they do not.

Another very important issue arising from the results is the identification of positive anomalies, or schools with higher scores than would be expected from their environment, because they are in a context of a neighbourhood of schools with low results. The identification of these schools provides an initial approach to the analysis of those which because of their intra-school characteristics, obtain outstanding results in an environment in which spatial contextual variables are affecting the results of all schools. These higher than expected results may highlight the existence of schools where successful initiatives are undertaken in terms of good practices by teachers (e.g. Amores and Ritacco, 2011; Cole, 2008), administrative curriculum management practices (Leithwood, 2009), leadership of management teams (Bolívar, 2005), involvement of families in their children's education (e.g. Berthelsen and Walker, 2008; Redding, 2000), etc.; so that the analysis of these practices and their relationship with the good results obtained means they can be transferred to other nearby schools located in equally vulnerable contexts. However, it is necessary to take into account that each intra-school situation has its own characteristics, which require different plans of action (e.g. Ainscow and West, 2008; Macarulla and Saiz, 2009).

As regards the limitations of this study, an exhaustive analysis comparing towns could have been performed, to explore the differences for CDI test results between subsidised/private and public schools, for example. However, the main objective of this study was to examine the spatial dimension of the results of these tests in depth.

Moreover, the method selected, with a long tradition in social sciences disciplines which handle large geographical sets, could be considered too complex compared to other methods, which have analysed the relationship between academic performance and contextual variables in many studies. However, most of those studies perform the analyses for all of the schools in a given territory (region, country, etc.) and ignore the spatial differences that may exist in certain specific areas. This could be partially remedied by a detailed analysis of the schools by administrative unit (e.g. by territorial areas or even municipalities). However, the small size of the spatial clusters identified, most of which were at a level even lower than the municipal scale, would require the use of smaller administrative units (districts or census tracts) or analyses based on spatial clusters, such as the one proposed in this study.

The final limitation refers to the need to undertake a longitudinal or multi-temporal analysis, which would enable the results of these tests to be compared over time. While data for CDI results is available for this analysis from the 2009/2010 academic year onwards, with tests designed based on the same learning standards, there are some doubts about their comparability, and it may be necessary to use instruments matching the tests during the time series.

Finally, as regards future research lines, the authors intend to explore both the differences in CDI test results in public and private/subsidised schools, adherence to the bilingual programme, etc. by analysis of variance (ANOVA); and to carry out a more in-depth examination of the relationships between socioeconomic variables and the results from a spatial perspective, by analysing the relationship between academic achievement and contextual variables in the spatial clusters identified, using techniques such as spatially weighted logistic regression (Fotheringham, Brunsdon and Charlton, 2002).

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Contact address: Francisco Aguilera Benavente. Universidad de Alcalá, Departamento de Geología, Geografía y Medio Ambiente. Colegio de Málaga, C/ Colegios, 2, 28801, Alcalá de Henares, Madrid. E-mail: f.aguilera@uah.es

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