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Spatial Demographic Aging Process through Spatial Auto Correlation and Regression

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Abstract: **This study is an attempt to assess the spatial population aging in Bangladesh using both census and survey data collected from Bangladesh Bureau of Statistics during the period 1951 to 2001. Different measures of population aging have been used for analysis. Spatial auto correlation and spatial regression model have also been used to analyse the data. It is found that the southern region is more aged than other region of the country. There exists a spatial variation of aging process when districts are considered as spatial unit. A negative relationship between the aging index and the CBR has been observed. From the spatial autocorrelation, it is found that there is a positive association among the spatial values of aging index. It is observed that the value of the AI at a given location tends to be similar to the values of that index in nearby locations. From the Spatial regression models it is observed that the spatial lag model fits the data well and supports the claim of spatial auto correlation.**

Keywords: **Spatial Demographic Aging Process, Spatial auto correlation and spatial regression model.**

1. INTRODUCTION

Spatial aging is relatively a new concept of demographic aging. It mainly concerns the population aging of all possible segments in a geographical area. The most fundamental geographic concepts are site and situation. Site refers to the characteristic features of a place, whereas situation refers to the way in which a place is connected to other places either by natural processes or by human processes, such as transportation or communication. (Gershmel, 2008).

The first law of geography is that everything is related to everything else, but near things are more related than distant things (Tobler, 1970). Population density is a fundamental measure in demographic research which is of particular interest to population geographers. It is measured by the ratio of the size of the population to the size of the geographic area that contains the population. It is an explicitly spatial concept. According to the United Nations, in 2005 the Netherlands had a population density of 395 per square kilometer, whereas Canada's population density was 3 per square kilometer. The variation in population density is striking.

Voss et al. (2004) explains that until the mid-20th century virtually all demography, in the United States at least, was spatial demography. Moreover, the field of spatial demography remained disengaged from the important trends that emerged in the 1980's in the disciplines of geography, regional science and spatial econometrics.

Many research and policy questions faced by demographers require analysis of complex patterns of interrelated social, behavioral, economic, and environmental phenomena. In addressing these questions, it is increasingly argued that both spatial thinking and spatial analytical perspectives have an important role to play (Entwisle, 2007).

Bangladesh contains an almost closed population due to lack of substantial population migration on regional or international scale, the main determinants of age structure is the course of fertility and mortality through time. Most of the studies on aging of Bangladesh emphasized on certain characteristics of the old people. Some of them are concerned with their economic, social, physical or health problems, and there is still dearth of research on particular aspect of population specially age structure and spatial aging (Elahi, 2003). In this article, an attempt has been made to identify the structural population aging of Bangladesh through time and space. It is also tried to assess the regional variation of aging with respect to geographical areas.

2. MATERIALS AND METHODS

This article uses the data from Bangladesh Bureau of Statistics (BBS). District wise age distribution is obtained from the Published Zila series of BBS for the census year 2001. Various aging measures such as proportion of elderly (P_{60}), proportion of children (P_{15}), aging index (AI) and Median age have been computed. Spatial autocorrelation coefficient (Moran's I Statistic) and Spatial regression models have been used for the better understanding of the spatial aging process in Bangladesh.

Proportion of elderly (P_{60}):

The ratio of the number of persons age 60 and over to the total population of a country at a certain time is known as proportion of elderly (P_{60}). If $N(t)$, $N_{60}(t)$ is the total population and total number of person age 60 and over of a country at time t , then the proportion of elderly is defined as

$$P_{60} = \frac{N_{60}(t)}{N(t)}$$

Proportion of Children (P_{15}):

The ratio of the number of person age below 15 to the total population of a country at a certain time is known as proportion of children. If $N(t)$, $N_{15}(t)$ is the total population and total number of person age below 15 of a country at time t , then the proportion of children is defined as

$$P_{15} = \frac{N_{15}(t)}{N(t)}$$

Aging Index (AI):

Aging measures such as proportion of elderly and proportion of children consider the elderly and children separately. But aging index (AI) considers the proportion of elderly and proportion of children simultaneously. So, it is better to understand the spatial aging process using AI.

The ratio of the total number of persons age 60 and over to per 100 persons age below 15 is known as Aging index. If $N_{60}(t)$, $N_{15}(t)$ is the total number of person age 60 and over and the total number of person age below 15 of a country at time t , then the Aging Index is defined as

$$AI = \frac{N_{60}(t)}{N_{15}} \times 100$$

Median Age (Me):

The median age of a population is that age which divides a population into two groups of the same size such that half of the total population is younger than this age and the other half older. Median age (Me) is computed by using the formula

$$Me = L + \frac{\frac{N}{2} - F}{f} \times c$$

3. SPATIAL AUTOCORRELATION

Observations made at different locations may not be independent. For example, measurements made at nearby locations may be closer in value than measurements made at locations farther apart. This phenomenon is called spatial autocorrelation. Spatial autocorrelation measures the correlation of a variable with itself through space. Spatial autocorrelation can be positive or negative. Positive spatial autocorrelation occurs when similar values occur near one another. Negative spatial autocorrelation occurs when dissimilar values occur near one another.

Spatial autocorrelation may be defined as the relationship among values of a single variable that comes from the geographic arrangement of the areas in which these values occur. It measures the similarity of objects within an area, the degree to which a spatial phenomenon is correlated to itself in space (Cliff and Ord, 1973, 1981). Thus, spatial autocorrelation is an assessment of the correlation of a variable in reference to spatial location of the variable. Moran's autocorrelation coefficient (denoted by *I*) measures the degree of spatial autocorrelation. It is an extension of Pearson's product-moment correlation coefficient to a univariate series (Cliff and Ord, 1973; Moran, 1950). The Pearson's correlation coefficient (denoted by $'r'$) between two variables x and y both of length n is:

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(y_i - \bar{y})^2}}$$

Where, $\bar{x}$ and $\bar{y}$ are the sample means of both variables. r measures whether, on average, x_i and y_j are associated. For a single variable, say x, $'I'$ will measure whether x_i and x_j, with i$\neq$ j, are associated.

In the study of spatial patterns and processes, it is logically expected that close observations are more likely to be similar than those far apart. It is usual to associate a weight to each pair ($x_i ; x_j$) which quantifies this (Cliff and Ord, 1981).

Thus, the Moran's I coefficient can be stated as follows:

$$I = \frac{n}{S_0} \frac{\sum_i \sum_j w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_i (x_i - \bar{x})^2},$$

It is based on cross-products of the deviations from the mean and is calculated for n observations on a variable x at locations i, j. where $\bar{x}$ is the mean of the x variable, w_{ij} are the elements of the weight matrix, and S_0 is the sum of the elements of the weight matrix: $S_0 = \sum_i \sum_j w_{ij}$.

4. SPATIAL REGRESSION

The general purpose of linear regression analysis is to find a linear relationship between dependent variable and a set of independent variables. The general linear regression model is expressed as $Y = X\beta + \varepsilon$, where X is a vector of independent variable, Y is dependent variable and ε is an error term. The method of Ordinary Least Squares (OLS) estimation is referred to estimate the parameters of the model. Certain assumptions about the random error term of linear regression model need to be made to estimate the parameters. But unfortunately, these assumptions may not be always satisfied. For example, when a value observed in one location depends on the values observed at neighboring locations, there is a spatial dependence. As a result spatial data may show spatial dependence in the variables and error term. One of the major reasons for spatial dependence is that the spatial dimension of social and economic may truly be an important aspect of a modeling.

Spatial regression methods capture spatial dependency in regression analysis, avoiding statistical problems such as unstable parameters and unreliable significance tests, as well as providing information on spatial relationships among the variables involved. Depending on the specific technique, spatial dependency can enter the regression model as relationships between the independent variables and the dependent, between the dependent variables and a spatial lag of itself, or in the error terms. There are two types of spatial regression model (Lloyd, 2011) such as: i) Spatial error model and ii) Spatial lag model.

Spatial lag regression model: $z = X\beta + \rho Wz + \varepsilon$

Spatial error regression model: $z = X\beta + \rho Wz - \rho WX\beta + \varepsilon$

Where, $\varepsilon \sim N(0, \sigma^2)$, ρ is the spatial autocorrelation and W is the weight matrix. When $\rho = 0$, these model reduces to regression model.

GeoDa software provides a range of diagnostics to detect spatial dependency. It provides unbiased regression estimates with Maximum Likelihood approach for spatial error model as well as spatial lag model.

5. RESULTS AND DISCUSSION

Bangladesh is one of the most densely populated countries in the world. It is divided into 64 district and each district is further subdivided into upazila/thana. The land area of Bangladesh is 148,000 square kilometre and there are 839 people live in per square kilometre (BBS, 2003).

The lowest TFR (1.96) is observed in Pirojpur district while the highest (3.3) in Nawabgonj district. The lowest CDR (3.13) is in Chuadanga while the highest (5.98) is in Magura district (Table 1). From the analysis, it is evident that there is a variation of fertility and mortality rates among the districts of Bangladesh.

According to proportion of elderly (P_{60}), the top three aged districts are Jhalkati, Manikgonj and Pirojpur. On the other hand, the lowest aged districts are Dhaka, Cox's bazar, Bandorban and Panchagarh.The highest proportion of children has been observed in Cox's bazar, Bhola, Noakali and Shariatpur district. On the other hand, the lowest proportion of children has been found in Dhaka, Gazipur, Noagaon, Meherpur and Khulna district (Table 1).

According to median age, the highest and the lowest aged districts are Noagaon and Cox,s bazar respectively. The other top aged districts are Panchagarth, Joypurhat, Meherpur, Manikgonj and Dhaka. On the other hand, Bhola and Noakhali district show the lowest aged district (Table 1).

It is observed that Cox's bazar and Manikgonj are in the bottom and top aged district of Bangladesh respectively according to AI. The district of Bargana, Bagherhat, Jahalkati and Pirojpur also show the more aged people than other region of Bangladesh (Table 1).

Thus, from the above analysis, it is clear that a huge spatial variation have been existed in district level data.

Table 1: Spatial district wise TFR, CBR, CDR and aging measures of Bangladesh Population, 2001

District	TFR	CBR	CDR	*AI	*P_{60}	*P_{15}	*Median age
Barisal	2.39	17.38	4.59	17.90	0.074	0.413	19.59
Bhola	2.40	17.50	5.36	12.33	0.057	0.461	17.3
Jhalkati	2.51	18.26	4.04	20.76	0.083	0.398	20.65
Pirojpur	1.96	18.23	5.11	20.84	0.080	0.384	21.41
Barguna	2.59	18.88	3.17	21.55	0.079	0.368	22.29
Patuakhali	2.65	19.27	4.82	17.95	0.072	0.400	20.37
Bandarban	2.81	20.52	4.22	11.81	0.048	0.403	20.14
Chittagong	2.35	17.11	5.42	14.84	0.056	0.379	20.22
Cox's Bazar	2.39	24.73	5.16	9.12	0.044	0.481	15.94
Brahmanbaria	2.81	20.50	4.45	14.93	0.068	0.455	17.49
Chandpur	2.51	18.32	4.91	17.98	0.077	0.430	18.59
Comilla	2.86	21.05	4.99	16.17	0.067	0.411	17.88
Khagrachhari	3.31	24.13	5.66	13.75	0.057	0.416	19.86
Feni	2.24	16.32	4.37	17.67	0.073	0.415	18.75
Lakshmipur	2.93	21.37	5.10	15.53	0.070	0.448	17.7
Noakhali	2.42	17.65	4.65	15.03	0.068	0.454	17.31

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Rangamati	2.68	19.55	5.30	12.84	0.051	0.393	20.56
Dhaka	2.42	17.62	4.70	13.66	0.042	0.304	23.12
Gazipur	3.00	21.86	5.21	17.19	0.059	0.341	22.78
Manikganj	2.39	17.46	5.01	22.86	0.081	0.354	22.97
Munshiganj	2.65	19.33	4.17	19.42	0.074	0.383	20.38
Narayanganj	2.22	16.22	3.53	12.32	0.050	0.404	20.07
Narsingdi	2.65	19.31	5.19	15.23	0.063	0.411	19.94
Faridpur	2.51	18.31	4.18	16.41	0.066	0.404	20.25
Gopalganj	2.10	15.32	4.36	17.11	0.071	0.415	19.43
Madaripur	2.84	20.69	4.74	17.37	0.073	0.423	19.25
Rajbari	2.37	17.30	4.63	18.36	0.072	0.390	20.75
Shariatpur	2.40	17.48	4.72	16.56	0.075	0.450	17.96
Jamalpur	2.94	21.44	4.77	15.80	0.060	0.378	22.49
Sherpur	2.53	18.42	4.27	15.16	0.062	0.406	20.8
Kishoreganj	2.74	20.01	5.24	17.46	0.069	0.397	21.04
Mymensingh	2.54	18.53	4.34	15.71	0.066	0.421	19.9
Netrokona	2.84	20.71	4.47	16.21	0.069	0.424	19.62
Tangail	2.28	16.63	4.30	20.27	0.074	0.363	22.28
Jessore	2.40	17.53	4.51	17.33	0.062	0.358	22.3
Jhenaidah	2.66	19.42	5.43	18.03	0.064	0.357	22.11
Magura	2.82	20.62	5.98	17.68	0.067	0.380	21.17
Narail	2.63	19.20	5.04	18.88	0.073	0.387	20.95
Bagerhat	2.18	15.90	4.94	21.05	0.077	0.365	22.28
Khulna	2.34	17.05	4.43	17.96	0.062	0.347	22.53
Satkhira	2.70	19.69	3.89	17.71	0.067	0.376	21.62
Chuadanga	2.71	19.76	3.13	18.88	0.073	0.387	20.95
Kushtia	2.07	15.02	4.77	18.52	0.066	0.354	22.21
Meherpur	3.07	22.45	5.01	19.48	0.065	0.334	23.08
Bogra	2.41	17.55	4.89	16.96	0.061	0.357	22.44
Joypurhat	3.03	22.12	5.81	17.53	0.060	0.341	23.18
Dinajpur	2.91	21.24	5.10	14.62	0.055	0.374	21.69
Panchagarh	2.88	21.00	4.60	13.77	0.049	0.355	23.4
Thakurgaon	2.97	21.62	4.48	12.32	0.050	0.403	20.19
Pabna	2.28	16.63	5.12	16.16	0.062	0.383	20.8
Sirajganj	2.53	18.48	5.01	14.90	0.059	0.397	20.24
Noagaon	2.39	17.41	4.44	18.91	0.061	0.323	24.06
Natore	2.48	18.11	5.39	17.27	0.059	0.341	21.24
Nawabganj	3.32	24.18	5.39	12.55	0.054	0.428	18.81
Rajshahi	2.47	18.02	5.27	15.18	0.054	0.353	22.07
Gaibandha	3.19	23.27	4.99	14.70	0.058	0.393	20.99
Kurigram	2.57	18.73	4.87	14.61	0.059	0.406	20.35
Lalmonirhat	2.65	19.35	4.92	14.34	0.055	0.380	21.44
Nilphamari	2.58	18.79	4.97	11.92	0.049	0.410	19.37
Rangpur	2.65	19.30	5.17	14.31	0.055	0.382	21.32
Habiganj	2.72	19.86	5.32	15.55	0.066	0.427	19.11
Moulvibazar	2.81	20.52	5.02	16.34	0.067	0.408	19.84
Sunamganj	2.95	21.48	4.94	15.07	0.065	0.431	18.83
Sylhet	2.36	17.24	4.63	14.66	0.062	0.421	18.87

Source: Sample and Vital Registration System 2002 (BBS, 2004) and * means the computed values of AI, P_{60}, P_{15} and median age.

Relationship between aging indices and CBR:

Correlation Matrix is a table of all possible correlation coefficients between a set of variables.

The analysis of the correlation matrix indicates that the observed relationships are not so strong (Table 2). AI is negatively correlated with CBR ($r = -0.37$) which implies that if CBR decreases, the AI increases and vise versa. Similarly, the proportion of elderly (P_{60}) is negatively correlated with CBR ($r = -0.31$). Median age is also negatively correlated with

CBR ($r = -0.16$). Therefore, it is clear that aging indices are negatively correlated with fertility and the society will be aged if fertility level decreases.

Relationship between aging indices and CDR:

The analysis of the correlation matrix indicates that the observed relationships are weak (Table 2). The AI is negatively correlated with CDR ($r = -0.216$). Similarly, the proportion of old (P_{60}) is negatively correlated with CDR ($r = -0.256$) which implies that if CDR decreases, the proportion of old (P_{60}) increases. Like AI, the median age and the proportion of children (P_{15}) are also negatively related with CDR. It is observed that all the aging indices are negatively correlated with mortality. Therefore, it is clear from the analysis that if mortality level decreases, the aging indices will be increased and the society will be gradually aged.

Relationship among conventional aging indices:

There may exist relationship among aging indices. The analysis of the correlation matrix indicates that few of the observed relationships are very strong (Table 2). It is found that peak aging index (P_{60}) is strongly positively correlated with AI ($r = 0.844$) which implies that if P_{60} increases, the AI increases. But the AI is negatively correlated with base aging index (P_{15}). Though the relationship is not so strong ($r = -0.437$), it support the idea that the society will be aged if proportion of children decreases. Again, it is observed that the AI is positively correlated ($r = 0.468$) with median age which implies that if median age increases, the AI will also increase. A very strong negative correlation ($r = -0.948$) has been observed between the proportion of children (P_{15}) and the median age. This implies that if proportion of children decreases, the median age increases. It is found that the CBR is positively correlated with CDR ($r = 0.316$). Therefore, it is clear from the analysis that AI increases, as P_{60} and median age increase. On the other hand, AI and median age increase, as P_{15} decreases.

Table 2 Correlation-matrix between aging index and determinants of population change

		CBR	CDR	AI	P60	P15	Median age
CBR	Pearson Correlation	1	0.316*	-0.374**	-0.312*	0.207	-0.160
	Sig. (2-tailed)		0.011	0.002	0.012	0.100	0.206
CDR	Pearson Correlation	0.316*	1	-.216	-0.256*	-0.011	-0.046
	Sig. (2-tailed)	0.011		0.086	0.041	0.934	0.716
AI	Pearson Correlation	-0.374**	-0.216	1	0.844**	-0.437**	0.468**
	Sig. (2-tailed)	0.002	0.086		0.000	0.000	0.000
P60	Pearson Correlation	-0.312*	-0.256*	0.844**	1	0.102	-0.038
	Sig. (2-tailed)	0.012	0.041	0.000		0.425	0.767
P15	Pearson Correlation	0.207	-0.011	-0.437**	0.102	1	-0.948**
	Sig. (2-tailed)	0.100	0.934	0.000	0.425		0.000
Median age	Pearson Correlation	-0.160	-0.046	0.468**	-0.038	-0.948**	1
	Sig. (2-tailed)	0.206	0.716	0.000	0.767	0.000	

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed).

Spatial Aging index through CBR and CDR: The spatial map of Aging index (AI) indicates that southern part of Bangladesh is more aged whereas northern and south-eastern parts are less aged than other parts of the country. It is observed that AI varies from 9.12 to 22.86 (Figure 1).

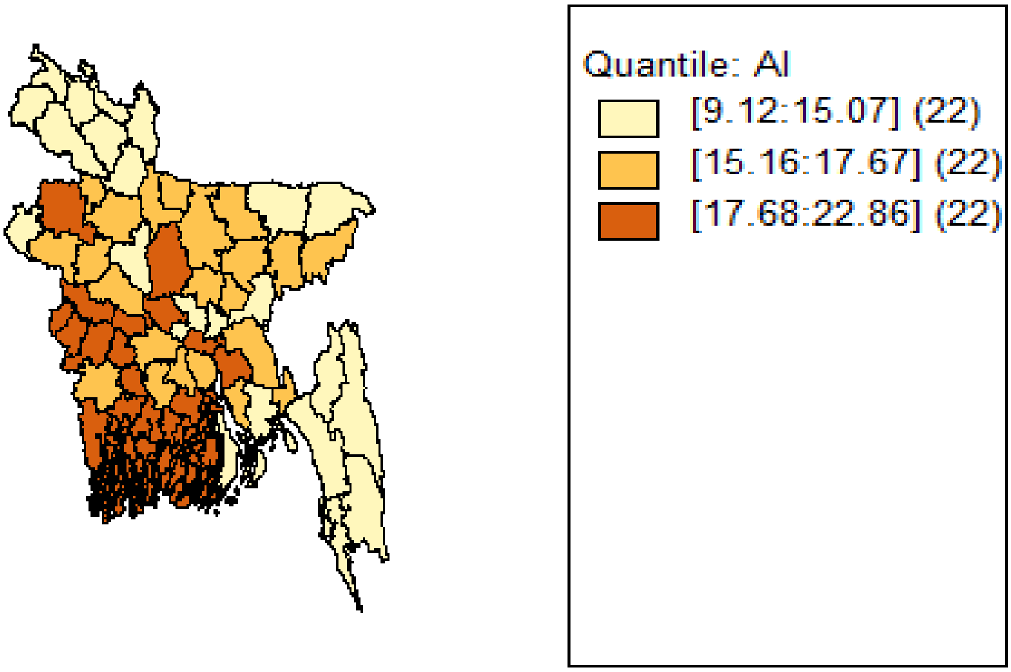

Figure 1: Spatial Population aging in Bangladesh

Generally, there is a negative relation with birth rate and aging process. The spatial map of CBR supports the hypothesis. The northern and south eastern part of Bangladesh show the high fertility rate compared to other areas. The southern part has low fertility rate and the middle part belong to the low to medium fertility. It is observed that CBR varied from 15.08 to 24.73 (Figure 2).

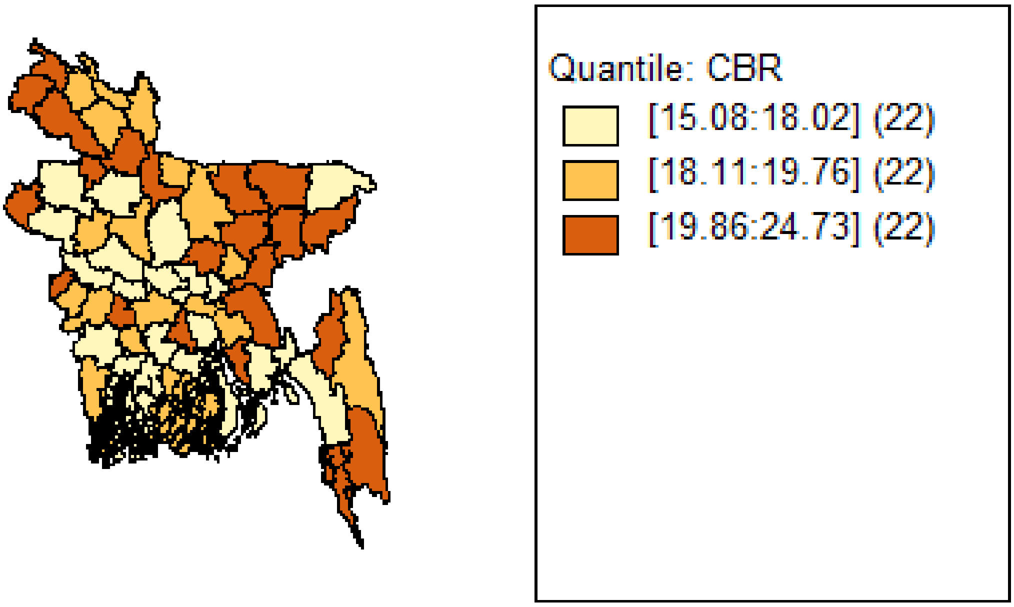

Figure 2: Spatial CBR of Bangladesh

Similarly, there is a negative relation with death rate and aging process. The spatial map of CDR supports the hypothesis. The western part and south eastern part of Bangladesh show the high mortality rate compared to other areas (Figure 3). The north and middle part of the country has low mortality rate compared to other parts of the country. It is also found that the CDR varied from 3.13 to 5.98 in 2000. Therefore it is clear from the mapping that the region with high CBR and CDR has less aged than the region with low CBR and CDR. The fertility and mortality rate plays very important role in spatial demographic aging in Bangladesh.

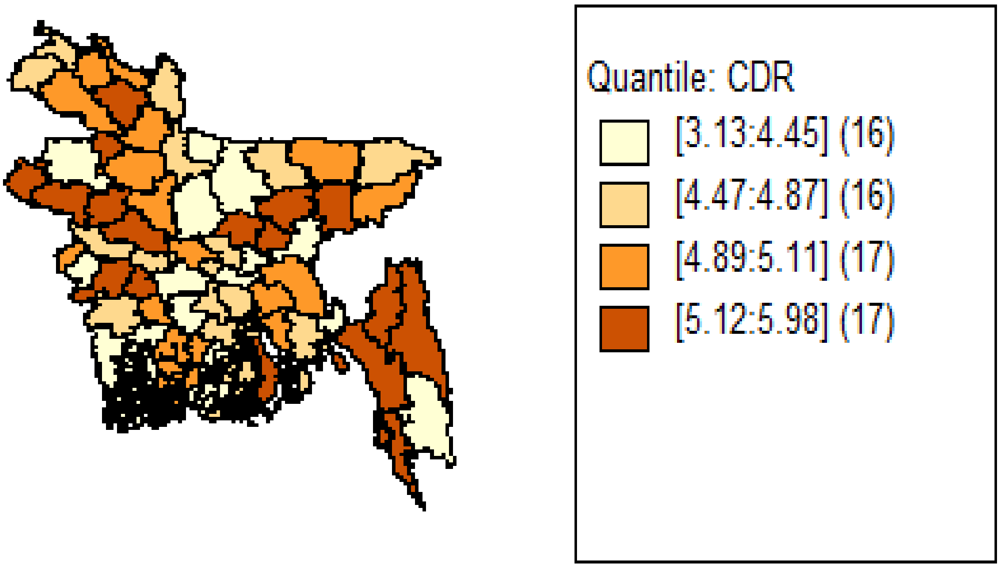

Figure 3: Spatial CDR of Bangladesh

Spatial autocorrelation in aging index:

It is very important to know that the observations are spatially dependent or not for further analysis. Moran's *I* statistic is very popular for measuring the spatial autocorrelation. From the analysis with first order queen contiguity it is found that the value of Moran's *I* statistic is 0.47 (Figure 4). It indicates that there is positive association among the spatial values of aging index. It also implies that the value of a variable at a given location tends to be similar to the values of that variable in nearby locations.

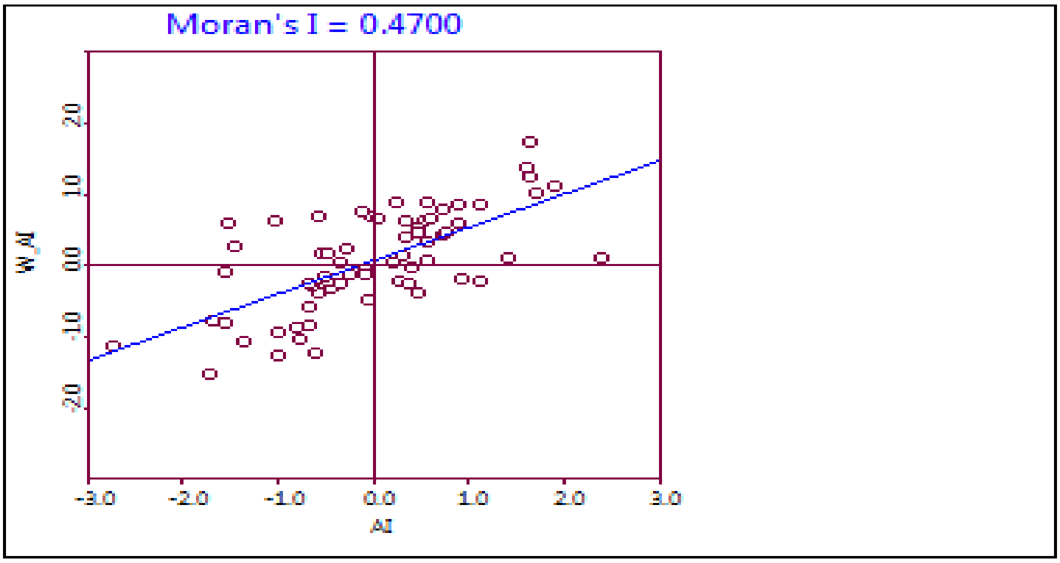

Figure 4: Plot of Moran's *I* for aging index

Spatial Regression models of aging index (AI) on CBR and CDR:

From the cluster mapping of aging index, crude birth rate and crude death rate, it is clear that the region with high birth rate and death rate represents young population. On the other hand the region with low birth rate as well as low death rate represents more aged population. A meaningful way of presenting the relation is the regression analysis technique. Three regression models have been considered. These are linear model, spatial lag model and spatial error model (Table 3). From the models, it is observed that the spatial lag model fits the data well though all the models are statistically significant as its AIC is the lowest and the log likelihood function is the highest.

Table 3: Results of Spatial Regression Models

Model	Intercept	CBR (p- value)	CDR (p- value)	AIC	Log-likelihood	R-square	Significance
Linear model	27.00 (0.0)	-0.4482 (0.00)	-0.4150 (0.49)	311.544	-152.772	0.153	0.005
Spatial Lag model	12.61(0.0)	-0.254(0.039)	-0.235(0.626)	293.623	-142.812	0.434	0.00
Spatial Error model	19.62 (0.0)	-0.156 (0.210)	-0.079 (0.873)	294.874	-144.437	0.413	0.00

6. CONCLUSION

From the spatial analysis, it is observed that the southern region is more aged than other region of the country. There exists a spatial variation of aging process. A negative relationship between the aging index and the CBR has been observed. From the spatial autocorrelation, it is found that there is a positive association among the spatial values of aging index. It also implies that the value of the aging index at a given location tends to be similar to the values of that index in nearby locations. From the Spatial regression analysis it is observed that the spatial lag model fits the data well and supports the claim of spatial autocorrelation.

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