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Studying the Effect of Spatial Variable on Kidney Failure Data in Baghdad for the SAC Model

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Abstract

In this paper, the effect of the spatial variable of kidney failure in Baghdad is studied using the general spatial autoregressive model (SAC), where the model was applied to the regular and modified spatial adjacency matrices and according to the adjacency criterion (Rook), using the estimation method represented by the maximum likelihood method, as it included the dependent variable (Y) is the number of people with creatinine in the blood, and the explained variables represent their levels after agreement with the specialized doctors as follows: (X1: Age, X2: Diabetes , X3:High blood pressure, X4: Gender, X5: Smoking). The most important results were that the data suffers from the effect of the spatial variable. It turns out that the modified spatial adjacency matrix (Rook) (Wadj) is the best in order to obtain the lowest standard value, and that the variables (X2, X3, X5) have a significant impact on Kidney failure disease in Baghdad.

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Introduction

The increasing population growth requires the study and analysis of spatial data. There are many observable phenomena, including health phenomena. The analysis of spatial data resulting from these phenomena has received great and widespread attention from researchers in recent years, even though many indicators and statistical methods may seem possible. Application in analyzing these data, but it cannot be devoid of illogicality, as the basic characteristic that distinguishes spatial data from time series data is the spatial arrangement of the observations [1]. Many data with spatial characteristics are an important source of information, and the use of spatial analysis determines for us the location, i.e. the region in which it is centered. Therefore, spatial statistical models are built and methods for estimating them are studied by calculating the dependence between observations, through which spatial information or spatial correlation between observations is found. In this research, the extent of the effect of the spatial variable on kidney failure disease was studied by taking a sample of ten areas of the city of Baghdad directly. And to identify the problem of kidney failure in terms of the identified areas and under the ROC spatial adjacency criterion for the spatial adjacency matrix, in order to estimate the general parametric spatial autoregressive model (SAC) using the modified maximum likelihood method (MLE) and relying on the explanatory variables represented by (age, diabetes, hypertension and creatinine in the blood) [7,11].

Study model

To analyze any phenomenon, an appropriate model must be built for it, that is, it represents the studied phenomenon. In this research, the general parametric spatial autoregressive model (SAC) was used, which searches for causal relationships between the factors of the studied phenomenon. The process of building the model is based on clarifying the circumstances and factors surrounding the phenomenon in light of the influences Spatial and in the form of a mathematical formula, which is as follows [5,6,]:

$$Y = \rho W_1 Y + X\beta + u$$
$$u = \lambda W_2 u + \varepsilon \qquad (1)$$
$$\varepsilon \sim N(0, \sigma^2 \varepsilon)$$

Where: Y: represents the dependent variable with dimension (nx1). X: represents a matrix of explanatory variables with dimensions (nxk). W_1 , W_2: Spatial weight matrices are represented in dimensions (nxn), as (W_1): represents the matrix of spatial adjacencies between views and adjacent areas, while (W_2) :represents the adjacencies between views and the city center. They are usually a proximity relationship or a distance function, and they are fixed and predetermined. , and they can be equal. ($W_1 = W_2$), ρ: represents the spatial dependence parameter. β: represents the vector of parameters with dimension (kx1) that are associated with the matrix of explanatory variables. λ: represents the spatial autoregressive parameter of errors i.e. the spatial lag coefficient of the error. u: spatially correlated errors [8,9].

Spatial adjacency criterion and matrix

The ROOK spatial adjacency criterion was used, and the general formula for the usual spatial adjacency matrix can be determined as [10]:

$$W_{ij} = \begin{Bmatrix} 1 & \text{if i neighbour j} \\ 0 & \text{otherwise} \end{Bmatrix} \qquad (2)$$

Through the usual spatial adjacency matrix, it is possible to find the modified spatial adjacency matrix, which is an extension of it and requires that the sum of the row be equal to one, and its formula is as follows [2]:

$$W_{ij(adj)} = \begin{cases} \dfrac{W_{ij}}{\sum W_{ij}} & \text{i neighbor j} \quad 0 < W_{ij} \le 1 \\ 0 & \text{other wise} \end{cases} \qquad (3)$$

Maximum Likelihood Estimation Method (MLE)

The probability of the joint distribution (Likelihood) of all observations is maximized with respect to the number of relevant parameters, as the estimation problems associated with spatial regression models vary with spatial lags and spatial errors [12].

An estimate in Model (1) is found by maximizing the Likelihood function:

$$L\left(\beta, \rho, \lambda, \frac{\sigma^2}{Y}, X\right) = -\frac{n}{2}\,\mathrm{Ln}2\pi - \frac{n}{2}\mathrm{Ln}\,\sigma^2 + \mathrm{Ln}|I - \rho W| + \mathrm{Ln}\,|I - \lambda W| - \frac{1}{2\sigma^2}\varepsilon'\varepsilon \qquad (4)$$

$$= -\frac{n}{2}\operatorname{Ln}2\pi - \frac{n}{2}\operatorname{Ln}\sigma^2 + \operatorname{Ln}|I - \rho W| + \operatorname{Ln}|I - \lambda W| - \frac{1}{2\sigma^2} * (I-\rho W)'Y'(I-\lambda W)'(I-\lambda W)Y(I-\rho W) - (I-\rho W)'Y'(I-\lambda W)'(I-\lambda W)X\beta - \beta'X'(I-\lambda W)'(I-\lambda W)Y(I-\rho W) + \beta'X'(I-\lambda W)'(I-\lambda W)X\beta \quad (5)$$

$$\frac{\partial\left(\beta,\rho,\lambda,\frac{\sigma^2}{Y},X\right)}{\partial\beta} = -\frac{1}{2\sigma^2}[-2X'(I-\lambda W)'(I-\lambda W)Y(I-\rho W) + X'(I-\lambda W)'(I-\lambda W)X\hat{\beta}_{mle}] \quad (6)$$

$$\frac{\partial\left(\beta,\rho,\lambda,\frac{\sigma^2}{Y},X\right)}{\partial\beta} = -\frac{1}{2\sigma^2}[-2X'(I-\lambda W)'(I-\lambda W)Y(I-\rho W) + X'(I-\lambda W)'(I-\lambda W)X\hat{\beta}_{mle}] \quad (6)$$

$$\hat{\beta}_{mle} = [X'(I-\lambda W)'(I-\lambda W)X]^{-1}X'(I-\lambda W)'(I-\lambda W)Y(I-\rho W) \quad (7)$$

Using numerical methods (Newton’s-Raphson Method) for the probability function, the value of the spatial dependence parameter (ρ) and the value of the spatial error parameter (λ) are estimated [8,12]:

$$\operatorname{Ln}|I-\rho W| = \sum_{i=1}^{n}\operatorname{Ln}(1-\rho w_i) \quad (8)$$

$$\operatorname{Ln}|I-\lambda W| = \sum_{i=1}^{n}\operatorname{Ln}(1-\lambda w_i) \quad (9)$$

$$\sigma^2 = \frac{\varepsilon'\varepsilon}{n} \quad (10)$$

Moran’s test to detect spatial dependence

In this test, the spatial dependence of the data is revealed. If the value of Moran’s coefficient is close to (1), it means the presence of spatial autocorrelation, and Moran’s formula is as follows[3]:

$$I_m = (\varepsilon' w \varepsilon)/(\varepsilon'\varepsilon) \quad (11)$$

Where W: matrix of spatial adjacencies with dimension (nxn) , n: sample size, ε: vector of random errors with dimension (n × 1).

Here, the Moran Z test is used for the purpose of knowing the value of the Moran coefficient that is statistically significant at a certain degree of confidence. Therefore, the test formula is as follows [4]:

$$Z = (I_m - E(I_m))/\sqrt{var\,(I_m)}\ , \qquad E(I_m) = tr(MW)/(n-k)\ , \quad (12)$$

$$E(I_m) = tr(MW)/(n-k)\ , \quad (13)$$

$$\mathrm{var}\,(I_m) = \frac{\mathrm{tr}(MWMW') + \mathrm{tr}(MWMW) + \left(\mathrm{tr}(MW)\right)^2}{(n-k)\,(n-k+2)} - \left(E(I_m)\right)^2 \qquad (14)$$

As: $M = I_n - X\,(X'X)\,X'$: a solid matrix that is square and symmetric. tr(MWMW'): The sum of the diagonal elements of the matrix. k: the number of independent variables.

Lagrange multiplicative test

To detect the presence of spatial dependence and the suitability of the model to the data, the Lagrange multiplier test was used for the parameter ρ as follows [3]:

$$M_\rho = \left(\frac{\varepsilon' W\, Y}{S^2}\right)^2 / D \quad ,\text{Where } D = \frac{(WXb)'M(WXb)}{S^2} + \mathrm{tr}(W'W + WW) \qquad (15)$$

S^2: Error variance of the general linear regression model.
Lagrange multiplier test formula for parameter λ [4]:

$$M_\rho = \left(\frac{\varepsilon' W\, Y}{S^2}\right)^2 / T \quad ,\text{Where } T = \mathrm{tr}\,[(w + w')w] \qquad (16)$$

To compare (LM_λ , LM_ρ) with a tabular value of $\chi^2(1, \alpha)$.

The applied aspect

Real data for kidney failure were taken randomly from the Medical City Hospital in Baghdad for the year 2019-2020. Kidney failure, which is known as the failure of the kidney to adequately filter metabolic wastes from the blood, is considered a late stage. Kidney failure occurs when kidney function decreases to less than 15% of normal levels. There are two main types of kidney failure: acute kidney failure. It is usually curable, and chronic kidney failure is usually incurable. The data was represented by the dependent variable (Y), which is represented by creatinine in the blood, and the five independent variables, which are (X_1 :Age, X_2 :Diabetes , X_3 :High blood pressure, X_4 :Gender, X_5 :Smoking), as these variables were determined by some doctors with Specialization.

Before estimating the general spatial regression model under the usual spatial adjacency matrix, Moran's test was used to detect spatial dependence and also to find some statistical indicators, which are shown in Table (1).

Table (1) shows some statistical evidence for the usual spatial adjacency matrix W_R under the Rook adjacency criterion.

F	R^2	R^2_{adj}	Z	LM_ρ	LM_λ	MAPE
27.7782	0.4927	0.4714	44.8416	9.4116	4.0367e+03	0.5384

Through Table (1), when using the usual spatial adjacency matrix W_R, it is found that the value of Moran's Z test is equal to 44.8416, which is greater than the tabular value, which is equal to (1.96) at a significance level of 0.05, and this indicates that there is spatial dependence.

Also, the value of the Lagrange test (LM_ρ) was found to be 9.4116, which is greater than the tabular value, which is equal to 3.84 at a significance level of 0.05, and this indicates the presence of spatial dependence.

Also, the value of the Lagrange test (LM_λ) is equal to 4.0367e+03, which is greater than the tabulated value, which is equal to 3.84 within the significance level of 0.05, and this indicates the presence of spatial dependence. Through the two tests (LM_ρ, LM_λ) indicates that the general spatial regression model (SAC) is appropriate to the data.

It was also shown from the F test that the calculated value at a significance level of 0.05 and the degree of freedom (1-k), which is equal to 27.7782, is greater than the tabular value, which is equal to 0.754492. This indicates that there is at least one of the independent variables that has a significant effect on the dependent variable, Y. It is also noted that the value of $R^2$is 0.4927. This indicates that 49% of the differences in the number of infected people under spatial effects are caused by independent variables, while 51% are caused by random differences.

After estimating the general spatial regression model using the maximum likelihood method under the use of the usual spatial adjacency matrix W_R and under the Rook adjacency criterion, the data were estimated for the dependent variable Y in addition to the true values, as shown in Table (2) and also the graph in Figure (1):

Table (2) shows the real and estimated values of the variable Y using the usual spatial adjacency matrix W_R under the Rook adjacency criterion.

Seq.	Y	$\hat{Y}$	Seq.	Y	$\hat{Y}$	Seq.	Y	$\hat{Y}$	Seq.	Y	$\hat{Y}$
1	1.9	3.6004	39	2.3	3.9936	77	0.8	2.1298	115	1.2	2.6833
2	1.1	2.6553	40	3	4.588	78	1.2	2.5778	116	1	2.5003
3	1.3	2.8496	41	1.83	3.2615	79	0.6	2.17	117	0.7	2.0777
4	1.9	3.3672	42	1.2	2.223	80	0.9	2.1448	118	3.2	5.1758
5	2.7	4.375	43	1.2	2.6808	81	1.7	3.416	119	0.9	2.3658
6	2.1	3.8828	44	1	2.6978	82	1.18	2.7669	120	1.83	3.8234
7	1.2	3.1075	45	1.1	2.688	83	2.5	4.0892	121	1.5	2.7522
8	1.1	2.6108	46	1.9	3.2357	84	1.8	3.573	122	1	2.4834
9	1.5	3.1258	47	0.9	2.1787	85	1	2.3645	123	0.75	2.3348
10	9.4	11.0066	48	0.6	1.9068	86	0.7	2.187	124	0.9	2.2284
11	4	5.5186	49	4.4	6.1916	87	1.1	2.4503	125	3.7	5.3411
12	0.9	2.1897	50	1	2.488	88	0.8	2.3757	126	1.3	2.5402
13	1.1	2.4792	51	1	2.5802	89	0.7	1.9059	127	2.1	3.2352
14	1.1	2.3601	52	1.4	2.6105	90	1.1	2.4856	128	0.8	2.3536
15	1	2.1369	53	6.8	8.3901	91	0.8	2.489	129	0.7	1.9739
16	1.3	3.3328	54	1	2.5591	92	1	2.6947	130	3.4	4.9711
17	0.9	3.0209	55	2.2	3.6083	93	1.18	2.4029	131	0.7	1.833
18	0.8	2.1812	56	2	4.2628	94	1.7	3.3455	132	6.1	7.7944
19	1	2.5088	57	2.7	4.3407	95	0.7	2.0486	133	1.18	2.266
20	1.9	3.2778	58	0.6	2.0646	96	1	2.4049	134	1.3	2.6091
21	1.3	2.7208	59	1.1	2.1639	97	1.3	2.8422	135	1.18	3.0132
22	1.6	3.0701	60	1.3	2.8182	98	1.1	2.8177	136	1.18	3.0893
23	0.9	2.2974	61	1	2.2245	99	1.2	2.5838	137	0.9	2.5769
24	0.8	2.3714	62	2.3	3.4577	100	1.1	2.7437	138	2.1	3.886
25	1.83	3.4762	63	1.1	2.4783	101	1.1	2.8353	139	1	2.6241
26	1.9	3.7651	64	1	2.384	102	1.18	2.8843	140	0.8	2.0622
27	1	2.9491	65	1.18	2.4584	103	1.1	2.9176	141	1.1	3.0976
28	1.3	2.7819	66	2.9	4.3663	104	1	2.1484	142	0.9	2.1933
29	5.8	7.4102	67	1.3	2.5748	105	2.3	3.6346	143	0.9	2.313
30	1.2	3.1003	68	1	2.6777	106	1.7	3.0641	144	0.9	2.2504
31	1.83	3.9163	69	1.2	2.9186	107	1.3	2.8592	145	1.7	3.1679
32	3	5.0856	70	1.83	3.6155	108	0.9	2.3323	146	0.7	1.9875
33	1	2.2059	71	0.8	1.9317	109	1.1	2.6183	147	0.7	2.0228
34	1.2	2.6119	72	0.9	2.3804	110	1.3	2.5505	148	1	2.7159
35	1	2.5746	73	1	2.9066	111	1.2	3.0996	149	1.83	3.7396
36	3.5	5.3521	74	1.3	2.9037	112	1.2	2.5713	150	0.9	2.3384
37	1	3.2219	75	1.2	2.8248	113	1.6	3.1143			
38	1	2.7683	76	0.7	2.1663	114	1.3	3.0116			

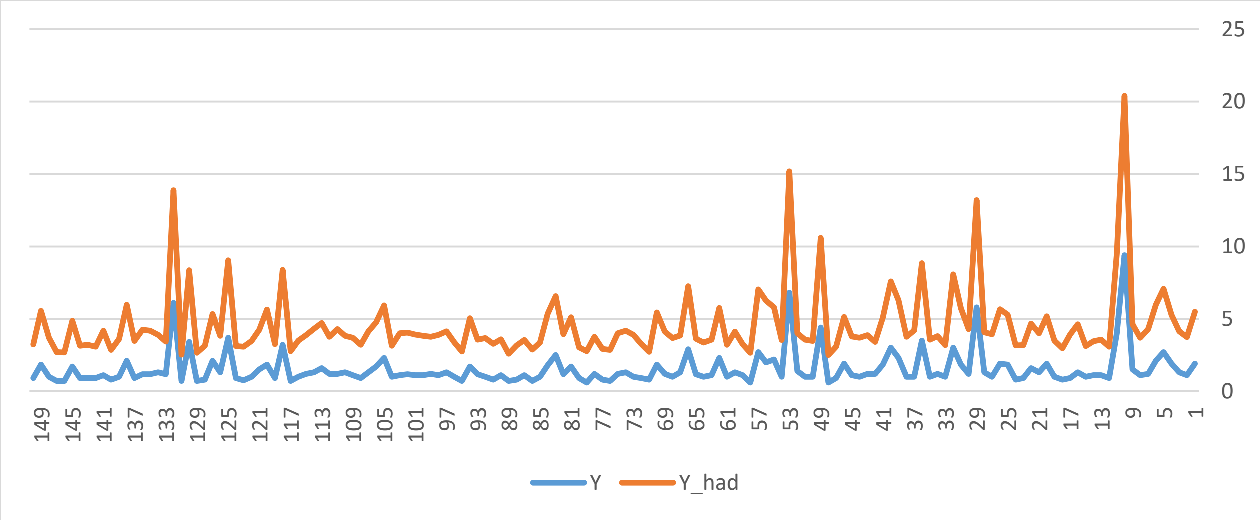

Figure (1): shows the real and estimated values of the variable Y using the usual spatial adjacency matrix W_R under Rook's adjacency criterion

Table (3): shows some statistical evidence for the modified spatial adjacency matrix W^{Adj} that induces the Rook adjacency criterion.

F	R^2	R^2_{adj}	Z	ML_ρ	LM_λ	MAPE
28.2469	0.4969	0.4758	5.8515	9.5694	3.8827e+03	0.5364

Through Table (3), when using the modified spatial adjacencies matrix W^{Adj} it is found that the value of Moran's Z test is equal to 5.8515, which is greater than the tabular value, which is equal to 1.96 at a significance level of 0.05, and this indicates the presence of spatial dependence.

Also, the value of the Lagrange test ML_ρ was found to be equal to 9.5694, which is greater than the tabular value, which is equal to 3.84 at a significance level of 0.05, and this indicates the presence of spatial dependence.

Also, the value of the Lagrange test LM_λ is equal to 3.8827e+03, which is greater than the tabulated value, which is equal to 3.84 within the 0.05 level of significance, and this indicates the presence of spatial dependence. Through the two tests (LM_ρ, LM_λ) indicates that the general spatial regression model (SAC) is appropriate to the data.

It was also shown from the F test that its calculated value at a significance level of 0.05 and the degree of freedom (k-1), which is equal to 28.2469, is greater than the tabular value, which is equal to 0.754492. This indicates that there is at least one of the independent variables that has a significant effect on the dependent variable, Y. It is also noted that the value of R^2 is 0.4969. This indicates that 49% of the differences in the number of infected people under spatial effects are caused by independent variables, while 51% are caused by random differences.

After estimating the general spatial regression model using the maximum likelihood method under the use of the modified spatial adjacency matrix W_{adj} and under the Rook adjacency criterion, the data were estimated for the dependent variable Y in addition to the true values, as shown in Table (4) and also the graph in Figure (2) below:

Table (4): shows the real and estimated values of the variable (Y) using the modified spatial adjacency matrix W_{adj} under the Rook adjacency criterion.

Seq.	Y	$\hat{Y}$	Seq.	Y	$\hat{Y}$	Seq.	Y	$\hat{Y}$	Seq.	Y	$\hat{Y}$
1	1.9	3.5894	39	2.3	3.9814	77	0.8	2.1143	115	1.2	2.6744
2	1.1	2.6443	40	3	4.5761	78	1.2	2.5646	116	1	2.4918
3	1.3	2.8387	41	1.83	3.2497	79	0.6	2.1568	117	0.7	2.0691
4	1.9	3.3563	42	1.2	2.2114	80	0.9	2.132	118	3.2	5.167
5	2.7	4.3641	43	1.2	2.6688	81	1.7	3.403	119	0.9	2.3571
6	2.1	3.8717	44	1	2.6856	82	1.18	2.7539	120	1.83	3.8146

7	1.2	3.0964	45	1.1	2.6761	83	2.5	4.0761	121	1.5	2.7436
8	1.1	2.5997	46	1.9	3.2237	84	1.8	3.5598	122	1	2.4747
9	1.5	3.115	47	0.9	2.1669	85	1	2.3515	123	0.75	2.3261
10	9.4	10.9957	48	0.6	1.8927	86	0.7	2.1739	124	0.9	2.22
11	4	5.5077	49	4.4	6.1774	87	1.1	2.4373	125	3.7	5.3323
12	0.9	2.1788	50	1	2.4742	88	0.8	2.3624	126	1.3	2.5278
13	1.1	2.4683	51	1	2.5661	89	0.7	1.8928	127	2.1	3.2226
14	1.1	2.3493	52	1.4	2.5968	90	1.1	2.4725	128	0.8	2.3409
15	1	2.1264	53	6.8	8.3761	91	0.8	2.4758	129	0.7	1.9612
16	1.3	3.3196	54	1	2.5451	92	1	2.6814	130	3.4	4.9582
17	0.9	3.0076	55	2.2	3.5944	93	1.18	2.3902	131	0.7	1.8204
18	0.8	2.1683	56	2	4.2484	94	1.7	3.3323	132	6.1	7.7814
19	1	2.496	57	2.7	4.3267	95	0.7	2.0339	133	1.18	2.2536
20	1.9	3.2649	58	0.6	2.0507	96	1	2.3901	134	1.3	2.5964
21	1.3	2.708	59	1.1	2.15	97	1.3	2.8272	135	1.18	3.0003
22	1.6	3.0571	60	1.3	2.804	98	1.1	2.803	136	1.18	3.0764
23	0.9	2.2845	61	1	2.2104	99	1.2	2.5691	137	0.9	2.5641
24	0.8	2.3582	62	2.3	3.444	100	1.1	2.7289	138	2.1	3.8731
25	1.83	3.4631	63	1.1	2.4626	101	1.1	2.8203	139	1	2.6113
26	1.9	3.7518	64	1	2.3683	102	1.18	2.8694	140	0.8	2.0493
27	1	2.9361	65	1.18	2.443	103	1.1	2.9027	141	1.1	3.0844
28	1.3	2.7687	66	2.9	4.3506	104	1	2.1338	142	0.9	2.1806
29	5.8	7.3971	67	1.3	2.5592	105	2.3	3.62	143	0.9	2.3001
30	1.2	3.087	68	1	2.6619	106	1.7	3.0495	144	0.9	2.2376
31	1.83	3.9029	69	1.2	2.903	107	1.3	2.8443	145	1.7	3.1549
32	3	5.0724	70	1.83	3.5994	108	0.9	2.3174	146	0.7	1.9746
33	1	2.1931	71	0.8	1.9162	109	1.1	2.6035	147	0.7	2.0098
34	1.2	2.6001	72	0.9	2.3645	110	1.3	2.5357	148	1	2.7027
35	1	2.5624	73	1	2.8907	111	1.2	3.0907	149	1.83	3.7264
36	3.5	5.3398	74	1.3	2.8877	112	1.2	2.5626	150	0.9	2.3253
37	1	3.2095	75	1.2	2.8091	113	1.6	3.1054			
38	1	2.7563	76	0.7	2.1506	114	1.3	3.003			

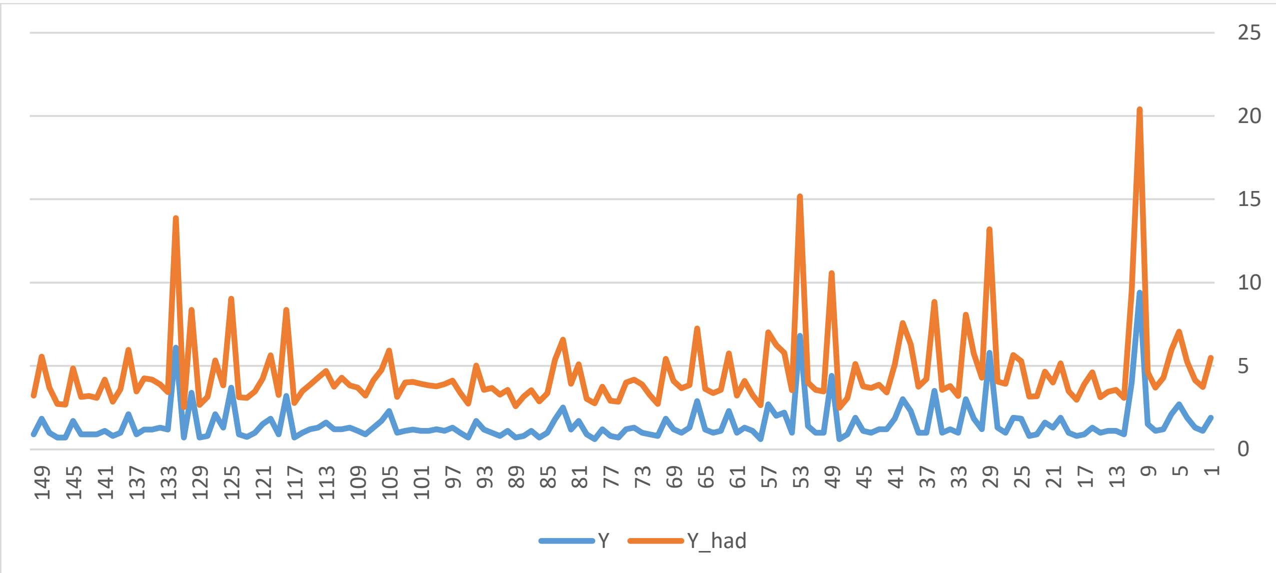

Figure (2) shows the real and estimated values of the variable (Y) using the modified spatial adjacency matrix W_{adj} under Rook's adjacency criterion

Conclusions

The most important conclusions reached by the researcher were as follows:

1. The results showed, when using the normal spatial weight matrix W_R and the modified W_{adj} , and under the Rook adjacency criterion, that the calculated Moran's Z test value is greater than the tabulated value at a significance level of 0.05, and this indicates the presence of spatial dependence.
2. The results also showed when using the regular spatial adjacency matrix W_R and the modified W^{Adj} and under the Rook adjacency criterion that the Lagrange multiplier tests are significant and this indicates the presence of spatial dependence and that the data fit the general spatial regression model.
3. Through the statistical indicators used, and when using the usual spatial adjacency matrix W_R and the modified W^{Adj} and under the Rook adjacency criterion, it was found that the F test is significant and this indicates that the differences are significant, meaning that there is at least one of the explanatory variables that has a significant impact on the dependent variable Y. It was also shown that the value of the coefficient of determination R2 in the case of the W_R matrix is equal to 0.4927 and in the case of the W_{adj} matrix it is equal to 0.4969. This indicates that 49% of the differences in the number of infected people under spatial effects are caused by independent variables, while 51% are caused by random differences.
4. The results when estimating the general spatial regression model using the usual spatial adjacency matrix W_R and under the Rook adjacency criterion showed that the estimated values in Table (3), (5) and Figure (1), (2) for the dependent variable Y are close to the true values.
5. Through the MAPE comparison criterion for the spatial adjacency matrix W_R with the spatial adjacency matrix W_{adj} , it appears that the spatial adjacency matrix $W_{adj}$is the best because it obtains the lowest value.

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دراسة تأثير المتغير المكاني لبيانات مرض الفشل الكلوي في بغداد لأنموذج SAC

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المستخلص

في هذا البحث يتم دراسة تأثير المتغير المكاني لمرض الفشل الكلوي في بغداد باستعمال أنموذج الانحدار الذاتي المكاني العام (SAC)، حيث تم تطبيق الانموذج على مصفوفتي التجاورات المكانية الاعتيادية والمعدلة وحسب معيار تجاور (Rook)، مستعملا طريقة التقدير والمتمثلة بطريقة الإمكان الأعظم، اذ تضمن المتغير المعتمد (Y) عدد المصابين بالكرياتينين في الدم وتمثل المتغيرات المفسرة مع مستوياتها بعد الاتفاق عليها مع الاطباء الاختصاص كالاتي: (X1 : العمر، X2 : السكري، X3 : ضغط الدم المرتفع، X4 : الصنف، X5 : التدخين) وأن من اهم النتائج التي تم التوصلها أن البيانات تعاني من تأثير المتغير المكاني، تبين ان مصفوفة التجاور المكاني (Rook) المعدلة (W_R) هي الافضل وذلك للحصول على اقل قيمة معيارية، وأن المتغيرات (X2، X3، X5) لها تأثير كبير على مرض الفشل الكلوي في بغداد.

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