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Studying Some Air Pollutants by Using the Nonlinear Autoregressive Distributed Lags (NARDL) Model

Haifa T. Abd	Aseel A. Rasheed
haefaa_adm@uomustansiriyah.edu.iq	aseelstat@uomustansiriyah.edu.iq

Department of Statistics, College of Administration and Economics, Al-Mustansiriyah University, Iraq

Rawaa S. Al-Saffar
rawaaalsaffar@uomustansiriyah.edu.iq
Department of Statistics, College of Administration and Economics, Al-Mustansiriyah University, Iraq

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Correspondence:
Haifa T. Abd
haefaa_adm@uomustansiriyah.edu.iq

Abstract

Air pollution is one of the major environmental risks to health, which leads to physiological damage to humans, animals and plants, air pollutants are new materials that are added to the atmosphere as a result of economic or industrial processes, such as dust, gases, and smoke, Hence the importance of this research in measuring and analyzing the relationship between some toxic gases, such as SO_2, CO, and CH_4, and its effect on suspended particles in the atmosphere, for the period from 1/1/2017 to 1/12/2020, as monthly data using the nonlinear autoregressive distributed lags model. The research concluded that there is a long-run and short-run relationship between each of these pollutants with suspended particles. Also, the negative shocks of carbon monoxide(CO) and sulfur dioxide(SO_2) gases are more effective than the positive shocks on suspended particles(PM10), while the positive effect of methane(CH_4) gas was more than the negative effect on suspended particles.

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Introduction

As temperatures rise and congestion increases, our engines continue to emit dirty emissions, half the world lacks access to clean fuels or technologies such as stoves and lamps, and the air pollution we breathe is growing dangerously: nine out of ten people now breathe polluted air, Which kills 7 million people. Air pollution has serious health implications - one third of deaths from stroke, lung cancer and heart disease are caused by air pollution.

Microscopic pollutants in the air can bypass our body's defenses, penetrate deep into our respiratory and circulatory systems, and damage our lungs, heart, and brain.

Due to the rapid environmental change, the researchers were interested in studying the environment and the proportions of air gases and their impact on the increase in environmental pollution. [1] (2022) Kumari researched the asymmetric relationship of Coved 19 and global warming through carbon dioxide, as the closure has greatly reduced carbon dioxide emissions As this unequal relationship led to a decrease in greenhouse gases.

In 2021, Sarfraz et al. [2] studied the nonlinear relationship of CO2 gas with Coved 19, new cases and confirmed deaths as dummy variables from January 30, 2020 to December 1, 2020 in India through asymmetric coefficients and long and short-term effects. The research confirmed that the unhealthy gases emitted In the air a cause of environmental destruction.

Researchers have also studied the impact of environmental pollution on economic growth, urbanization, on the use of alternative or clean energy, etc.. Hence the importance of studying the effect of SO2, CO, and CH4 gases on suspended particles PM10 by using A nonlinear Autoregressive Distributed lag (NARDL) model to study the effects of The positive and negative shocks of these variables in terms of signal and size, and the authorities must consider or limit emissions to eliminate or reduce environmental pollution.

Methodology of NARDL

The ARDL model assumes that there is a linear relationship between the explanatory variables, and it is an assumption based on scientific facts. scientist Shin[3] presented a scientific research in which he re-analyzed most of the phenomena, to conclude that there is a long-term asymmetry relationship between the explanatory variables through the NARDL model. The cointegration test is based on the symmetrical assumption that the explanatory variable linearly affects the dependent variable, which depends on estimating the long-term correlation and the fact that any variable can change in any direction, whether positive or negative, and have an effect on the independent variable. In order to clarify the asymmetry in the NARDL model, it is assumed that there are two complementary series of the same order, let them be of the first order, namely yt, zt, and they can be divided into positive particles and negative particles according to the following formula: [4]:

$$z_t = z_0 + \mathrm{z}_\mathrm{t}^+ + \mathrm{z}_\mathrm{t}^- \tag{1}$$

So that:

$\mathrm{z}_\mathrm{t}^+,\ \mathrm{z}_\mathrm{t}^-$: Refers to the partial sum of the positive and negative changes, and is calculated from the following formulas:

$$z_t^+ = \sum_{j=1}^{t} \Delta\, z_j^+ = \sum_{j=1}^{t} Max\left(\Delta z_j, 0\right) \tag{2}$$

$$z_t^- \sum_{j=1}^{t} \Delta\, z_j^- = \sum_{j=1}^{t} Min\left(\Delta z_j, 0\right) \tag{3}$$

$$y_t = \beta_1^+ z_t^+ + \beta_2^- z_t^- + u_t \tag{4}$$

Equation (4) represents the case of asymmetric regression, which shows that the long-term relationship between y_t, z_t has been entered into the model as a linear gradient relationship, and the $z_t$values are divided into negative changes and positive changes. If $\beta_1^+ \neq \beta_2^-$, it indicates The long-run effect of unit negative changes in z_tt differs in effect from positive unit changes in z_t, and the regression can be linear symmetric only if $\beta_1^+ = \beta_2^-$.

The ARDL model, which shows asymmetry relationships in the short and long term, according to the following formula:

$$y_t = \sum_{j=1}^{p} \alpha_j y_{t-j} + \sum_{j=0}^{q} \left(\beta_1^+ z_{t-j}^+ + \beta_2^- z_{t-j}^-\right) + u_t \tag{5}$$

So that: α: autoregressive parameter

β_j^-, β_j^+: Parameters of asymmetrically distributed gaps.

From equation (5), an error correction model can be derived according to [5], which is called NARDL (nonlinear distributed lag autoregressive model) and according to the formula:

$$\Delta y_t = C + \alpha_j y_{t-1} + \beta^+ z_{t-1}^+ + \beta^- z_{t-1}^- + \sum_{j=1}^{p-1} \gamma \Delta y_{t-j} + \sum_{j=0}^{q-1} \left(\theta^+ z_{t-j}^+ + \theta^- z_{t-j}^-\right) + u_t \quad (6)$$

And by using the nonlinear distributed gap autoregressive model (NARDL), the cointegration and asymmetry relationships are estimated with high efficiency, and this model is able to use variables of different order in terms of integration, whether of zero degree I (0) or of the first order I (1), but the most important thing is that it is not stable at the second difference I (2), which is one of the most important conditions for using NARDL. [4]

- **The stages of estimating the model in an equation**
  - ***Estimating long-term parameters through short-term parameters*****:** according to the following formulas:

$$\mathrm{L}x^+ = \frac{\hat{\beta}^+}{\alpha}$$
$$\mathrm{L}x^- = \frac{\hat{\beta}^-}{\alpha} \quad (7)$$

  - ***Wald test:*** This test is used to test long-term and short-term symmetry. The purpose of this test is to determine whether there is an asymmetric effect, meaning that any effect in positive changes differs from the effect of negative changes. According to this test, whether the parameters of positive changes are equal to the parameters of negative changes or not.? Or, in other words, is the relationship between the dependent and independent variable linear or non-linear? This will be done according to the following tests: [5,6]

Short-term symmetry test, and this is done through the $\left(\theta_j^+ = \theta_j^-\right)$ test, by means of the Wald test. If the short-term symmetry hypothesis is rejected, then equation (5) will be put into the form of (NARDL) in the long run in the form of the following equation(6):

$$\Delta y_t = C + \alpha y_{t-1} + \beta^+ z_{t-1}^+ + \beta^- z_{t-1}^- + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{j=0}^{q-1} \theta_j \ \Delta z_{t-j} + u_t \quad (8)$$

While the long-term symmetry test will be done through the $(\beta^+ = \beta^-)$relationship test, also through the Wald test, if the long-term symmetry hypothesis is rejected, then equation (5) will be put in the form The (NARDL) model in the short term is as follows [7]:

$$\Delta y_t = C + \mu y_{t-1} + \beta \ \ e_{t-1} + + \sum_{j=1}^{p-1} \gamma_j \Delta y_{t-j} + \sum_{j=0}^{q-1} (\theta_j^+ \Delta z_{t-1}^+ + \theta_j^- \Delta z_{t-1}^-) + u_t \quad (9)$$

  - **Measurement of dynamic complications:** These multiples represent the amount of influence on the dependent variable as a result of changing each of $x^-, x^+$by one unit and can be expressed as follows:

$$x_h^+ = \sum_{j=0}^{h} \frac{\delta\omega_{t+j}}{\delta x_t^+}$$
$$x_h^- = \sum_{j=0}^{h} \frac{\delta\omega_{t+j}}{\delta x_t^-} \quad (10)$$

So that:

$$h \to \infty \ then \begin{matrix} x_h^+ \to L\, x^+ \\ x_h^- \to L\, x^- \end{matrix}$$

The practical side

- ***Data collection***

Data from the Ministry of Planning website were used, which represent some air pollutants, including SO_2, CO, CH_4, and the effect of each type of these pollutants on suspended particles (PM10) for the period from (1-2017 to 12-2020).

- ***Description of the research sample***

1. SO_2 This gas is generated from the combustion of coal and oil in electric power plants, or in home heating, as well as incinerators in hospitals, as well as factories such as oil and paper factories and others. This gas affects human health, especially the respiratory system, and causes many diseases such as asthma, bronchitis, and lung cancer.
2. CO, which is one of the gases generated from the partial oxidation process, and organic compounds, it occurs when oxygen is scarce and in enclosed spaces, or when fires occur, it affects people in general, especially children, pregnant women, and the elderly, where this gas leads to brain damage.
3. CH4 is a strong gas and remains in the atmosphere for about nine years, it contributes to global warming by half of what CO2 contributes, CH4 gas is generated from natural sources, such as rotting plants in swamps, or due to human or industrial activities, it causes heart disease, asthma, and birth defects in newborn babies.
4. PM10 suspended particles, which are any substances dispersed in the air, which may be solid, liquid, or gases, and are transmitted in the air by weather factors to long distances, and affect lung functions.

- ***Analyze and interpret the results***

We note from Figure (1) and Table (1), that the time series of the variables are stable and do not need to take differences, this is evident from my exams, A.D.F and P.P., as the P-Value is less than 0.05, This confirms the rejection of the null hypothesis, that the time series are not stationary, and accept the alternative hypothesis, that the time series is stationary.

Table (1): Test (A.D.F. & P.P) for the four time series

	A.D.F. Test		**P.P. Test**	
Variables	T- Statistic	P-Value	T- Statistic	P-Value
PM10	-3.242999	0.0236	-3.242999	0.0236
SO2	-6.430578	0.000	-6.423885	0.000
CO	-3.107127	0.0328	-3.316503	0.0197
CH4	-3.859197	0.0046	-3.891762	0.0042

To test the existence of a long-term equilibrium relationship, between each explanatory variable (SO_2, CO, CH_4), with the dependent variable PM10, using the Wald test, and relying on the value of F, and compare it with the critical values for the upper limit at a significant level of 0.05, as shown in Table (2), This proves the existence of a long-term equilibrium relationship for the positive and negative shocks of the three gases and their impact on suspended particles (PM10).

Table (2): Bounds Test for Nonlinear Cointegration

Variable	**F-Statistic**	**95% Lower bound**	**95% Upper bound**
SO2	10.89738	3.1	3.87
CO	4.326926	3.1	3.87
CH4	3.962224	3.1	3.87

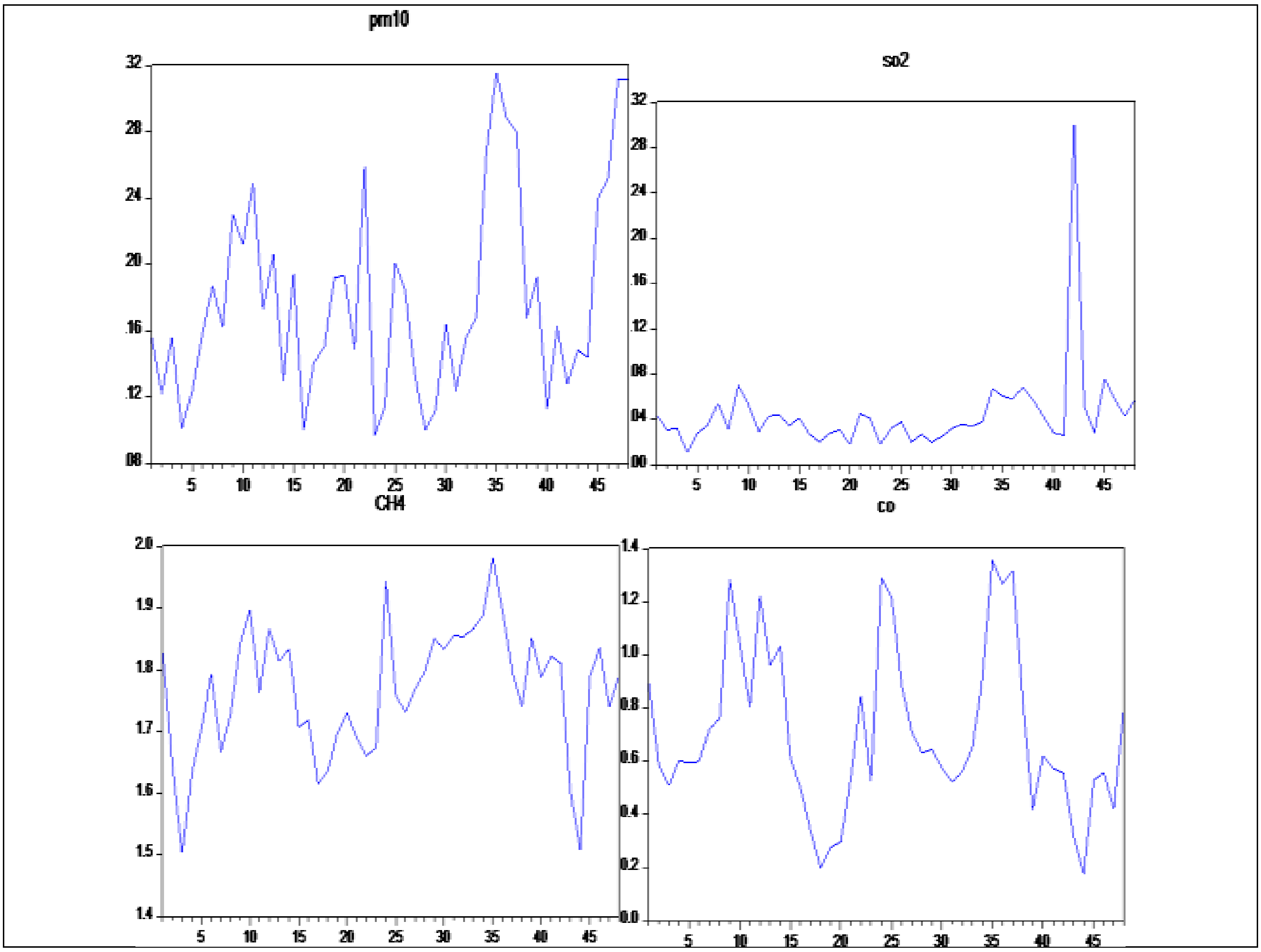

Figure (1): Graph of time series (PM10, SO_2, CO, CH_4)

The negative shocks of (SO_2) gas are significant with (PM10). The negative shocks of (SO_2) gas are significant with (PM10), when there is no slowdown period, and this is clear from Table (3), when the percentage of SO_2 gas in the atmosphere decreases by one unit, the PM10 decreases by (3.412322).

As for the negative shocks of CO gas, they are significant with (PM10) in the air, when there is one slowing period, That is, when the percentage of (CO) in the atmosphere decreases by one unit, the percentage of (PM10) decreases by (0.133552).

While the positive shocks of CH4 gas have a positive relationship with (PM10), when there is no slowdown period, where we notice, when the percentage of (CH4) gas in the atmosphere increases by one unit, the value of (PM10) increases by (0.192031).

Table (3): Estimating the effect in the short term of suspended particles with gas (SO2, CO, CH4)

Variable	Coefficient	Std. error	T-Statistic	Prob.
C	0.212138	0.036762	5.770615	0.0000
PM10(-1)	-1.042780	0.170786	-6.105780	0.0000
SO2-POS(-1)	2.928890	0.613059	4.777497	0.0000
SO2-NEG(-1)	2.846670	0.623152	4.568176	0.0001
D(PM10(-1))	0.200556	0.151808	1.321114	0.1946
D(PM10(-2))	0.382515	0.126099	3.033451	0.0044
D(SO2-POS)	-0.016810	0.148147	-0.113468	0.9103
D(SO2-NEG)	3.412322	0.688261	4.957891	0.0000

Variable	Coefficient	Std. error	T-Statistic	Prob.
C	0.096772	0.035481	2.727432	0.0097
PM10(-1)	-0.533145	0.217133	-2.455389	0.0189
CO-POS	0.042865	0.029131	1.471446	0.1496
CO-NEG(-1)	0.032005	0.027371	1.169285	0.2498
D(PM10(-1))	-0.090978	0.216461	-0.420297	0.6767
D(PM10(-2))	0.227539	0.159854	1.423421	0.1630
D(CO-NEG)	0.081532	0.055585	1.466801	0.1509
D(CO-NEG(-1))	0.133552	0.058203	2.294592	0.0275

Variable	Coefficient	Std. error	T-Statistic	Prob.
C	0.097232	0.033323	2.917846	0.0059
PM10(-1)	-0.651839	0.173693	-3.752811	0.0006
CH4-POS	0.192031	0.086210	2.227484	0.0319
CH4-NEG(-1)	0.172458	0.088725	1.943725	0.0594
D(PM1O(-1))	0.154552	0.183895	0.840433	0.4059
D(PM10(-2)	0.340430	0.149636	2.275051	0.0286
D(CH4-NEG)	-0.149458	0.133524	-1.119334	0.2700

Through Table (4) and Figure (2), the relationship between the positive and negative shocks of (SO_2) gas is significant at the level (5%), which indicates that the proportion of (PM10) has been affected by (SO_2) gas in the long term.

As for (CH4) gas, we notice that the relationship between positive shocks is significant with (PM10), and the relationship between negative shocks is not significant with (PM10) in the long term.

As for the relationship between the positive and negative shocks of (CO) gas, it is not significant at the level (5%), which indicates that (PM10) is not affected by (CO) gas in the long term.

Table (4) Estimating the long-term effect of suspended particles with gas (SO2, CO, CH4)

Variable	Coefficient	Std. error	T-Statistic	Prob.
SO2-POS	2.808733	0.489463	5.738401	0.0000
SO2-NEG	2.729887	0.500576	5.453486	0.0000
C	0.203435	0.012653	16.07800	0.0000

Variable	Coefficient	Std. error	T-Statistic	Prob.
CO-POS	0.080400	0.043310	1.856381	0.0714
CO-NEG	0.060030	0.042313	1.418717	0.1644
C	0.181512	0.031979	5.675928	0.0000

Variable	Coefficient	Std. error	T-Statistic	Prob.
CH4-POS	0.294600	0.132626	2.221281	0.0324
CH4-NEG	0.264571	0.136923	1.932271	0.0608
C	0.149166	0.029212	5.106281	0.0000

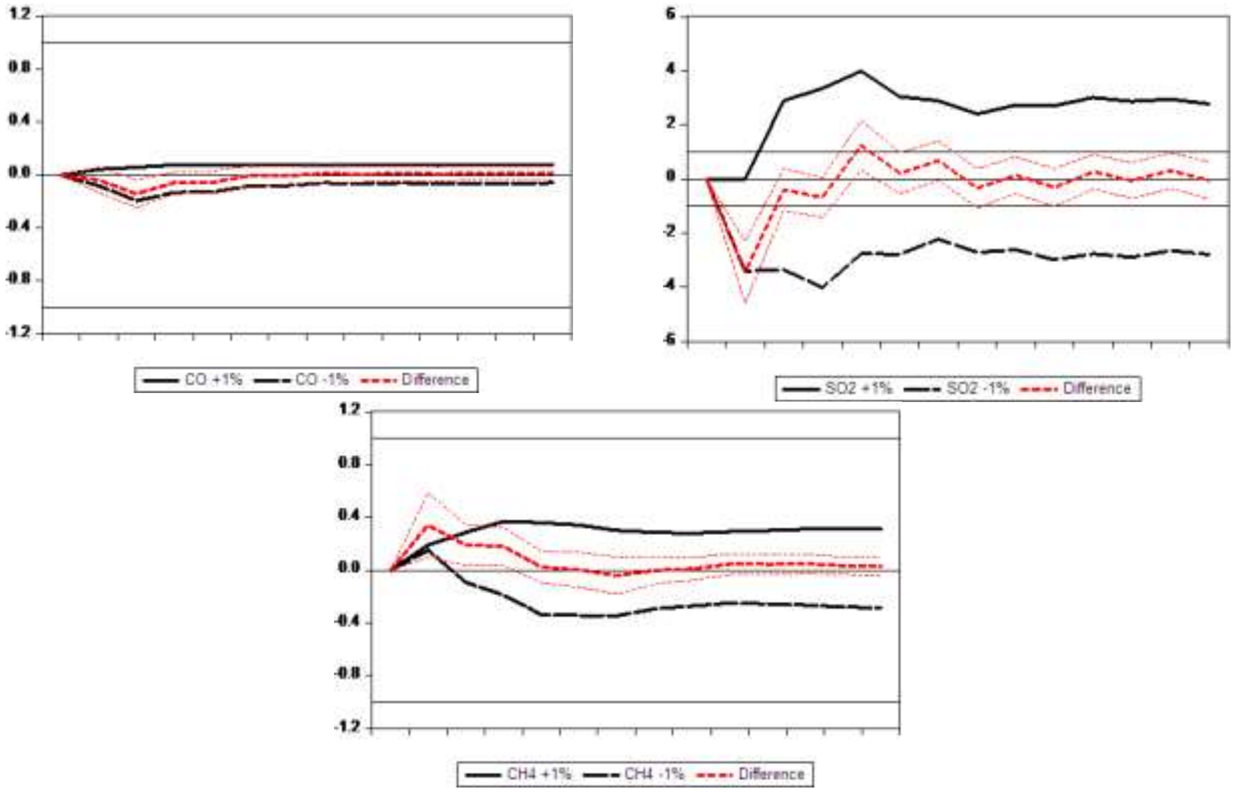

Figure (2): Multiplier

Table (5): Estimates of the error correction model for the three gases

Variable	Coefficient	Std. error	T-Statistic	Prob.
D(PM10(-1))	0.200556	0.131010	1.530843	0.1343
D(PM10(-2))	0.382515	0.113408	3.372909	0.0018
D(SO2-POS)	-0.016810	0.134212	-0.125249	0.9010
D(SO2-NEG)	3.412322	0.509887	6.692314	0.0000
COINTEQ(-1)	-1.042780	0.151905	-6.864677	0.0000

Variable	Coefficient	Std. error	T-Statistic	Prob.
D(PM10(-1))	-0.090978	0.141810	-0.641548	0.5251
D(PM10(-2))	0.227539	0.130390	1.745060	0.0893
D(CO-NEG)	0.081532	0.046280	1.761700	0.0864
D(CO-NEG(-1))	0.133552	0.047090	2.836068	0.0074
COINTEQ(-1)	-0.533145	0.123253	-4.325625	0.0001

Variable	Coefficient	Std. error	T-Statistic	Prob.
D(PM10(-1))	0.154552	0.170871	0.904495	0.3714
D(PM10(-2))	0.340430	0.139366	2.442697	0.0193
D(CH4-NEG)	-0.149458	0.106249	-1.406675	0.1676
COINTEQ(-1)	-0.651839	0.157631	-4.135230	0.0002

We note from Table (5), that there is a co-integration between the variables, as the results of the error correction model showed, The values of the coefficients are negative and significant at the level (5%), for the three gases (SO_2, CO, CH_4), that is, the deviations in the balance of (PM10) value are corrected in the following month by 100% for SO_2, 53% for CO, and 65% for CH_4.

Finally, in order to test the stability of the Nardl model, cusum test was plotted. We note the occurrence of the graph of the study variables within the critical limits at a significant level (5%), and this indicates that the parameters are stable during the research period.

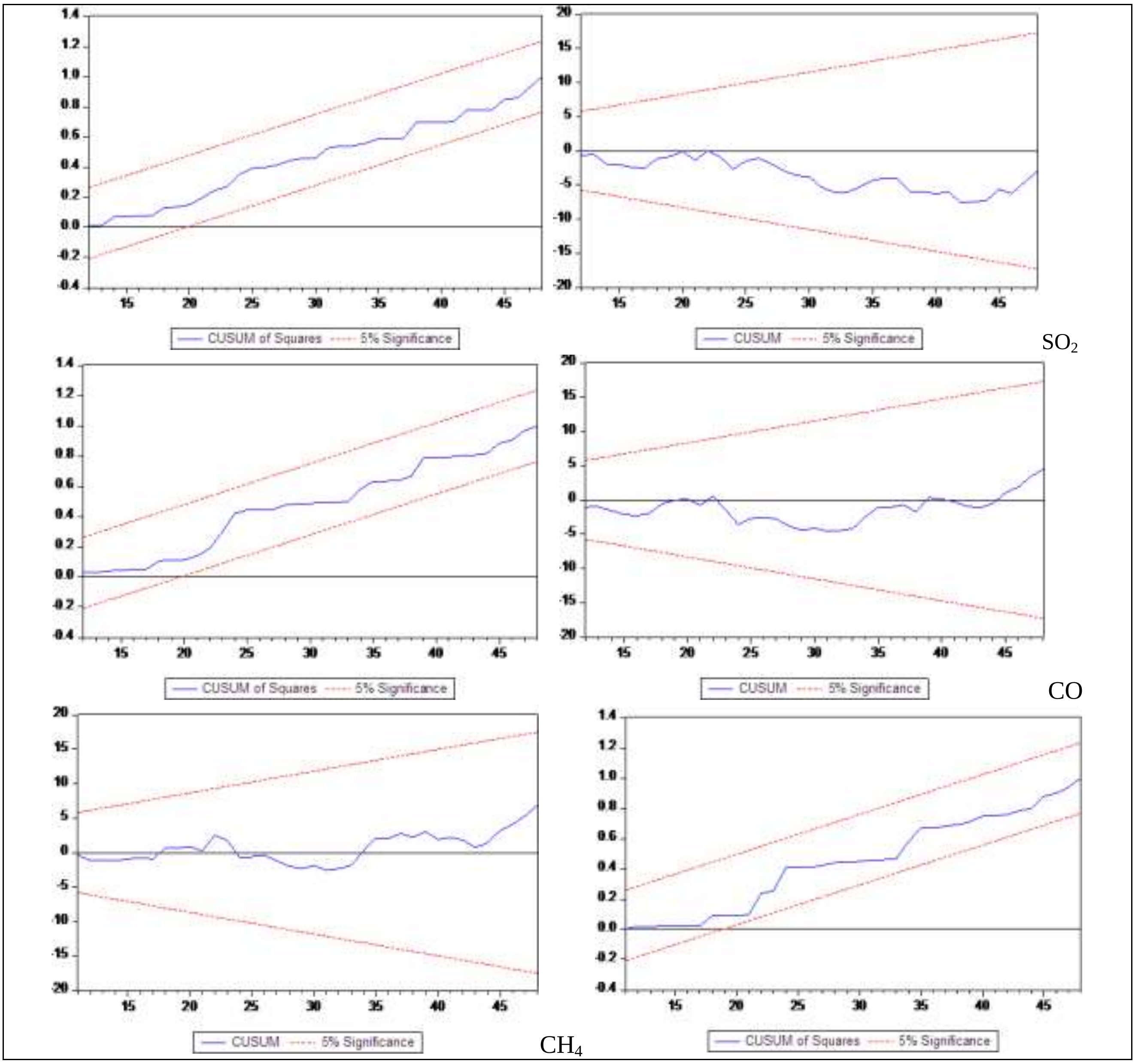

Figure (3): cusum test and cusum of Square

Conclusions and recommendations

1. There is a long-term balanced relationship between gases (SO_2, CO, CH_4) and the value of (PM10) in the atmosphere.
2. There is an effect of the negative shocks of (SO2, CO) gas more than the positive shocks on the value of (PM10).
3. There is an effect of the positive shocks of (CH4) gas more than the negative shocks on the percentage of (PM10) in the atmosphere, this means that an increase in (CH4) gas leads to an increase in the percentage of (PM10).
4. There is an effect of (SO2, CH4) gases on (PM10) in the long run.
5. The stability of the NARDL model for all study variables with (PM10).
6. Paying attention to the treatment of air pollutants, through the use of renewable energy sources, such as solar energy and wind energy, as an alternative to fuel.
7. Providing more accurate data by increasing the number of stations, for the purpose of enhancing monitoring of air pollutants in the Iraqi governorates.

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دراسة بعض ملوثات الهواء باستخدام نموذج الانحدار الذاتي الموزع (NARDL)

أسيل عبد الرزاق رشيد	هيفاء طه عبد
aseelstat@uomustansiriyah.edu.iq	haefaa_adm@uomustansiriyah.edu.iq
قسم الاحصاء - كلية الادارة والاقتصاد - الجامعة المستنصرية، بغداد، العراق	
روا ء صالح الصفار	
rawaaalsaffar@uomustansiriyah.edu.iq	
قسم الاحصاء - كلية الادارة والاقتصاد - الجامعة المستنصرية، بغداد، العراق	

المستخلص

يعد تلوث الهواء من أكبر المخاطر البيئية على الصحة، حيث يؤدي إلى أضرار فسيولوجية للإنسان والحيوان والنبات، وملوثات الهواء هي مواد جديدة تضاف إلى الغلاف الجوي نتيجة العمليات الاقتصادية أو الصناعية، مثل الغبار والغازات، والدخان، ومن هنا تأتي أهمية هذا البحث في قياس وتحليل العلاقة بين بعض الغازات السامة، مثل ثاني أكسيد الكبريت، وأول أكسيد الكربون، والميثان وتأثيرها على الجزيئات العالقة في الغلاف الجوي، للفترة من 1/1/2017 إلى 1/1/2017. /2020/12، كبيانات شهرية باستخدام نموذج الانحدار الذاتي غير الخطي للتأخر الموزع. وخلص البحث إلى أن هناك علاقة طويلة المدى وقصيرة المدى بين كل من هذه الملوثات والجزيئات العالقة. كما أن الصدمات السلبية لغازات أول أكسيد الكربون (CO) وثاني أكسيد الكبريت (SO2) أكثر فعالية من الصدمات الإيجابية على الجسيمات العالقة (PM10)، بينما كان التأثير الإيجابي لغاز الميثان (CH4) أكثر من التأثير السلبي على الجسيمات العالقة (PM10).

معلومات البحث

تواريخ البحث:
تاريخ تقديم البحث: 2022/12/12
تاريخ قبول البحث: 2023/2/26
تاريخ رفع البحث على الموقع: 2023/12/31

الكلمات المفتاحية:
تلوث الهواء، نموذج ARDL غير الخطي، SO2، CO، CH4، PM10

للمراسلة:
هيفاء طه عبد
haefaa_adm@uomustansiriyah.edu.iq

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