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Estimating Climate Influence Of The Potential Covid-19 Pandemic Spreading In Algeria

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Sabah Fadel, ORCID ID: https://orcid.org/0000-0002-4247-922X

Associate Professor, High National School of Management, Algeria.

Khaled Rouaski, ORCID ID: https://orcid.org/0000-0002-2265-2224

Professor, High National School of Statistics and Applied Economy, Algeria.

Ahmed Zakane, ORCID ID: https://orcid.org/0000-0002-0349-4259

Professor, High National School of Statistics and Applied Economy, Algeria.

Asmaa Djerboua

Master's Degree, High National School of Statistics and Applied Economy, Algeria.

Abstract

This document aims to investigate the potential influence of climate on the spread of the COVID-19 pandemic, the direct and indirect effects of climate are felt all over the planet, although their magnitude and manifestations vary. According to estimates by the World Health Organization (WHO), climate change could be the cause of nearly 250,000 additional deaths per year worldwide between 2030 and 2050 (Word Health Organization, 2021). This study focused on examining the relationship between climate (Temperature, humidity, and wind speed) and hospitalizations due to COVID-19 in a well-selected sample of wilayas in Algeria. In this brief, we want to shed light on the likely course and geographic spread of the epidemic. The purpose of this article is to answer the main question of the study: We do this by examining the effect of climate (temperature, humidity, and wind speed) on hospitalizations due to COVID-19 in the wilayas of Algiers, Blida, Oran, Adrar, Setif and Tamanrasset. The choice of wilayas is based on the availability, quality, and consistency of the data required. Our analysis suggests that high temperature and humidity or high relative wind speed tend to hamper the spread of the virus and that a high population density tends to facilitate its transmission. This does not mean that higher temperatures are enough to contain the disease. The climate potentially plays a role in the spread of many respiratory viruses. It appeared important to know if this could also be the case for the new coronavirus, COVID-19. While the role of climate in the transmission is still difficult to quantify, it is clear that other factors are taken into account in the transmission of COVID-19, namely mainly compliance with the rules of physical distancing and barrier gestures. This study focused more particularly on the effects of absolute climate (Temperature, humidity, and wind speed). 90% of infections would have occurred in areas where the temperature is between 3 and 17 degrees and the absolute humidity is between 4 and 9 g / m3, 35 to 85% relative humidity (Bukhari Q., Jameel Y., 2020). We address the issue of the impact of climate on the spread of COVID-19, we use the SUR (Seemingly Unrelated Regression) model to estimate the relationship between climate and COVID-19 cases in Algeria during the period between April 18th, 2020, and April 17th, 2021 inclusive. The results of the SUR model estimate, also showed that there is no real climate that can damage the pandemic situation in Algeria during the period studied.

Keywords: Covid-19, pandemic, Seemingly Unrelated Regression (SUR), climate, temperature, humidity, wind speed.

JEL Classification: I12, C32, C51, C52.

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I. Introduction

The coronavirus, dubbed COVID-19 on February 11th, 2020, has traveled since the first onset of symptoms in a resident of Hubei province, China. On December 31st, the World Health Organization (WHO) was informed of an outbreak of "pneumonia of unknown cause" in the city of Wuhan, China's seventh-largest city with 11 million people. The first infected individuals had all been at a seafood market in Wuhan. The market has been closed since January 1st, 2020. The first onset of symptoms outside of China was in Thailand on January 13th, less than two weeks after the outbreak began. It was a Chinese traveler who carried the virus. The East Asian country, however, contained the disease well. As of December 17th, 2021. On January 24th, Europe identifies three first cases. These are three French who stayed in Wuhan. The first death outside Asia also occurred in France on February 15th. Since then, the virus has spread to a majority of countries on the European continent. The first case identified in North America dates back to January 22nd, in the United States. The spread has since accelerated. The virus is now present in more than 190 countries on five continents. As of December 17th, 2021, 273,651,528 cases of COVID-19 have been confirmed and more than 5,343,300 people have died (WHO 12/17/2021).

In Algeria, the first positive case of COVID 19 was declared on February 25th, 2020. Six weeks after the epidemic entered Algeria, and in the latest official statistics announced by the Algerian Ministry of Health on April 9th, 2020, the number of registered cases reached 1666 cases distributed over 45 wilayas across the country, and the number of deaths reached 235 deaths distributed over 36 wilayas across the country. The Ministry of Health has 347 cases of recovery distributed over 13 wilayas across the country. Here we note a large discrepancy in the number of wilayas compared to the three variables: the number of cases, the number of deaths, and the number of cases of recovery (Rouaski, K., 2020). These are statistically significant numbers, as the virus started from Blida, with its first case recorded on February 29, 2020, and in Algiers, the first case was recorded on March 1st, 2020 (with an estimated time range of four days), to spread to the rest of the wilayas (the first case in Tizi Ouzou on March 11th, 2020, the first case in Setif on March 17th, 2020, the first case in Oran on March 18th, 2020, the first case in Bejaia on March 17th, 2020, the first case in El Borj on March 17th, 2020, and so on, bringing the virus to 48 wilayas) (Rouaski, K., 2020). As of December 17th, 2021, 214,044 cases of COVID-19 have been confirmed and more than 6175 people have died (Algerian Ministry of Health 12/17/2021).

From several studies, we know that environmental conditions have an impact on the transmission and survival of viruses responsible for respiratory diseases such as influenza and SARS viruses (Tamerius et al., 2013; Yuan et al., 2006; Denes K.A. Rosario and al., 2020). In addition, conditions such as temperature, humidity, and wind speed according to the different countries affected by the pandemic. Knowing the role of climatic conditions in the transmission of the COVID-19 virus is of crucial importance to raise awareness about preventing the spread of the disease. Therefore, this article assessed the relationship between the potential influence of climate and the spread of the COVID-19 pandemic in Algeria.

We take a population health approach and report the results of a SUR model of the incidence of COVID-19 in the six selected wilayas (Algiers, Blida, Oran, Adrar, Setif, and Tamanrasset) of Algeria. We combine data on reported cases of the disease with meteorological information, to create a spatiotemporal data set spanning 365 days. We then join this dataset at the regional level (By Wilaya) to control our key climate variables. These data are analyzed using a spatial unrelated regressions (SUR) approach, which allows us to model the incidence of COVID-19 as a contagion process.

1. Literature Review

An important question in the research literature is whether or not are weather conditions one of the factors of Covid-19 transmission and development disease? From April, contacts with members of the French Society of Disaster Medicine (SFMC) have made conceive of the idea of less development of the epidemic in the intertropical zone, in particular in the departments overseas. The study of the evolution of the epidemic in the intertropical zone compared to that of temperate countries could it bring arguments in favor of weather-sensitivity Covid-19?. An investigation has been launched, including French departments and African countries in which were available members or correspondents of the SFMC. The aim was to identify epidemiological data on Covid-19 and local weather factors. The comparison with two temperate countries, France and Italy, was retained. The academy of medicine supported this initiative which gave rise to a recommendation (Henri Julien, Claude-Pierre Giudicelli, Jean-Pierre Carpentier, 2020).

The novel coronavirus (2019-nCoV) has spread rapidly to multiple countries and has been declared a pandemic by the World Health Organization. While the influenza virus is affected by weather, it is unknown if COVID19 is similarly affected. In the work of (Qasim Bukhari and Yusuf Jameel.,2020), they analyze the patterns in local weather of the regions affected by the 2019-nCoV virus until March 22, 2020. 83% of testing have been conducted in non-tropical countries (30N and above), and 90% of the 2019-nCoV cases have been recorded in the same countries within a temperature range of 3 to 17C. Similarly, ~72% of the measurements were done in countries with humidity between 3 and 9g/m 3, and 90% of the cases were observed within the same range of absolute humidity (AH). The higher number of tests and global connectivity of the northern-cooler countries may explain the difference in the number of confirmed 2019-nCoV cases between cooler and warmer-humid regions. Nonetheless, several countries between 30N and 30S such as Australia, UAE, Qatar, Singapore, Bahrain, Qatar, and Taiwan have performed extensive testing per capita and the number of positive 2019-nCoV cases per capita is lower in these countries compared to several European countries and the US. The results of the work in no way suggest that 2019-nCoV would not spread in warm humid regions and effective public health interventions should be implemented across the world to slow down the transmission of 2019-nCoV (Qasim Bukhari and Yusuf Jameel, 2020).

In a recent study that discusses the relationship between COVID-19 and weather in a tropical country. This study aimed to evaluate the relationship between weather factors (temperature, humidity, solar radiation, wind speed, and rainfall) and COVID-19 infection in the State of Rio de Janeiro, Brazil. Solar radiation showed a strong (-0.609, $p < 0.01$) negative correlation with the incidence of novel coronavirus (SARS-CoV-2). Temperature (maximum and average) and wind speed showed a negative correlation ($p < 0.01$). Therefore, in this studied tropical state, high solar radiation can be indicated as the main climatic factor that suppresses the spread of COVID-19. High temperatures and wind speed also are potential factors. Therefore, the findings of this study show the ability to improve the organizational system of strategies to combat the pandemic in the State of Rio de Janeiro, Brazil, and other tropical countries around the world (Denes k.a. Rosario and al., 2020).

The effects of regional climatic conditions on the spread of COVID-19 on a global scale prove that the pandemic outbreak of the novel coronavirus epidemic disease (COVID-19) is spreading like a diffusion-reaction in the world and almost 208 countries and territories are being affected around the globe. It became severe health and socio-economic problem, while the world has no vaccine to combat this virus. This research aims to analyze the connection between the fast spread of COVID-19 and regional climate parameters over a global scale. In this research, we collected the data of COVID-19 cases from the time of 1st reported case to the 5th June 2020 in different affected countries and regional climatic parameters data from January 2020 to 5th June 2020. It was found that most of the countries located in the relatively lower temperature region show a rapid increase in the COVID-19 cases than the countries located in the warmer climatic regions despite their better socio-economic conditions. A correlation between metrological parameters and COVID-19 cases was observed. Average daylight hours are correlated to total COVID-19 cases with a coefficient of determination of 0.42, while average high-temperature shows a correlation of 0.59 and 0.42 with total COVID-19 cases and death cases respectively. The finding of the study will help international health organizations and local administrations to combat and well manage the spread of COVID-19 (Muhammad Mazhar Iqbal and al., 2020).

No evidence of temperature dependence of the Covid-19 epidemic, it is the results of the study which showed that the pandemic of the COVID-19 extended from China across the north temperate zone, and more recently to the tropics and southern hemisphere. The hypothesis that COVID-19 spread is temperature-dependent was tested based on data derived from nations across the world and provinces in China. No evidence of a pattern between spread rates and ambient temperature was found, suggesting that the COVID-19 is unlikely to behave as a seasonal respiratory virus (Tahira Jamil and al., 2020).

Another study discussed the problem of Temperature, Humidity, and Latitude Analysis to Estimate the Potential Spread and Seasonality of Coronavirus Disease 2019 (COVID-19). Coronavirus disease 2019 (COVID-19) infection has resulted in a global crisis. Investigating the potential association of climate and seasonality with the spread of this infection could aid in preventive and surveillance strategies. To examine the association of climate with the spread of COVID-19 infection. This cohort study examined climate data from 50 cities. Worldwide with and without substantial community spread of COVID-19. Eight cities with the substantial spread of COVID-19 (Wuhan, China; Tokyo, Japan; Daegu, South Korea; Qom, Iran; Milan, Italy; Paris, France; Seattle, US; and Madrid, Spain) were compared with 42 cities that have not been affected or did not have substantial community spread. Data were collected from January to March 10, 2020. Substantial community transmission was defined as at least 10 reported deaths in a country as of March 10, 2020. Climate data (latitude, mean 2-m temperature, mean specific humidity, and mean relative humidity) were obtained from ERA-5 reanalysis. The 8 cities with substantial community spread as of March 10, 2020, we're located on a narrow band, roughly on the 30° N to 50° N corridor. They had consistently similar weather patterns, consisting of mean temperatures of between 5 and 11 °C, combined with low specific humidity (3-6 g/kg) and low absolute humidity (4-7 g/m3). There was a lack of substantial community establishment in expected locations based on proximity. For example, while Wuhan, China (30.8° N) had 3136 deaths and 80 757 cases, Moscow, Russia (56.0° N), had 0 deaths and 10 cases, Hanoi and Vietnam (21.2° N), had 0 deaths and 31 cases (Mohammad M. Sajadi and al., 2020).

Studies of weather, seasonality and environmental influences on COVID-19 have yielded inconsistent and confusing results. To provide policy-makers and the public with meaningful and actionable environmentally-informed COVID-19 risk estimates, the research community must meet robust methodological and communication standards. In this context, the study by (Benjamin F. Zaitchik and al., 2020) proposes a framework for research linking weather, climate, and COVID-19. The objective is to recognize the rapid and high profile nature of COVID-19 research, investigators should apply careful checks throughout the Data and Design, Analysis, Interpretation, Publication, and Dissemination phases of their work. This includes iteration to ensure that dissemination of any policy-relevant conclusions is grounded in study design and analysis, with results updated to reflect current understanding.

2. Methodology

Based on the nature of the study and the information to be obtained to Using the Seemingly Unrelated Regression equations model to estimate the potential influence of climate on the spread of the COVID-19 pandemic in Algeria.

Theoretical aspect: By using the descriptive analytical approach to study the activities, the descriptive approach to present the phenomenon as it is, and express it in quantity and quality, the quantity express means using the language of the number, while the qualitative express is the one who describes the phenomenon and highlights its characteristics, and it does not stop there, but goes beyond it to the analytical approach, through the interpretation and linking between the factors related to the phenomenon to reach results and conclusions regarding the basic concept of this phenomenon studies, in the case of our study is to find the relationship between climate and spread of the COVID-19 pandemic in Algeria.

Practical aspect: We address this question using a Spatio-temporal analysis in Algeria of the incidence of COVID-19, the disease caused by the virus. The use of spatial Seemingly Unrelated Regressions (SUR) allows us to model the incidence of reported cases of the disease. The Seemingly Unrelated Regression equations model (SUR hereafter) is a multivariate econometric model used in different fields when the structure of the data consists of cross-sections for different periods.

The SUR model: Seemingly Unrelated Regressions (SUR) is a class of multivariate regression (multiple regressions) models, normally belonging to the sub-class of linear regression models. A distinctive feature of SUR models is that they consist of several unrelated systems of equations "Unrelated" here means that any variable, dependent and or independent, is present in only one system or, in other words, the systems have no common variables. The Seemingly Unrelated Regression equations model (SUR hereafter) is a multivariate econometric model used in different fields when the structure of the data consists of cross-sections for different periods (Antonio Paez and al., 2020). The basis of this approach is well-known since the initial works of (Zellner, A., 1962) and has become a popular methodology included in several econometrics textbooks. Anselin has discussed SUR from a spatial perspective, in the context of Spatio-temporal analysis. In his text, Anselin discussed a model made of "an equation for each period, which is estimated for a cross-section of spatial units" (Anselin, 1988). À partir de ce jalon, un vaste corpus de recherche s'est développé pour étendre le SUR classique dans un cadre spatial (par exemple, Rey et Montouri 1999 ; Lauridsen et al. 2010 ; Le Gallo et Dall'Erba 2006 ; López, Martínez-Ortiz et Cegarra -Navarro 2017). Under such possibilities, instead of estimating the equations separately, they should be jointly estimated through Zellner's suggested Seemingly Unrelated Regression Estimation (SURE) procedure, including testing whether the error terms of the individual equations are correlated (Zellner, A., 1962 and Zellner, A., 1963). Normally, one would try to solve such systems of equations independently, e.g. using the least-squares method for each system separately. But in SUR models the error terms from different systems are correlated. At the same time, according to the general theory of the least square method, which takes covariances of errors into account, such systems should be solved as a whole set of equations. Otherwise, the minimal variance of the errors in estimated regression parameters cannot be achieved.

The classical SUR model without spatial effects (from here, SUR-SIM) is a stack of equations as follows:

$$Y = X\beta + \varepsilon \tag{1}$$

$E(\varepsilon) = 0$, $V(\varepsilon) = \sum \otimes I_T$ (Rang (X_i) = k_i avec ; $i = 1, 2, .. m$)

$$X = \begin{bmatrix} X_1 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & X_m \end{bmatrix}, \text{ Rang }(X) = \sum_{i=1}^{m} k_i$$

It is clear that if we apply the method of (OLS) to this model, the estimators will be so biased but not optimal because the distribution of the disturbances is not spherical this leads us to resort to the method of generalized least squares (GLS) which give:

$$\widetilde{\beta_{gls}} = [X' (\sum \otimes I_T)X)^{-1} X]^{-1} X' ((\sum \otimes I_T)^{-1} Y = [X' (\sum \otimes I_T) X]^{-1} X'((\sum \otimes I_T)^{-1} Y$$

The mathematical expectation of $\widetilde{\beta_{gls}}$:

$$\widetilde{\beta_{gls}} = [X' (\sum \otimes I_T)X)^{-1} X]^{-1} X' ((\sum \otimes I_T)^{-1} Y = [X' (\sum \otimes I_T) X]^{-1} X'((\sum \otimes I_T)^{-1} Y$$

$$\widetilde{\beta_{gls}} = [X' (\sum \otimes I_T) X]^{-1} X'((\sum \otimes I_T)^{-1}(X\beta + \varepsilon) = \beta + [X' (\sum \otimes I_T)^{-1} X]^{-1} X'(\sum \otimes I_T)^{-1} \varepsilon$$

By introducing the mathematical expectation on $\widetilde{\beta_{gls}}$, we obtain:

$$E(\widetilde{\beta_{gls}}) = \beta + [X' (\sum \otimes I_T)^{-1} X]^{-1} X'(\sum \otimes I_T)^{-1} E(\varepsilon) = \beta$$

Variance of $\widetilde{\beta_{gls}}$:

$$\mathrm{V}(\widetilde{\beta_{gls}}) = \{[\widetilde{\beta_{gls}} - E(\widetilde{\beta_{gls}})][\widetilde{\beta_{gls}} - E(\widetilde{\beta_{gls}})]'\} = [X' (\sum \otimes I_T)^{-1} X]^{-1}$$

If the sample data is generated by the SUR regression model, then the GLS estimator is unbiased, efficient, and a maximum likelihood estimator. The reason that the GLS estimator is more precise than the OLS estimator is that it uses it to obtain information about non-spherical disturbances contained in parameter estimates.

Properties of the GLS estimator: If the sample data is generated by the SUR regression model, then the GLS estimator is unbiased, efficient, and a maximum likelihood estimator. The reason that the GLS estimator is more precise than the OLS estimator is that it uses it to obtain information about non-spherical disturbances contained in parameter estimates.

Feasible Generalized Least Squares (FGLS) Estimator: The FGLS estimator is also referred to as the weighted least squares estimator. It requires specifying a heteroskedasticity or autocorrelation model. If the data is generated by the general linear regression model, the FGLS estimator has then the FGLS estimator may or may not be distorted in a small sample. However, if the heteroskedasticity or autocorrelation model is asymptotic, it is efficient and consistent. In this case, Monte Carlo studies have shown that the FGLS estimator generally gives better estimates than the OLS estimator.

As is the case with cross-sectional data, it is possible to test the residuals of Model (1) for spatial autocorrelation, and several tests have been developed to test the null hypothesis of spatial independence (López, Mur, and Angulo 2014). When the null hypothesis is rejected, several alternative specifications have been proposed to include spatial effects (Anselin., 1988). In this paper, we consider a spatial SUR model that incorporates a spatial lag of the dependent variable as an explanatory factor. Spatial analytical approaches have been used to understand contagion-diffusion processes in the case of infectious disease in general and the 2003–2004 SARS outbreaks. While we are mindful of the same caveat that the novel SARS-CoV2 may not follow the patterns of previous diseases, there is still evidence from the United States that COVID-19 displays spatial patterns that are consistent with a diffusion process. For this reason, the spatial lag model is appropriate to model the incidence of COVID-19 geographically, since it accounts for potential spatial patterns that result from a process of contagion, as explained next (Antonio Paez and al., 2020). The following statistical tests can be used to test the hypotheses on the SUR model: The asymptotic t-test, The approximate F-test, The Wald test, The Likelihood ratio test, The Lagrange multiplier test. One should choose the appropriate test to test the interesting hypothesis since in a small sample the t-test and the F-test cannot be used. This is because if the sample data is generated by the ON model the sampling distribution of the t statistic or the F-statistic is additionally unknown; each of these tests is applied to the large equation.

Cross-equation restrictions: Economic theory and other sources of advanced information oftentimes imply that the values of two or more parameters in two or more equations are the same, or a parameter in an equation is a linear or nonlinear function d 'one or more parameters in one or more other equations. They are called inter-equation restrictions. For example, in a system of M consumption demand equations implied by maximized utility behavior, the same parameters appear in different demand equations. These inter-equation restrictions can be easily tested and enforced as part of the SUR model.

Fit quality: The R^2 statistic that is used to measure the goodness of fit of a classical linear regression model is not appropriate for the SUR regression model. Many statistical programs will report an R^2 statistic for each equation for the SUR model, but these R^2 statistics make little or no sense. They do not measure the proportion of the variation in the dependent variable that is explained by the variation in the explanatory variables of the individual equation, and they can take values less than zero and greater than one.

3. Data

Our dataset includes information about the daily number of cases of COVID-19 reported in Algeria at the regional level for the five wilayas of the study (Algiers, Blida, Oran, Adrar, Sétif, and Tamanrasset.) (According to statistical data from the National Institute of Public Health of Algeria) for the period between April 18th, 2020, and April 17th, 2021 inclusive. The Algerian national government publishes periodic updates at the regional level (https://insp.dz). This information is compiled from several sources, mainly the official government web pages, the official web pages of the wilayes of the study (Algiers, Blida, Oran, Adrar, Sétif, and Tamanrasset). We consider two sets of explanatory variables. The first, and the object of this research, are the three environmental variables, collected from official sources of the website "Weather history: weather records for the whole world" (https://www.historic-meteo.net). The second set provides some relevant checks, as noted above, and is also collected from official sources, namely (NSO), the National Statistics Office (https://www.ons.dz/). The data presents the descriptive statistics used in this research.

The spatial and temporal coverage of the data is as follows. Our data set begins on April 18th, 2020, which is the earliest date each wilaya has reported at least one case of COVID-19 and continues until April 17th, 2021 for 365 days. The unit of analysis is the Wilaya. The Wilayes in Algeria are 58 Wilayas are selected from the four corners of Algeria (North, South, East, and West). For example, the wilaye of Tamanrasset is in the extreme south of Algeria. The size of the wilayas is relatively large although this is a relatively large degree of spatial aggregation, reports on COVID-19 are not yet consistent in smaller geographic areas, or cases are not due all reported at this level. An important aspect of working with environmental data such as temperature, humidity, and wind speed, is the incubation period of the disease. (Lauer et al., 2020) report for the case of COVID-19 a median incubation period of 5.7 days (with a confidence interval between 4.9 to 7.8 days). The vast majority of cases (95%) develop symptoms between 2.6 days and 12.5 days. For this reason, we judge it best to use lagged values of the environmental variables (Antonio Paez, 2020).

4. Modeling the potential influence of climate on the spread of the COVID-19 pandemic in Algeria

According to the data includes information on the daily number of COVID - 19 cases reported in Algeria at the regional level for the five wilayas of the study (Algiers, Blida, Oran, Adrar, Setif and Tamanrasset.) (Based on the data. statistics of the National Institute of Public Health of Algeria) for the period between April 18th, 2020 and April 17th, 2021 inclusive, and according to the three environmental variables, collected from official sources of the site “Weather history: weather records for the whole world” (https://www.historic-meteo.net) using the SUR (Seemingly Unrelated Regression) model to estimate the model equations based on the following system of the equation:

System of equation:

- $\mathbf{Lnc_{alg}} = \beta_0 + \beta_1\,Ltmax_{alg} + \beta_2\,Ltmin_{alg} + \beta_3\,Lh_{alg} + \beta_4\,Lv_{alg} + \varepsilon_{alg}.$
- $\mathbf{Lnc_{bld}} = \beta_5 + \beta_6\,Ltmax_{bld} + \beta_7\,Ltmin_{bld} + \beta_8\,Lh_{bld} + \beta_9\,Lv_{bld} + \varepsilon_{bld}.$
- $\mathbf{Lnc_{orn}} = \beta_{10} + \beta_{11}\,Ltmax_{orn} + \beta_{12}\,Ltmin_{orn} + \beta_{13}\,Lh_{orn} + \beta_{14}\,Lv_{orn} + \varepsilon_{orn}.$
- $\mathbf{Lnc_{adr}} = \beta_{15} + \beta_{16}\,Ltmax_{adr} + \beta_{17}\,Ltmin_{adr} + \beta_{18}\,Lh_{adr} + \beta_{19}\,Lv_{adr} + \varepsilon_{adr}.$
- $\mathbf{Lnc_{stf}} = \beta_{20} + \beta_{21}\,Ltmax_{stf} + \beta_{22}\,Ltmin_{stf} + \beta_{23}\,Lh_{stf} + \beta_{24}\,Lv_{stf} + \varepsilon_{stf}.$
- $\mathbf{Lnc_{tmr}} = \beta_{25} + \beta_{26}\,Ltmax_{tmr} + \beta_{27}\,Ltmin_{tmr} + \beta_{28}\,Lh_{tmr} + \beta_{29}\,Lv_{tmr} + \varepsilon_{tmr}.$

The dependent variable:

- **(Lnc)**: is the new cases of covid-19 in the six wilayas presented above after introducing the natural logarithm.

The independent variables:

- **(Ltmax) :** The maximum temperature for the wilayas of the study (Algiers, Blida, Oran, Adrar, Sétif, and Tamanrasset) after introducing the natural logarithm.
- **(Lmin) :** The minimum temperature for the wilayas of the study (Algiers, Blida, Oran, Adrar, Sétif, and Tamanrasset) after introducing the natural logarithm.
- **(Lh):** Humidity for the wilayas of the study (Algiers, Blida, Oran, Adrar, Sétif, and Tamanrasset) after introducing the natural logarithm.
- **(Lv)**: The wind speed for the wilayas of the study (Algiers, Blida, Oran, Adrar, Sétif, and Tamanrasset) after introducing the natural logarithm.

The parameters to be estimated are β_0 ….. β_{29}.

Model errors: ε_{alg}, ε_{bld}, ε_{orn}, ε_{adr}, ε_{stf}, ε_{tmr}.

5. Results and Discussion

Normality Test: The following Table 1 summarizes the results of the Skewness, Kurtosis, and Jarque-Bera residue system normality test (Appendix 1).

Table 1. Residue System Normality Test

Composantes	Skewness prob	kurtosis prob	Jarque-bera prob
1	0.0000	0.4271	0.0001
2	0.6025	0.0000	0.0000
3	0.6106	0.8878	0.8697
4	0.0135	0.0000	0.0000
5	0.9072	0.0004	0.0002
6	0.5018	0.0000	0.0000

Source: compiled by authors.

According to the results obtained by the test of normality of residues, we see that the probabilities of the test of skewness of the components (2, 3, 4, 5, and 6) are greater than 5% but the first component is of (Prob = 0.0000) less than 5%, so we must accept H1 the hypothesis of non-normality of the errors. For the kurtosis test, we notice that the probabilities of the components (2, 4, 5, and 6) are less than 5%, hence we must accept the hypothesis of the abnormal distribution of the residuals. The jarque-bera test on the residuals shows that the probabilities of components 1, 2, 4, 5 at 6 are less than 5% so we reject the null hypothesis of the normality of the errors. So, we can say that the residual system does not have a normal distribution.

The correlation test of the whole system: the results of the coat rack test (Box Pierce and Ljung-Box) are shown in Table 2, the objective of this test is to see the correlation of the whole system series.

Table 2. Coat rack test (Box-Pierce and Ljung-Box).

System Residual Portmanteau Tests for Autocorrelation
Null Hypothesis: no residual autocorrelations up to lag h
Date :08/09/21 Time : 21:22
Sample : 4/18/2020 4/17/2021
Included observations : 365

Lags	Q-Stat	Prob.	Adj Q-Stat	Prob.	df
1	18.33224	0.9936	18.85602	0.9917	36
2	34.37889	1.0000	35.84659	0.9999	72
3	46.76036	1.0000	49.35365	1.0000	108
4	55.07584	1.0000	58.70856	1.0000	144
5	66.77949	1.0000	72.29990	1.0000	180
6	74.74116	1.0000	81.85390	1.0000	216
7	93.25832	1.0000	104.8407	1.0000	252
8	102.5946	1.0000	116.8445	1.0000	288
9	122.8285	1.0000	143.8230	1.0000	324
10	136.5469	1.0000	162.8178	1.0000	360
11	145.8211	1.0000	176.1726	1.0000	396
12	158.6679	1.0000	195.4428	1.0000	432

*The test is valid only for lags larger than the System lag order.
df is degrees of freedom for (approximate) chi-square distribution

Source: compiled by authors.

According to the coat rack test, all the probabilities are greater than 5%. So the null hypothesis is accepted which shows that there is no serial correlation between the equations of the model.

Analysis of estimation results: After estimating the IFGLS (Iterated Feasible Generalized Least of Squares) model, Appendix 2 shows that the model is statistically accepted.

a) Equation of the propagation of COVID-19 in Algiers:

Table 3 shows the equation estimate for the contamination of the COVID-19 virus in Algiers.

Table 3. Estimate of the spread of covid-19 in Algiers

	Coefficient	Std. Error	t-Statistic	Prob
C(1)	7.033211	1.037320	6.780177	0.0000
C(2)	-0.983811	0.365417	-2.692294	0.0072
C(3)	0.241292	0.296628	0.813451	0.4161
C(4)	-0.22682	0.158792	-1.402353	0.1610
C(5)	-0.072536	0.090492	-0.801573	0.4229
Equation : LNCALG = C(1)+ C(2)*LTMAXALG+C(3)LTMINALG+C(4)*LHALG+C(5)*LVALG Observation : 364				
R-squared	0.033583	Mean dependent var		3.567622
Adjusted R-squared	0.022815	S.D dependent var		0.84641
S.E of regression	0.838904	Sum squared resid		252.6496
Durbin-Watson stat	0.400218			

Source: compiled by authors.

Interpretation of the goodness of fit coefficient: R-square is (0.033), which shows that the spread of COVID-19 virus is explained with (33%) by the climate of Algiers, the remaining (67%) is explained by other independent variables which do not exist in this model.

Independent variable analyzes: The maximum temperature is (p = 0.0072) <5%) is significant, with a negative coefficient (-0.983811), which shows that the temperature evolution harms the spread of COVID-19 virus in Algiers, c that is, a single unit of **(Ltmax)** results in a (-98.3811%) increase in COVID-19 virus contamination. Indeed, when **(Ltmax)** increases by 1% the spread of the COVID-19 virus increases by (-0.983811). The other independent variables, minimum temperature, humidity, and wind speed have probabilities greater than 5% which shows that they are not significant. According to the ($F_{\text{-statistic)}}$ test, the model of the first equation is significant because ($F_{cal} = 3.11$) greater than ($F_{tab} = 2.17$).

Regression diagnostics: Autocorrelation and heteroskedasticity are considered to be one of the biggest problems with the regression model. Table 4 and 5 shows the results obtained by the LM (Lagrange Multiple) and ARCH tests.

Table 4. ARCH test of the first Algiers equation

Heteroskedasticity Test: ARCH			
F-statistic	125.4865	Prob . F(1,360)	0.0000
Obs*R-squared	93.56824	Prob. Chi-Square (1)	0.0000

Source: compiled by authors.

The ARCH test gives (p = 0.0000 <0.05), we reject the null hypothesis, which means there is a heteroscedasticity, from where we see that during our study, the wilaya of Algiers has experienced significant climate change.

Table 5. LM test of the first Algiers equation

Breuch-Godfrey Serial Correlation LM Test			
F-statistic	351.6080	Prob . F(2,357)	0.0000
Obs*R-squared	241.4325	Prob. Chi-Square (2)	0.0000

Source: compiled by authors.

b) Equation of the propagation of COVID-19 in Blida:

Table 6 shows the equation estimate for the contamination of the COVID-19 virus in Blida.

Table 6. Estimate of the spread of COVID-19 in Blida

	Coefficient	Std. Error	t-Statistic	Prob.
C(6)	1.476691	1.051246	1.404705	0.1603
C(7)	-0.929725	0.330023	-2.817154	0.0049
C(8)	1.057983	0.248418	4.258887	0.0000
C(9)	0.276536	0.137796	2.006852	0.0449
C(10)	0.068432	0.106727	0.641191	0.5215
Equation: LNCBLD = C(6)+ C(7)*LTMAXBLD+C(8)LTMINBLD+C(9)*LHBLD+C(10)*LVBLD Observation: 361				
R-squared	0.56216	Mean dependent var		2.797393
Adjusted R-squared	0.045612	S.D dependent var		0.834303
S.E of regression	0.815054	Sum squared resid		236.4957
Durbin-Watson stat	1.116023			

Source: compiled by authors.

Interpretation of the goodness of fit coefficient: R-square is (0.056216), which shows that the spread of COVID-19 virus is explained with (5.62%) by the climate of Blida, the remaining (94.37%) is explained by other independent variables which do not exist in this model.

Independent variable analyzes: The maximum temperature is (p = 0.0049) <5%) is significant, with a negative coefficient (-0.929725), which shows that the temperature evolution harms the spread of COVID-19 virus in Blida, c that is, a single unit of (Ltmax) results in an increase of (-92.29725%) in COVID-19 virus contamination. The spread of the COVID-19 virus increases by (-0.983811) when (Ltmax) increases by (1%). The minimum temperature is (p = 0.0000) <5%) is significant, with a low and positive coefficient (1.057983), which shows that the minimum temperature has a positive effect on the spread of the COVID-19 virus in Blida, that is to say, that a single unit of (Ltmax) causes an increase of (105.79%) of contamination of COVID-19 virus Indeed, when (Ltmax) increases by 1%, the spread of the COVID-19 virus increases by (105.79%). Humidity is significant with a probability of (p = 0.0449) <5%), and with a low and positive coefficient (0.276536), which shows that humidity has a positive effect on the spread of the COVID -19 virus to Blida, that is, a single unit of (Ltmax) causes a (27.6536%) increase in the spread of COVID-19. Indeed, when (Ltmax) increases by (1%), the spread of the COVID-19 virus increases by (27.6536%). Wind speeds have probabilities greater than (5%) which shows that they are not significant. According to the ($F_{\text{-statistic}}$) test, the model of the second equation is significant because ($F_{cal} = 5.30$) greater than ($F_{tab} = 2.17$).

Regression diagnostics: Autocorrelation and heteroscedasticity are considered to be one of the biggest problems with the regression model. Table 7 and 8 below show the results obtained by the LM (Lagrange Multiple) and ARCH tests.

Table 7. ARCH test of the second Blida equation

Heteroskedasticity Test : ARCH			
F-statistic	12.41499	Prob. F (1,354)	0.0005
Obs*R-squared	12.06210	Prob. Chi-Square (1)	0.0005

Source: compiled by authors.

The ARCH test gives (p = 0.0005 <0.05), we reject the null hypothesis which shows that there is heteroskedasticity, and then there is significant climate change in Blida.

Table 8. LM test of the second Blida equation

Breuch-Godfrey Serial Correlation LM Test			
F-statistic	74.24297	Prob. F (2,354)	0.0000
Obs*R-squared	106.6765	Prob. Chi-Square (2)	0.0000

Source: compiled by authors.

The LM test gives p = 0.000 <0.05, so we reject the null hypothesis which shows that the serial correlation exists in the second equation.

c) Equation of the propagation of COVID-19 in Oran:

Table 9 shows the equation estimate for the contamination of the COVID-19 virus in Oran.

Table 9. Estimate of the spread of COVID-19 in Oran

	Coefficient	Std. Error	t-Statistic	Prob.
C(11)	7.535736	1.289212	5.845226	0.0000
C(12)	-1.332105	0.388845	-3.425799	0.0006
C(13)	0.398681	0.325338	1.225438	0.2206
C(14)	-0.256563	0.193216	-1.327854	0.1844
C(15)	-0.126951	0.103506	-1.226506	0.2202
Equation : LNCORN = C(11)+ C(12)*LTMAXORN+C(13)LTMINORN+C(14)*LHORN+C(15)*LVORN Observation : 362				
R-squared	0.042036	Mean dependent var		3.056407
Adjusted R-squared	0.031303	S.D dependent var		1.069870
S.E of regression	1.052992	Sum squared resid		395.8390
Durbin-Watson stat	0.537221			

Source: compiled by authors.

Interpretation of the goodness of fit coefficient: R-square is (0.042036), which shows that the spread of COVID-19 virus is explained with (4.2036%) by the Oran climate, the remaining (95.79%) is explained by other independent variables that do not exist in this model.

Independent variable analyzes: The maximum temperature is (p = 0.0006<5%) is significant, with a negative coefficient (-1.332105), which shows that the temperature evolution harms the spread of the COVID-19 virus in Oran. The other variables are not significant because they have probabilities greater than (5%). According to the (F-$_{\text{statistic)}}$ test, the model of the third equation is significant because (F_{cal} = 3.916) greater than (F_{tab} = 2.17).

Regression diagnostics: Autocorrelation and heteroscedasticity are considered to be one of the biggest problems with the regression model. Tables 10 and 11 below show the results obtained by the LM (Lagrange Multiple) and ARCH tests.

Table 10. ARCH test of the Third Oran equation

Heteroskedasticity Test: ARCH			
F-statistic	9.805235	Prob. F (1,354)	0.0019
Obs*R-squared	9.596019	Prob. Chi-Square (1)	0.0019

Source: compiled by authors.

The ARCH test gives (p = 0.0019 <0.05), we reject the null hypothesis which shows that there is heteroscedasticity, and then there is significant climate change in Oran.

Table 11. LM test of the Third Oran equation

Breuch-Godfrey Serial Correlation LM Test			
F-statistic	252.3833	Prob. F (2,355)	0.0000
Obs*R-squared	212.5292	Prob. Chi-Square (2)	0.0000

Source: compiled by authors.

The LM test gives (p = 0.000 <0.05), so we reject the null hypothesis which shows that the serial correlation exists in the third equation.

d) Equation of the propagation of COVID-19 in Adrar:

Table 12 shows the equation estimate for the contamination of the COVID-19 virus in Adrad.

Tables 12. Estimate of the spread of COVID-19 in Adrar

	Coefficient	Std. Error	t-Statistic	Prob.
C(16)	-3.068807	2.318617	-1.323550	0.1858
C(17)	1.254322	0.981087	1.278502	0.2013
C(18)	-0.388712	0.602425	-0.645245	0.5189
C(19)	-0.091655	0.191032	-0.479789	0.6314
C(20)	0.400978	0.190708	2.102579	0.0357
Equation : LNCORN = C(16)+ C(17)*LTMAXORN+C(18)LTMINORN+C(19)*LHORN+C(20)*LVORN Observation : 185				
R-squared	0.073013	Mean dependent var		1.113973
Adjusted R-squared	0.052413	S.D dependent var		0.972932
S.E of regression	0.947092	Sum squared resid		161.5469
Durbin-Watson stat	1.092948			

Source: compiled by authors.

Interpretation of the goodness of fit coefficient: R-square is (0.073013), which shows that the spread of COVID-19 virus is explained with (7.3013%) by the climate of Adrar, the remaining (92.6987%) is explained by other independent variables which do not exist in this model.

Independent variable analyzes: The wind speed is ($p = 0.0357<5\%$) is significant, with a positive coefficient (0.400978), which shows that the evolution of the wind speed has a positive effect on the spread of the COVID-19 virus in Adrar. The other variables are not significant because they have probabilities greater than 5%. According to the ($F_{\text{statistic}}$) test, the model of the fourth equation is significant because ($F_{cal} = 3.58$) greater than ($F_{tab} = 2.17$).

Regression diagnostics: Autocorrelation and heteroscedasticity are considered to be one of the biggest problems with the regression model. Tables 13 and 14 below show the results obtained by the LM (Lagrange Multiple) and ARCH tests.

Table 13. ARCH test of the fourth Adrar equation

Heteroskedasticity Test : ARCH			
F-statistic	2.2043405	Prob. F (1,105)	0.1558
Obs*R-squared	2.042576	Prob. Chi-Square (1)	0.1530

Source: compiled by authors.

The ARCH test gives ($p = 0.1530 <0.05$), we accept the null hypothesis which shows that there is no heteroskedasticity, then the wilaya of Adrar has not experienced significant climate change during our study.

Table 14. LM test of the fourth Adrar equation

Breuch-Godfrey Serial Correlation LM Test			
F-statistic	11.88603	Prob. F (2,178)	0.0000
Obs*R-squared	21.79604	Prob. Chi-Square (2)	0.0000

Source: compiled by authors.

The LM test gives ($p = 0.000 <0.05$), so we reject the null hypothesis which shows that the serial correlation exists in the fourth equation.

e) Equation of the propagation of COVID-19 in Setif:

Table 15 shows the equation estimate for the contamination of the COVID-19 virus in Setif.

Table 15. Estimation of the spread of COVID-19 in Setif

	Coefficient	Std. Error	t-Statistic	Prob.
C(21)	2.028195	1.453136	1.395737	0.1630
C(22)	0.079004	0.324312	0.243604	0.8076
C(23)	0.288456	0.191189	1.508753	0.1316
C(24)	-0.145489	0.216621	-0.671631	0.5019
C(25)	0.006508	0.106098	0.061340	0.9511
Equation : LNCSTF = C(21)+ C(22)*LTMAXSTF+C(23)LTMINSTF+C(24)*LHSTF+C(25)*LVSTF Observation : 318				
R-squared	0.070804	Mean dependent var		2.388171
Adjusted R-squared	0.058929	S.D dependent var		1.005010
S.E of regression	0.974949	Sum squared resid		297.5143
Durbin-Watson stat	1.064377			

Source: compiled by authors.

Interpretation of the goodness of fit coefficient: R-square is (0.070804), which shows that the spread of COVID-19 virus is explained with (7.0804%) by the climate of Setif, the remaining (92.9196%) is explained by other independent variables that do not exist in this model.

Independent variable analyzes: Note that the probabilities of all the variables are greater than (5%), which explains the non-significance of the variables. According to the (F-$_{statistic}$) test, the model of the fifth equation is significant because ($F_{cal} = 5.96$) greater than ($F_{tab} = 2.17$).

Regression diagnostics: Autocorrelation and heteroscedasticity are considered to be one of the biggest problems with the regression model. Tables 16 and 17 below show the results obtained by the LM (Lagrange Multiple) and ARCH tests.

Table 16. ARCH test of the Fifth Setif equation

Heteroskedasticity Test : ARCH			
F-statistic	3.956848	Prob. F (1,278)	0.0477
Obs*R-squared	3.929387	Prob. Chi-Square (1)	0.0474

Source: compiled by authors.

The ARCH test gives ($p = 0.0474 < 0.05$), we reject the null hypothesis which shows that there is heteroscedasticity, so there is significant climate change in Setif.

Table 17. LM test of the Fifth Setif equation

Breuch-Godfrey Serial Correlation LM Test			
F-statistic	55.40890	Prob. F (2,311)	0.0000
Obs*R-squared	83.54332	Prob. Chi-Square (2)	0.0000

Source: compiled by authors.

The LM test gives ($p = 0.000 < 0.05$), so we reject the null hypothesis which shows that the serial correlation exists in the fifth equation.

f) Equation of the propagation of COVID-19 in Tamanrasset:

Table 18 shows the equation estimate for the contamination of the COVID-19 virus in Tamanrasset.

Table 18. Estimate of the spread of COVID-19 in Tamanrasset.

	Coefficient	Std. Error	t-Statistic	Prob.
C(26)	-2.867668	2.287015	-1.253891	0.2101
C(27)	0.702209	1.111631	0.631693	0.5277
C(28)	0.250333	0.899120	0.278420	0.7807
C(29)	0.155466	0.285652	0.544252	0.5863
C(30)	0.007899	0.278899	0.028323	0.9774
Equation : LNCSTF = C(26)+ C(27)*LTMAXTMR+C(28)LTMINTMR+C(29)*LHTMR+C(30)*LVTMR Observation : 64				
R-squared	0.065043	Mean dependent var		0.952636
Adjusted R-squared	0.001656	S.D dependent var		0.892003
S.E of regression	0.891264	Sum squared resid		46.86675
Durbin-Watson stat	2.078970			

Source: compiled by authors.

Interpretation of the goodness of fit coefficient: R-square is (0.065043), which shows that the spread of COVID-19 virus is explained with (6.5043%) by the Tamanrasset climate, the remaining (93.49%) is explained by other independent variables which do not exist in this model.

Independent variable analyzes: Note that the probabilities of all the variables are greater than (5%), which explains the non-significance of the variables. According to the (F-$_{\text{statistic}}$) test, the model of the sixth equation is not significant because ($F_{cal} = 1.026$) is less than ($F_{tab} = 2.17$).

Regression diagnostics: Autocorrelation and heteroscedasticity are considered to be one of the biggest problems with the regression model. Table 19 and Table 20 below show the results obtained by the LM (Lagrange Multiple) and ARCH tests.

Table 19. ARCH test of the Sixth Tamanrasset equation

Heteroskedasticity Test : ARCH			
F-statistic	0.068137	Prob. F (1,23)	0.7964
Obs*R-squared	0.073843	Prob. Chi-Square (1)	0.7858

Source: compiled by authors.

The ARCH test gives ($p = 0.7858 > 0.05$), we accept the null hypothesis which shows that there is no heteroskedasticity, so climate change in Tamanrasset is not important.

Table 20. LM test of the Sixth Tamanrasset equation

Breuch-Godfrey Serial Correlation LM Test			
F-statistic	1.035740	Prob. F (2,57)	0.3615
Obs*R-squared	2.244310	Prob. Chi-Square (2)	0.3256

Source: compiled by authors.

The LM test gives ($p = 0.3615 < 0.05$), so we reject the null hypothesis which shows that the serial correlation exists in the last equation.

Conclusion

The impact of the COVID-19 epidemic on the health of Algerians does not depend only on universal access to hospital care; it also raises the capacities for prevention and mitigation against the risks of COVID-19 through basic and primary health structures and community engagement mechanisms. Surveillance efforts, especially at the community level, play a critical role in preventing increased morbidity and mortality. In this context, the epidemic risks affecting populations unevenly, depending on the level and continuity of their access to public health messages, screening, and preventive care the situation geographic location of households, their living conditions, their level of income, education, physical or mental autonomy, or social inclusion are all factors of inequality in the face of the epidemic. It should also be noted that health workers have been the most exposed to the health risks associated with the virus.

In our study, we tried to estimate the impact of climatic variables on the contamination of the COVID-19 virus in the selected wilayas (Algiers, Blida, Oran, Adrar, Setif, and Tamanrasset). After analyzing the results of the estimation of the SUR model, we conclude that the explanatory variables (the climatic variables) do well explain the variable to be explained (the spread of COVID-19 in Algeria). according to the results of the wilayas we found that:

For the wilaya of Algiers, the maximum temperature is significant; however, the other variables are not significant.
For the wilaya of Blida, the maximum temperature, minimum temperature, and humidity are significant, the other variables are not significant.
For the wilaya of Oran, the maximum temperature is significant, the others are not significant.
For the wilaya of Adrar, the wind speed is significant; the other variables are not significant.
For the wilayas of Sétif and Tamanrasset, all the variables are not significant.

The purpose of this study is to find out if there is a real impact of climate change on the spread of COVID-19 in Algeria according to the study period between April 18th , 2020, and April 17th , 2021, inclusive, to help the government Algerian to adapt to climate change.

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Appendix 1. Normality test result

System SYS01
Estimation Method : Seemingly Unrelated Regression
Date :08/10/20 Time : 22:53
Sample : 4/18/2020 4/17/2021
Included observations : 365
Total System (Unbalanced) observation 1654
Linear estimation after one – step weighting matrix

	Coefficient	Std. Error	t-Statistic	Prob
C(1)	7.033211	1.037320	6.780177	0.0000
C(2)	-0.983811	0.365417	-2.692294	0.0072
C(3)	0.241292	0.296628	0.813451	0.4161
C(4)	-0.22682	0.158792	-1.402353	0.1610
C(5)	-0.072536	0.090492	-0.801573	0.4229
C(6)	1.476691	1.051246	1.404705	0.1603
C(7)	-0.929725	0.330023	-2.817154	0.0049
C(8)	1.057983	0.248418	4.258887	0.0000
C(9)	0.276536	0.137796	2.006852	0.0449
C(10)	0.068432	0.106727	0.641191	0.5215
C(11)	7.535736	1.289212	5.845226	0.0000
C(12)	-1.332105	0.388845	-3.425799	0.0006
C(13)	0.398681	0.325338	1.225438	0.2206
C(14)	-0.256563	0.193216	-1.327854	0.1844
C(15)	-0.126951	0.103506	-1.226506	0.2202
C(16)	-3.068807	2.318617	-1.323550	0.1858
C(17)	1.254322	0.981087	1.278502	0.2013
C(18)	-0.388712	0.602425	-0.645245	0.5189
C(19)	-0.091655	0.191032	-0.479789	0.6314
C(20)	0.400978	0.190708	2.102579	0.0357
C(21)	2.028195	1.453136	1.395737	0.1630
C(22)	0.079004	0.324312	0.243604	0.8076
C(23)	0.288456	0.191189	1.508753	0.1316
C(24)	-0.145489	0.216621	-0.671631	0.5019
C(25)	0.006508	0.106098	0.061340	0.9511
C(26)	-2.867668	2.287015	-1.253891	0.2101
C(27)	0.702209	1.111631	0.631693	0.5277
C(28)	0.250333	0.899120	0.278420	0.7807
C(29)	0.155466	0.285652	0.544252	0.5863
C(30)	0.007899	0.278899	0.028323	0.9774
Determinant residual covariance	0.089122			