15TH NATIONAL CONVENTION ON STATISTICS
03-05 OCTOBER 2022

Organized by the Philippine Statistical System
Spearheaded by the Philippine Statistics Authority

Spatiotemporal Modeling of COVID-19 in the Philippines in the Presence of Structural Change

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04October 2022

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Introduction

- Covid-19 is caused by the Novel Coronavirus subtype Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-Cov-2).
- It started in Wuhan, China in 2019 and has now succeeded in spreading in most parts of the world.
- Viruses like SARS-CoV-2 continuously evolve as modifications in the genetic code (genetic mutations) occur during replication of the genome.
- Surge follows whenever the new variant circulates.
- Occurrence of the surges in the pandemic experience in the Philippines creates severe fluctuations in the prevalence of the disease in the general susceptible setting, resulting to possible structural change in the behavior of the model.

Introduction

- Research Objectives
  - This paper aimed to apply the model proposed by Bastero and Barrios in 2011, in their paper entitled Robust Estimation of a Spatiotemporal Model with Structural Change to the covid-19 data in the Philippines.
  - Two models, spatiotemporal model with structural change and spatiotemporal model without the structural change were generated.

Methodology

Data

- The study used the COVID-19 data in the Philippines from April 1, 2020 to September, 15 2021 right after the decline in cases due to the fourth surge caused by the Delta variant.
- The different locations are the 82 provinces in the Philippines where data is available and the 17 cities and municipality in Metro Manila.
- The research relied on secondary data provided by the Department of Health (DOH) regional offices, Philippine Statistics Authority (PSA), Department of Environment and Natural Resources (DENR), Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), and other governmental agencies for COVID-19 statistics in the Philippines.

Methodology

Covariates in the Province X_{it}
Total number of senior citizens in the province in 2020
Total number of males in the province in 2020
Total Number of health workers in the province
Total number of laboratories in 2020
Number of cities in the province
Total number of Pneumonia cases in the province in 2020
Total revenue per person in the province
Total number of flu vaccinated senior citizens in the province
Total number of Flu cases in the province in 2020
Total number of Cardio-diabetes cases in the province in 2020
Total number of breast cancer cases in the province in 2020
Total number of tuberculosis cases in the province in 2020

Covariates in the Neighborhood W_{it}
Air quality index in the neighborhood of the province
Relative humidity in the neighborhood of the province
Wind Speed in the neighborhood of the province
Number of hospital beds in the neighborhood of the province

Dependent Variable Y_{it}
Prevalence rate of Covid-19 per million

Methodology

Spatiotemporal Model (No Structural Change)

$$Y_{it} = \beta X_{it} + \gamma W_{it} + \varepsilon_{it} \quad i = 1,2,\dots,N \quad t = 1,2,\dots,T \tag{1}$$

$$\varepsilon_{it} = \rho \varepsilon_{i,t-1} + a_{it} \tag{2}$$

$$|\rho| < 1 \quad a_{it} \sim IID(0, \sigma^2 a) \tag{3}$$

- The parameters β and γ are simultaneously estimated through the forward search algorithm.

- Compute the residuals : $e_{it} = Y_{it} - \hat{Y}_{it}$, $\hat{Y}_{it} = \hat{\beta} X_{it} + \hat{\gamma} W_{it}$. Perform autoregression on the residuals to estimate ρ.

Methodology

Spatiotemporal Model (with structural change)

$$Y_{it} = \beta X_{it} + \gamma W_{it} + g_{i*}(t^*, \lambda) + \varepsilon_{it} \quad i = 1,2,\dots,N \quad t = 1,2,\dots,T \quad (4)$$

$$g_{i*}(t^*, \lambda) = \lambda_0 exp\{-\lambda_1 t^*\} \quad (5)$$

- The parameters β and γ are simultaneously estimated through the forward search algorithm.
- The parameters of the temporary structural change is then estimated through the maximum likelihood estimation using residuals from the previous step as the dependent variable.
- Compute the residuals. Perform autoregression on the residuals to estimate ρ.

Results and Discussion

Spatiotemporal model β and γ Estimates

Variables	Estimates of the Coefficients (Model without intercept)	Estimates of the Coefficients (Model with Intercept)
Intercept		-74.705393
Covariates in the Province X_{it}		
Seniors	-1.21697E-05	-4.66217E-05
Males	-8.69061E-06	-4.71282E-07
HW	-0.003028227	-0.003459109
LCTL	0.079620008	0.079349751
NC	0.106617234	-0.004530526
Pneumonia	3.71788E-05	4.75866E-05
RCP	0.000301258	0.000303664
ImmuSen	1.70854E-05	-4.26448E-05
Flu	-0.000744725	-0.001109362
CardioDiab	-0.000106393	-6.81354E-05
CancerBC	0.000114589	9.03955E-05
TB	0.004644289	0.005432818
Covariates in the Neighborhood W_{it}		
AQI	1.831498141	1.758557119
RH	-0.009176009	0.849579406
WindSpeed	-9.024547632	-7.712952634
Hosbeds	0.064968154	0.071572062

Results and Discussion

Estimates of λ_0 and λ_1 of the additional term in the Spatiotemporal Model Structural Change

Estimator	Estimates (Model without Intercept)	Estimates (Model with Intercept)
$\hat{\lambda}_0$	44.82967	42.20119
$\hat{\lambda}_1$	-0.002119797	-0.002240637

Estimates of ρ

Without Structural Change		With Structural Change	
Without intercept	With intercept	Without intercept	With intercept
0.636105	0.636105	0.5064203	0.505737

Mean Absolute Deviation

Without Structural Change		With Structural Change	
Without intercept	With intercept	Without intercept	With intercept
49.44	49.34	44.71	44.60

Conclusion

- A generalized model for epidemics that can summarize spatial and temporal dependencies of the population even in the presence of structural change postulated by Bastero and Barrios in 2011 was used in the study of the COVID-19 data in the Philippines.
- The proposed model incorporates a temporary structural change.
- This structural change in the COVID-19 data may be caused by the surges triggered by the different variants of the SARS-CoV-2 virus.
- The spatiotemporal model with structural change showed a better fit for modelling COVID-19 in the Philippines.

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