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PUBLIC HEALTH POLICY STANCE OPTIONS IN RESPONSE TO COVID – 19: AN EVOLUTIONARY GAME THEORY MODELLING APPROACH

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Abstract

The dynamics of COVID-19 pandemic calls for urgent policy questions that must be addressed with empirical results, since the efficacy of vaccines is still highly debatable and the rate of mutation is mostly novel. Immediate policy options such as quarantines, movement restrictions, self-isolation and physical distancing have been attempted across the globe, and empirical evaluations of their effectiveness are difficult with such an unpredictable virus. The study considered an evolutionary game approach to Covid-19 interventions by South Africa and Zimbabwe, where a social learning path in an imitation dynamic game was hypothesised and established. The results suggested that restrictions increased and decreased the rate of positive cases at different phases. A possibility of natural herd immunity was also noted. A public centred approach to future restriction and stringent measures was recommended.

***Key words**: Covid-19, Health policy, Game Theory Modelling*

INTRODUCTION

The Coronavirus Disease of 2019 (Covid-19) pandemic has caused more than 213 000 000 confirmed cases and more than 4 400 000 deaths across the globe as of 24 August 2021 (WHO, 2021). On the same date, Zimbabwe had an accumulated case roll of 123 000 cases and 4 293 deaths while South Africa was at 2 700 000 confirmed cases against 79 584 deaths. The attention to trends of Covid-19 statistic are drawing traction on various health policies compounded with high experimentations. Among public-health strategies aimed at suppressing and controlling the spread of the virus (Anderson, et al., 2020) such as quarantines, movement restrictions, self-isolation, physical distancing and vaccination; strict stay-at-home orders have been essential policy tools (Coates, et al., 2020). Detrimental strict orders have severe economic costs, such as businesses closure, reduced services, and reduced employment time which reduces people's incomes (Kabir and Tanimoto, 2020). What is of paramount importance is to identify the most probable effective way of curbing the virus without gambling through all possible strategies so as to reduce adverse effects of mixed detrimental strategies.
The policy response to Covid-19 was centered on restrictions of movements such that in Zimbabwe a 21-day national lockdown was declared, starting on the 30th of March 2020. By the 25th of May 2020, two months after initial lockdown, Zimbabwe had 56 confirmed cases, including 27 active cases, 4 deaths and 25 recoveries. On an earlier date, the 23rd of March 2020, South Africa had announced a national 21-day lockdown beginning on 27 March to 16 April 2020. By 24 March 2020, all nine South African provinces had confirmed cases. The country's first death was announced on 27 March 2020. Policy responses were seemingly symmetric between these two countries. The table below presents a sequential health policy coordination between South Africa and Zimbabwe from March 2020 to July 2021.

Table 1: First Wave to Third Wave Sequential Policy Interventions

Waves	South Africa (Player 1)	Zimbabwe (Player 2)
First Wave *(Mar 2020 to Nov 2020)*	***23 March 2020*** – A tight 21 day National Lockdown announced	***30 March 2020*** - The Zimbabwean government announces a Level 1 lockdown for a period of 21 days to curb the spread of COVID-19.
	09 April 2020 – South Africa announced that a nationwide lockdown set to expire on April 17 has been extended by two weeks to Thursday, April 30	***19 April 2020*** - Lockdown extended by a further 14 days
	01 May 2020 - Level 4 began by allowing residents to exercise outdoors and some	***03 May 2020*** - Zimbabwe has been under Level 1 lockdown for five weeks. National lockdown

	businesses to reopen.	extended indefinitely
	13 May 2020 – Intentions to easy lockdown announced.	***16 May 2020*** - Country placed under Level 2 lockdown
	12 July 2020 - The alcohol ban was reintroduced along with a new curfew from 21:00 until 4:00.	***21 July 2020*** – A stringent daily curfew was announced, with only essential services allowed to operate between 8am and 3pm.
	15 August 2020 – Curfew hours relaxed	***18 August 2020*** - Curfew hours relaxed
	16 September 2020 – Further lowering of restrictions announced.	***21 September 2020*** – Further lowering of restrictions announced.
	11 November 2020 – International travelling allowed.	***01 December 2020*** – Zimbabwe opens Beitbridge border post for international travelling.
Second Wave *(Dec 2020 to April 2021)*	***28 December 2020*** – Partial lockdown announced, introduced a curfew from 9 pm to 6 am, the ban on sale and transport of alcohol, closure of public amenities	***02 January 2021*** - 30-day curfew introduced. ***13 January 2021*** - Traditional funerals were banned
	01 February 2021 – First Shipment of vaccines received and vaccination commences.	***18 February 2021*** – Mass vaccination began.
Third Wave *(May 2021 to Aug 2021: Present date of authorship)*	***30 May 2021*** – Tight lockdown measures introduced.	***13 June 2021*** - Localised lockdowns introduced.
	15 June 2021 – Further measure introduced, reinforced by more measures on 27 June 2021.	***29 June 2021*** - Imposed a dusk to dawn curfew, banned inter-city travel and cut business hours
	11 July 2021 - Continuation of lockdown measures announced.	***14 July 2021*** – Government extends lockdown to vaccinate 1 000 000 people.
	24 August 2021 – Number of people fully vaccinated: 4,983,911 (8.5%)	***24 August 2021*** – Number of people fully vaccinated: 1,483,968 (9.8%)
Sources: Dzobo, M, I Chitungo and T Dzinamarira (2020); GoZ (2020); Ramaphosa (15 March 2020); Evans (2020) Mkhize (2021); Moultrie, et al. (2021); WHO (2020); Pillay-van Wyk, (2020); Mueller (2021); Bradshaw (2021); Crisp (2021); Reynolds (2020); York (2021); WHO (2021); Olander (2021).		

This shows that quite a number of strategies were swiftly introduced in order to fight Covid-19. These include adoption of vaccines, community engagement, introduction of lockdown, quarantining of returns from outside among others. What is of paramount importance is whether the policies were equally effective in these countries and if the systematic coordination was of much relevance in guiding future health policy stance.

LITERATURE

The study on Covid-19 requires a proper epidemiological analysis. Epidemiology is the branch of medical science dealing with the incidence, distribution, and control of diseases in a population, with an aim to identify the factors driving the behaviour of a disease. The emergence and worldwide spread of repeated pandemics as well as severe modern epidemics have become serious threats to mankind. Literature is awash with methods of evaluating the potential methods for controlling the breakout and spreading of these epidemic diseases. Econometric modelling is one of the important tools in analysing the spread and control of infectious diseases bearing in mind the key factors governing the development of a disease, such as transmission and recovery rates which can be used to predict how the disease will spread over time. For an in-depth analysis of the behaviour of epidemics, various models of non-linear ordinary differential equations have been studied by different of scholars (Podder, et al. 2007; Kabir and Tanimoto, 2019; Kuga, Tanimoto and Jusup, 2019).
The novel Covid-19 analysis presents a situation that can be hypothesised as an evolutionary game theory. This is a theory combining game theory analysis and dynamic evolutionary process analysis. Evolutionary game theory has its foundations in the theory of biological evolution. The theory divorces itself from the classical game theory in economics which assumes conditions of rationality and posits a human behaviour of seeking to achieve the balance of game through trial and error. The theory is, therefore, in a better position to analyse and solve a complex of factors such as social habits, norms, institution and the problems in the process of spontaneous evolution.
The novelty of the pandemic situation puts the government and the public's awareness of the epidemic situation in a constantly changing process. This also makes the response strategies adopted be contained in a process of dynamic adjustment. The choice of participants are subject to the "bounded rationality" hypothesis that the participants of evolutionary game adopt imitation behaviour. What matters most in the evolutionary game analysis is to determine the mode of learning and strategy adjustment of the government, and the public

during the development of the pandemic. Following the evolutionary game theory, the interaction between the government and the public was coerced during the prevention and control of Covid-19. These became the dynamic evolutionary process of the two players' repeated game over time which should reach a certain steady state.

Several scholars have studied the epidemic prevention and control from the perspective of the government intervention and the public behaviour. Scholars point out that government intervention measures (Zhang, 2003; Li and Che, 2014; Sega, et al., 2015; Zheng, Wu and Li, 2016), cautious attitude towards epidemic (Kleczkowski, at el., 2015), trust in information (Cui, et al., 2017) and risk awareness (Poletti, Ajelli and Merler, 2011) will affect the control of epidemic. Moreover, the effectiveness of the new management model of the government (Taherkhani and Farshadpour, 2017) and how to control the spread of infectious diseases effectively from the perspective of law enforcement (Qi and Chen, 2009) have been studied. From the perspective of the government and the public, the above scholars have analysed and summarized the prevention and control of the epidemic by using qualitative methods at the macro level, providing experience for the study of the COVID-19 epidemic.

In addition, some scholars have used Susceptible-Infected (SI) model (Li, et al., 2003), Susceptible- Infected-Recovered (SIR) model (Poletti, Ajelli and Merler, 2011), generalized stochastic Petri net model and equivalent Markov chain model (Li, Wang and Qiao, 2014), propagation dynamics model (Endo, Ejima and Nishiura, 2018), and other mathematical tools to analyse major public health events. Li, Sun and Zhen (2011) studied an epidemic model with both diffusion and migration. Jin and Li (2018) constructed an evolutionary game model based on the credibility of the government and the trust of the people. Zu et al., (2015) evaluated the effectiveness of border quarantine, isolation, treatment and other measures to prevent influenza by establishing a computer epidemic model. Sun and Zhang (2016) built a disease transmission control model based on the spread force, and simulated the spread process of the disease to build an infection tree, and proposed the target immune algorithm to provide support for the emergency management of disease control. Mei, He and Zhu (2016), introduced spatial information, urban traffic, individual behavior and other factors into the urban air infectious disease diffusion model, and verified the effectiveness of the model by simulating the spread of infectious diseases with a simulation system.

These studies give a foundation for this study by using an econometric model though further models still need to be further optimized. Since the global outbreak of Covid-19 in 2020, some scholars have researched the epidemic from the aspects of clinical characteristics and bio-informatics. Zhu et al. (2020), reviewed the clinical and chest imaging features of Covid-19 and compared them with other infectious and non-infectious diffuse lung diseases to find clues for the diagnosis of Covid-19 to ensure accurate diagnosis and treatment. Chen et al., (2020), identified a novel human corona virus based on RNA from two cases of pneumonia in Wuhan in 2019. Chan et al., (2020) carried out bioinformatics analysis on the viral genome of a patient infected with Covid-19 and compared it with other corona virus genomes to provide a basis for studying the pathogenesis, optimal diagnosis, antiviral and vaccination strategies of the disease. Yang et al., (2020) made a comparative analysis of the SARS pandemic and the 2019-nCoV. Combined with the lessons of SARS epidemic, the nucleic acid sequence can be determined and isolation strategy can be adopted quickly. The above studies mainly compare and analyze the Covid-19 with other pulmonary diseases. There are few studies involving evolutionary games and government intervention in Covid-19.

These above studies mainly focus on qualitative analysis or quantitative analysis but there are few studies on modelling and forecasting the development of Covid-19 using evolutionary game from the perspective of the government.

METHOD AND DATA

In an evolutionary game theory, the interaction between the policy stances of the two ideally coordinated governments which share the same border and common trade patterns will inevitably occur during the prevention and control of major epidemics. Similarly, the interaction with its citizens in face of Covid-19 has its pay-off. These interactions can clearly be a game process. Assume that the strategy set of Government I (One) is "Restrict" strategy (R) and "Laissez-faire" strategy (L), that is, GI = {R, L}. Similarly, the reaction of Government II is "Restrict" strategy (R) and "Laissez-faire" strategy (L), that is, G2 = {R, L}. The "Restrict" strategy mainly refers to a series of measures taken by the government to actively respond to the epidemic situation, such as large-scale screening and isolation for close contacts and suspected exposed persons of Covid-19, strict epidemic reporting, strengthening the management of medical institutions and targeted treatment. The "Laissez-faire" strategy means that the government is indifferent to the Covid-19 epidemic. However given that the governments have been taking an active restrict approach, though at different levels, the success of such strategies depends on the level of compliance (C) by the public. Given the choice, the public may evade (E) the restrictions and make the policy ineffective or comply (C) and render it effective. When choosing a strategy, the pay-off of the public depends on a balance of them perceived pay-off of compliance (C) against the pay-off of risking infection through evasion (E). Staying home has its economic cost while being infected has its cost. The public weigh the two and consider the one with lower cost. Thus, the effectiveness of each policy largely

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depends on the public's willingness to comply. If this is not the case, then possible control of the virus without policy effectiveness implies herd immunity. Arbitrarily, the following equilibrium scenarios may be hypothesised:

Scenario I: In the first days of the epidemic, the governments knew little about the Covid-19. Both of them may not be willing to 'restrict' early. However, if the governments take evasive actions (L) or respond lately, the social losses would be high.

Scenario II: Governments would consider political and economic factors, and previous experience in fighting the epidemic, by considering restricting (R). At this time, the probability of large-scale spread of Covid-19 is reduced. This equilibrium is attained after bearing losses from the prior-loss-bearing equilibrium at Scenario (I). This is to mean, Scenario (II) is most likely to be reached if the game is played repeatedly given that the public complies (C).

Scenario III: Governments may restrict (R) in all its best means but due to conditions of the restrictions which would not provide the public with a means of living, the public will evade (E) restrictions. The policy positions would be found to be increasing the spreading rate.

Scenario IV: Policy stances may not be influencing the rate of spreading at all but signs of control may be visible on the contagion side. Herd immunity may be the intuition behind this.

In order to model this, the paper follows Casini and Perron (2018) closely, by considering a linear regression with n breaks (or $n + 1$ regimes):

$$Y_t = x_t'\beta + w_t'\vartheta_j + \varepsilon_t, \quad t = T_{j-1} + 1, \dots, T_j \dots \dots \dots . . (1)$$

for $j = 1, \dots, n + 1$, following Bai and Perron (1998). In this model, Y_t is the observed dependent variable; $x_t(p \times 1)$ and $w_t(p \times 1)$ are vectors of covariates; β and $w_t(j = 1, \dots, n + 1)$ are the corresponding vectors of coefficients; ε_t is the disturbance. The break dates $(T_t, \dots, T_n)$ are unknown (the convention that $T_0 = 0$ and $T_{n+1} = T$ is used). The aim is to estimate the regression coefficients and the break points when T observations on (Y_t, x_t, w_t) are available. This is a partial structural change model since the parameter vector β is not subject to shifts. When $p = 0$, a pure structural change model can be obtained. A partial structural change model can be beneficial in terms of obtaining more precise estimates and more powerful tests. The method of estimation is standard least-squares (OLS), which minimizes the overall sum of squared residuals (SSR):

$$\sum_{i=1}^{n+1} \sum_{t=T_{i-1}+1}^{T_i} [Y_t - x_t'\beta - w_t'\vartheta_i]^2 \dots \dots \dots \dots \dots . (2)$$

Let: $\hat{\beta}(T_j)$ and $\hat{\vartheta}(T_j)$ denote the estimates based on a partition $(T_1, \dots, Tn)$ denoted by (T_j). Substituting these in the objective function and denoting the resulting SSR as $S_t(T_1, \dots, T_n)$, the estimated break points are:

$$(\hat{T}_1, \dots, \hat{T}_j) = argmin_{(T_1, \dots, T_n)} S_T(T_1, \dots, T_n), \dots \dots \dots \dots (3)$$

with the minimization taken over a set of admissible partitions. The parameter estimates are those associated with the partition $(\hat{T}_j)$, i.e., $\hat{\beta} = \hat{\beta}(\{\hat{T}_j\}), \hat{\vartheta} = \hat{\vartheta}(\{\hat{T}_j\})$. Since estimation is based on OLS, even if changes in the variance of ε_t are allowed, provided they occur at the same dates $(T_1, \dots, T_n)$, they are not exploited to increase the precision of the break date estimators unless a quasi-likelihood framework is adopted. Model (1) was estimated where the number of T was obtained and the confidents of the structural breaks were used to infer on the impact of phased policies in corresponding breaks.

Data on the Positive Rate (PR) and the Stringency Index (SYI) computed by the Our World in Data (OWID, 2021) using Covid-19 statistics submitted by the South African and Zimbabwean governments were used. The Stringency Index (SYI) is a composite measure based on nine response indicators which are: '*school closures; workplace closures; cancellation of public events; restrictions on public gatherings; closures of public transport; stay-at-home requirements; public information campaigns; restrictions on internal movements; and international travel controls, rescaled to a value from 0 to 100 (100 = strictest)*' (OWID, 2021). The PR was modelled as the independent variable and the SYI as the dependent variable.

RESULT AND DISCUSSION

Descriptive statistics

The rate of positive cases is higher in South Africa than in Zimbabwe though the highest level of stringency are equal between the two countries. On average, Zimbabwe is found to be more stringent than South Africa.

Table 2: Descriptive Statistics

	South Africa		Zimbabwe	
	PR	**SYI**	**PR**	**SYI**
Mean	0.1254	61.324	0.0704	70.897
Median	0.0935	57.410	0.0480	71.300
Maximum	0.3260	87.960	0.2870	87.960
Minimum	0.0150	13.890	0.0010	27.780

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Std. Dev.	0.0871	17.108	0.0629	12.982
Skewness	0.7060	-0.1230	1.2400	-0.4686
Kurtosis	2.1667	2.1326	3.7485	2.6285

Stationarity Tests

The below Table shows that only PR for Zimbabwe is non-stationary at levels while all other variables are stationary. The PR of Zimbabwe became stationary after first differencing.

Table 3: Non-Stationarity Test Results

Country	**Variable**	**ADF in Levels ~ I (0)**	**Decision**	**ADF – Fist Differenced~ I(1)**	**Decision**
South Africa	PR	-2.6196* (0.0896)	Stationary	N/A	N/A
	SYI	-2.6996* (0.0747)	Stationary	N/A	N/A
Zimbabwe	PR	-2.2178 (0.2003)	Non-stationary	-10.4908*** (0.0000)	Stationary
	SYI	-3.7268*** (0.0040)	Stationary	N/A	N/A

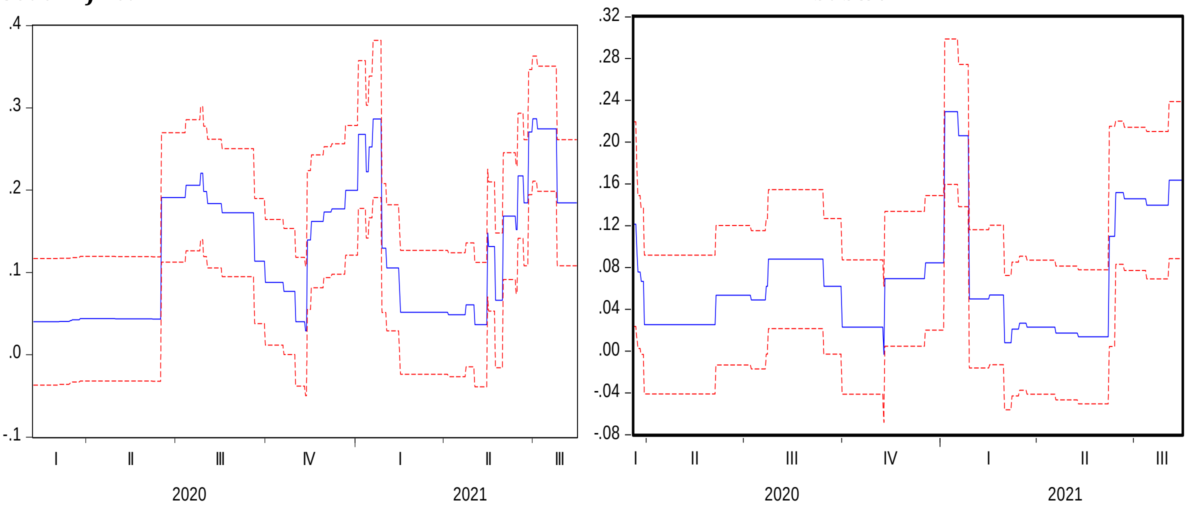
****and * Denote level of significance at 1% and 10% respectively; figures in parentheses indicate p-values.*

IDENTIFICATION OF SERIAL LEARNING PATH

The Fig 1 below shows the diagrammatic representation of serial learning paths between the two countries. A symmetrical serial learning path with five structural breaks was established between the two countries. This is to mean, a close to identical path where Zimbabwe was mimicking South Africa in reaction to Covid-19 cases was observed. The outcome can used to reflect a dynamic sequential game.

Fig 1: South Africa and Zimbabwe Serial Social Learning Paths

South Africa ***Zimbabwe***



INTENDED OUTCOMES SERIAL INTERVENTION PATH: POSSIBLE DYNAMIC EQUILIBRIA ANALYSIS

The researchers estimated the structural break model to determine the possible equilibria over a series of interventions. Data revealed five estimable structural breaks where each set of interventions represented by the stringency index can be evaluated. The two countries were implementing policies sequentially and symmetrically, where South Africa was arbitrarily the first player and Zimbabwe responding, ideally taking their best strategies. Thus the evolutionary equilibria created can be regarded as Nash. Results are presented in Table 4 below.

Table 4: Structural Breaks Policy Coefficients Estimates

Structure	South Africa				Zimbabwe			
	Variable	**Coefficient**	**Std. Error**	**Prob.**	**Variable**	**Coefficient**	**Std. Error**	**Prob.**
One	***3/10/2020 - 6/16/2020 -- 99 obs***				***5/14/2020 - 7/21/2020 -- 69 obs***			
	C	0.0399***	0.0090	0.0000	C	0.1525***	0.0543	0.0052
	SYI	0.0000	0.0001	0.7022	SYI	0.0015**	0.0007	0.0362
Two	***6/17/2020 - 11/12/2020 -- 149 obs***				***7/22/2020 - 11/10/2020 -- 112 obs***			
	C	-0.1146***	0.0291	0.0001	C	-0.4687***	0.0745	0.0000
	SYI	-0.0040***	0.0005	0.0000	SYI	-0.0069***	0.0010	0.0000
Three	***11/13/2020 - 1/27/2021 -- 76 obs***				***11/11/2020 - 1/28/2021 -- 79 obs***			
	C	-0.0076	0.0585	0.8963	C	-0.4815***	0.0575	0.0000
	SYI	-0.0041***	0.0012	0.0005	SYI	-0.0081***	0.0008	0.0000
Four	***1/28/2021 - 5/15/2021 -- 108 obs***				***1/29/2021 - 6/08/2021 -- 131 obs***			
	C	-0.1042***	0.0265	0.0001	C	-0.0359**	0.0143	0.0123
	SYI	0.0032***	0.0005	0.0000	SYI	0.0010***	0.0003	0.0001
Five	***5/16/2021 - 7/30/2021 -- 76 obs***				***6/09/2021 - 8/15/2021 -- 68 obs***			
	C	-0.0442*	0.0255	0.0839	C	0.0298	0.1614	0.8533
	SYI	0.0044***	0.0004	0.0000	SYI	0.0018***	0.0024	0.4603
	R-squared 0.817917 Adjusted R-squared 0.814626 F-statistic 248.5573 Prob(F-statistic) 0.000000				R-squared 0.746954 Adjusted R-squared 0.741882 F-statistic 147.2647 Prob(F-statistic) 0.000000			
Break type: Bai-Perron tests of L+1 vs. L sequentially determined breaks *Break selection: Trimming 0.15, , Sig. level 0.05*								

***** or ** and * Denote level of significance at 1%, 5% and 10% respectively;**

The structural breaks portray five repeated game shots, where in each phase players update their strategies depending on the last season's payoff. The coefficients for government policy (SYI) were significant for all players at all rounds of play (different stages of adjustments or regimes) except for South Africa in the first round. This means that policies had a significant component in influencing Covid-19 outcomes though the intended intervention results were mixed. The structures were sequentially predicted with precision starting from the second which ended at 12 November 2020, followed by the third elapsing at 20 January 2021, then the fourth which had a long drag on Zimbabwe's interventions up to 08 June 2021. In the last band, South Africa had interventions which were significant up to 30 July 2021 while Zimbabwe had a further drag to 15 August 2021.

Based on coefficients in the first structure, the outcomes confirmed the hypothesised scenario (I) where a high probability of late intervention was noted. South Africa's intervention at this stage proved to be insignificant in curbing the virus while in Zimbabwe a worsening condition was resultant. High losses were therefore incurred.

The second and the third phases were characterised by consistent intended outcomes. The intervention by the governments could reduce the rate of positive cases in the range of 0.0040 and 0.0041 for South Africa then 0.0061 and 0.0081 for Zimbabwe. This confirms the hypothesised scenario (II) as governments could have gathered more information (Learning-Path) about the novel virus and the public were in high compliance. The stringency policy stances were successful in curbing the spreading of the virus.

However, phases four and five were characterised by adverse intended outcomes. Policy interventions were increasing the rate of positive cases. In South Africa, it ranged from 0.0032 to 0.0044 for the respective phases while in Zimbabwe it was much lower at 0.0010 and 0.0018 for the two phases. In line with scenario (III), it can be inferred that the public had suffered enough costs of staying home and other stringent measures thus resorting to evasion as a strategy. Resultantly, the stringency policy stances failed in curbing the spreading of the virus.

The intercept statistic, measuring self-containment of the virus, had interesting results. It was negative in all cases except in the first phase for both countries and in the last phase for Zimbabwe. An evidence of an in-built heard immunity can be inferred. It is important to note that the statistic has been fairly decreasing though out the phases for Zimbabwe but fluctuating for South Africa. This could be highly related to the different Covid-19 variants associated with the three waves of the virus mutations.

CONCLUSION

The study considered Covid-19 as a novel infectious disease that is spread through direct contact between individuals. Outbreak control measures implemented to reduce the contacts within the population can reduce the height of the peak, the speed at which the virus spreads, and the impact of the infection. In South Africa and Zimbabwe, different policies and strategies have been implemented, based on the experience and recommendations of WHO to control the spreading of Covid-19 as information was availed with time. An evolutionary game was modelled with a learning-aspect assumed component where players had an imitation tendency. The results showed evidence of a social learning path with phased interventions. This became a game with repeated plays. Convergence in policy stance by the two countries revealed a possible gain in the first phases but losses in the last two phases. The delayed intervention in the first phase had implicated losses. The research posited a high level of evasion by the public on stringency conditions by the governments as indicated by the results of the last two phases. Further, an evidence of natural heard immunity was noted between the two countries. It was recommended that future stringent policies should be public centred where governments attend to public needs whenever stringent conditions are applied. These include provision of a source of living and other needs which may force people to evade restrictions.

REFERENCES

[1] Anderson, R.M., Heersterbeek, H., Klinkenberg, D. & Hollingsworth, T. D. (2020). How will country based mitigation measures influence the course of the COVID-19 epidemic. Lancet 395, 931–934. (doi:10.1016/S0140- 6736(20)30567-5)

[2] Bradshaw, D., Laubscher, R., Dorrington, R., Groenewald, P. & Moultrie, T., (2021). Report on weekly deaths in South Africa 14 – 20 Mar 2021. Burden of Disease Research Unit, South African Medical Research Council

[3] Caihong, S., & Boshu, Z. (2016). Epidemic spreading and emergency controlling model based on targeted inoculations. Management Review, 28(8), 167.

[4] Casini, A. & Perron, P. (2018). Structural Breaks in Time Series. Oxford Research Encyclopedia of Economics and Finance. Boston University

[5] Chan, J. F. W., Kok, K. H., Zhu, Z., Chu, H., To, K. K. W., Yuan, S., & Yuen, K. Y. (2020). Genomic characterization of the 2019 novel human-pathogenic coronavirus isolated from a patient with atypical pneumonia after visiting Wuhan. Emerging microbes & infections, 9(1), 221-236.

[6] Chen, L., Liu, W., Zhang, Q., Xu, K., Ye, G., Wu, W., ... & Liu, Y. (2020). RNA based mNGS approach identifies a novel human coronavirus from two individual pneumonia cases in 2019 Wuhan outbreak. Emerging microbes & infections, 9(1), 313-319.

[7] Coates, B., Cowgill, M., Chen, T. & Mackey, W. (2020) Shutdown: estimating the COVID-19 employment shock. Melbourne, Australia: Grattan Institute.

[8] Crisp, N. (2021). Circular: COVID-19 vaccination roll-out: Information for vaccination sites: 19th August 2021. COVID-19 South African Online Portal

[9] Cui, B., Liao, Q., Lam, W. W. T., Liu, Z. P. & Fielding, R. (2017). Avian influenza A/H7N9 risk perception, information trust and adoption of protective behaviours among poultry farmers in Jiangsu Province, China. BMC public health. 2017; 17(1): 463.https://doi.org/10.1186/s12889-017-4364-yPMID: 28521760

[10] Dzobo, M., Chitungo, I. & Dzinamarira, T. (2020). COVID-19: a perspective for lifting lockdown in Zimbabwe. The Pan African Medical Journal Vol 35, Suppl 2, Article 13

[11] Endo, A., Ejima, K., & Nishiura, H. (2018). Capturing the transmission dynamics of the 2009 Japanese pandemic influenza H1N1 in the presence of heterogeneous immunity. Annals of epidemiology, 28(5), 293-300.

[12] Evans, J. (2020) "Covid-19: SA enters second wave as Mkhize warns of surge in infections among teens". News24.

[13] GoZ (2020). Ministry of Health and Childcare COVID-19 Update, 2 August, Government of Zimbabwe, Harare

[14] GoZ (2020). Ministry of Health and Childcare COVID-19 Update, 2 August, Government of Zimbabwe, Harare.

[15] Jin, X., & Li, Y. L. (2018). An analysis on the decision-making behavior of local government and farmers in the public crisis of animal epidemic based on evolutionary game. Journal of Domestic Animal Ecology, 39, 69-74.

[16] Kabir, K. M. A. & Tanimoto, J. (2019). Dynamical behaviors for vaccination can suppress infectious disease-a game theoretical approach. Chaos Solitons Fractals 123 229–39

[17] Kleczkowski, A., Maharaj, S., Rasmussen, S., Williams, L., & Cairns, N. (2015). Spontaneous social distancing in response to a simulated epidemic: a virtual experiment. BMC Public Health, 15(1), 1-13.
[18] Kuga, K., Tanimoto, J. & Jusup, M. (2019). To vaccinate or not to vaccinate: a comprehensive study of vaccination subsidizing policies with multi-agent simulations and mean-field modelling. J. Theor. Biol. 469 107–26
[19] Li, L., Sun, G. Q., & Jin, Z. (2009). Traveling pattern induced by migration in an epidemic model. Journal of Biological Systems, 17(02), 319-328.
[20] Li, Y. J., Wang, X. Q., & Qiao, X. J. (2014). Spread model of major infectious disease based on generalized stochastic petri nets. Chinese Journal of Management Science, 22(3), 74-80.
[21] Li, Y. L. & Che, H. (2014). Analysis on decision-making behavior by local government in public crisis of sudden animal disease outbreak. Journal of Domestic Animal Ecology. 2014; 35: 87–90.
[22] Li, Z. L., Cui, H. J., Yang, H., & Li, X. W. (2003). SI models and piecewise SI model on SARS forecasting. Journal of Remote Sensing-Beijing-, 7(5), 345-349.
[23] Lv, Y. J. (2014). Analysis of strategy of HIV/AIDS prevention and control in Vietnam. Southeast Asian Studies. 2014; (01): 4–9.
[24] Mkhize, Zwelini (8 May 2021). "Update on Covid-19 (08th May 2021)". COVID-19 South African Online Portal. Retrieved 20 August 2021.
[25] Moultrie, T., Dorrington, R., Laubscher, R., Groenewald, P., & Bradshaw, D. (23 February 2021). "Correlation of excess natural deaths with other measures of the COVID-19 pandemic in South Africa" . Burden of Disease Research Unit, South African Medical Research Council
[26] Mueller, B., Robbins, R. & Chutel, L., (2021). AstraZeneca's Vaccine Does Not Work Well Against Virus Variant in South Africa. The New York Times. ISSN 0362-4331
[27] Olander, E. (2021). 200,000 Chinese Vaccines Will Soon Arrive in Zimbabwe. The China Africa Project.
[28] OWID (2021). South Africa: Coronavirus Pandemic Country Profile. Our World in Data. https://ourworldindata.org/coronavirus/country/south-africa
[29] OWID (2021). Zimbabwe: Coronavirus Pandemic Country Profile. Our World in Data. https://ourworldindata.org/coronavirus/country/zimbabwe
[30] Pillay-van Wyk, V., Bradshaw, D., Groenewald, P., Seocharan, I., Manda, S., Roomaney, R. A., Awotiwon, O., Nkwenika, T., Gray, G., Buthelezi, S. S. & Mkhize, Z. L. (2020). COVID deaths in South Africa: 99 days since South Africa's first death. South African Medical Journal. 110 (11): 1093.
[31] Podder, C. N., Gumel, A. B., Bowman, C. S. & Mcleod, R. G. (2007). Mathematical study of the impact of quarantine, isolation and vaccination in curtailing an epidemic. J. Biol. Syst. 15 185–202
[32] Poletti, P., Ajelli, M., & Merler, S. (2011). The effect of risk perception on the 2009 H1N1 pandemic influenza dynamics. PloS one, 6(2), e16460.
[33] Ramaphosa, C. (15 March 2020). "Statement by President Cyril Ramaphosa on measures to combat COVID-19 epidemic". The Presidency.
[34] Reynolds, M. (2020). What is coronavirus and how close is it to becoming a pandemic?. Wired UK. ISSN 1357-0978
[35] Santermans, E., Robesyn, E., Ganyani, T., Sudre, B., Faes, C., Quinten, C., ... & Plachouras, D. (2016). Spatiotemporal evolution of Ebola virus disease at sub-national level during the 2014 West Africa epidemic: model scrutiny and data meagreness. PloS one, 11(1), e0147172.
[36] Sega, L., Maxin, D., Eaton, L., Latham, A., Moose, A., & Stenslie, S. (2015). The effect of risk-taking behaviour in epidemic models. Journal of biological dynamics, 9(1), 229 246.
[37] Shan, M., Hua, H., & Yifan, Z. (2016). Modeling the Spreading of Airborne Infectious Diseases in a City. Management Review, 28(8), 158.
[38] Taherkhani, R., & Farshadpour, F. (2017). Lurking epidemic of hepatitis C virus infection in Iran: A call to action. World journal of hepatology, 9(24), 1040.
[39] WHO (2020). Republic of Zimbabwe. World Health Organization, available at https://www.who.int/countries/zwe.
[40] WHO (2020). "Coronavirus disease (COVID-19) situation report 163" . World Health Organization.
[41] WHO (2021). COVID-19 situation report for WHO Africa Region. NIHR Global Health Research Unit Tackling Infections to Benefit Africa at the University of Edinburgh.

[42] Xing, Q. I., & Li, C. H. E. N. (2009). The legal system in China of infectious disease prevention and control by discussing A/H1N1 influenza. Journal of Tianjin Administrative Cadre College of Politics and Law.
[43] Yang, Y., Peng, F., Wang, R., Guan, K., Jiang, T., Xu, G., ... & Chang, C. The deadly coronaviruses: The 2003 SARS pandemic and the 2020 novel coronavirus epidemic in China, 5 2020. J. Autoimmun, 102434.
[44] York, G. (2021). Mounting desperation in Africa as COVID-19 vaccine shortage persists. The Globe and Mail. Harare and Johannesburg.
[45] Zhang, G. Q. (2003). The administration of public crises, and the goverment's responsibility Take SARS epidemic control as an example. Management World. (12): 42–50.
[46] Zheng, H. E., Wu, J. & Li, X. Y. (2016). Risk narrative of rural emergency in the context of risk society: metaphor, hidden danger and response—a case study of avian influenza. Journal of Nanjing Agricultural University (Social Science Edition). 2016; 16: 9 21+162
[47] Zhu, Y., Chen, L., Ji, H., Xi, M., Fang, Y., & Li, Y. (2020). The risk and prevention of novel coronavirus pneumonia infections among inpatients in psychiatric hospitals. Neuroscience bulletin, 36(3), 299-302.
[48] Zu, Z. H., Xu, Q., Zhang, B., Xu, Z. K. & Zheng, T. (2015) Prevention strategies for novel influenza pandemics based on computational experiments. Systems Engineering Theory & Practice. 2015; 35:2513–2522.