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The Complex Dynamic of Human Immunodeficiency Virus Spread

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ABSTRACT

This study used the Complex Adaptive System approach to illustrate the global HIV/AIDS epidemic. Complex Adaptive System approach derived feature similarity that represented the heterogeneity of the HIV phenomenon. Rather than seeing HIV infection as a linear cause and effect model, it was understood through the lens of complex adaptive systems by recognizing the intricate interactions and relationships of different agent and components that shaped this phenomenon. Results show that HIV per capita is well controlled by the health care service in all countries except for countries with disproportionate responses of HIV/capital incidences. These countries with disproportionate responses have modifiable and non-modifiable factors that contributed to the complex dynamic of HIV spread. The migratory pattern of these countries is also a contributory factor to the spread of HIV. The rise and spread of HIV are therefore, multi-dimensional and not just a health care issue. Focusing on behavior change or therapy alone may not combat this epidemic. The approach needs to be multifaceted and interdisciplinary taking into consideration the context and the economic and social realities at multiple scales which may include: socio-

economic, political, cultural, gender equality, migration or mobility patterns, spirituality, and environment, among others. To eradicate or minimize the spread of HIV, there should be a holistic approach to attacking this epidemic.

Keywords: Complex Adaptive System, HIV/AIDS, socio-economic, political, cultural, gender equality

INTRODUCTION

This study used the Complex Adaptive System approach to illustrate the global HIV/AIDS epidemic. HIV/AIDS epidemic is a complicated and unpredictable phenomenon. This complexity makes HIV difficult to study. The transmission of HIV for instance, is very complex and adaptive, with agents interacting with one another constantly and adapting their behavior to others' behavior. The complex Adaptive System approach allows for greater heterogeneity in understanding the HIV epidemic. The complex adaptive system can be used to identify the emergent feature that will represent combined effects of health care index and the number of persons living with HIV per capita in 79 countries. Identification of emergent feature may lead to more effective HIV prevention and control strategies in the future.

Literature suggests that complex systems approaches may greatly contribute to the evolving HIV epidemiology and prevention. Marshall et al.,(2012) and a multidisciplinary team of experts developed an Agent-Based-Model (ABM) which can closely approximate trends in the HIV epidemic. This ABM model was able to demonstrate the capacity for complex systems approaches to overcome many challenges observational studies encounter such as cost and difficulty capturing non-linear adaptive dynamics (Brandon, 2012). Another study by Burman(2016) in Limpopo province South Africa emphasizes that it is possible to simulate new social practices that will contribute to reduction of HIV using Complex Adaptive System. In this study, the researchers introduced an innovative intervention that is designed to respond to complex aspects of the HIV landscape.

Complex Adaptive System approach will be utilized in this study to derive feature similarity that will represent the heterogeneity of the HIV phenomenon. This study will generate mathematical representations of the combined effects of Health Care and number of persons living with HIV per capita globally. From these information, an emergent feature will be deduced.

This study is limited by the following delimitations: that data are generated through data mining and that countries which do not have available data

for comparison were not included in the study. By utilizing the Complex Adaptive System in the analysis of the HIV epidemic, we can see the intricate interactions and relationships of different agent and components that shaped this phenomenon.

FRAMEWORK

This study is anchored on the self-generated Complexity Model. According to the self-generated complexity Model, the repetition/iteration of a few basic rules causes the emergence of structure having features which are not shared by the rules themselves. The relevance of these phenomena and their universal properties discovered by statistical mechanical methods indicate self-generation as the most promising and meaningful paradigm for the study of complexity.

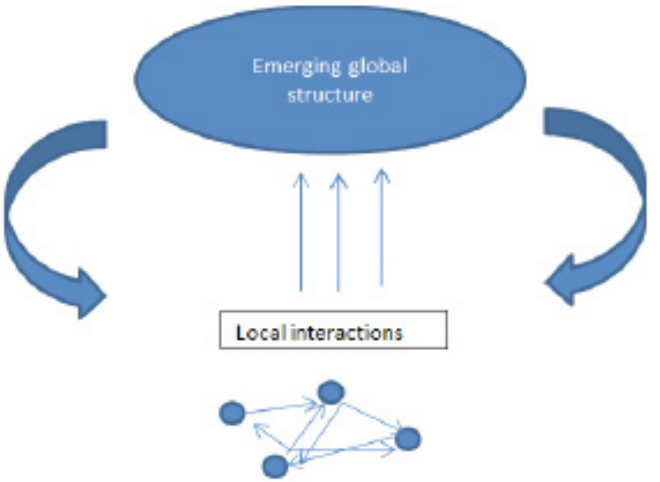

Figure 1. Synergistic Representation

Figure 1 shows that the global emergent feature may change local interactions, and local interactions will also influence the global emergent feature. The objective of this work is not to change the viewpoint from reductionism (escape into detail) to holism (ignore the detail), but to apply both approaches as they are two sides of the same model.

OBJECTIVES OF THE STUDY

The study sought to identify an emergent feature using mathematical representations of health care expenditure and persons living with HIV per capita globally.

METHODS

This is a descriptive type of research, utilizing new methodologies of data mining, cluster analysis, and complex adaptive system. Data sets used in this study are from CIA World Fact book (2017) on the Global data on Human Immunodeficiency Virus per capita and Numbeo.com (2017) for the global health care expenditure data sets. These data were analyzed, summarized and processed for emergent feature.

Factor analysis is used to determine the features described by the variables. These features are used as inputs to calculate the synergies. Positive synergies imply feature similarities. In calculating the synergy, a program or application from Northwestern Mindanao State College of Science and Technology (NMSCST) was utilized. Histogram is shown to summarize the synergy generated. A scatterplot was also generated to look at emerging patterns. The results are then analyzed and discussed.

RESULTS AND DISCUSSION

Table 1 shows the result of the factor analysis performed to extract the features from the original data sets.

Table 1

Factor Analysis of HIV/Capita 2017 & HCI 2017

Unrotated Factor Loadings and Communalities			
Variable	**Factor1**	**Factor2**	**Communality**
HIV/Capita 2017	0.717	-0.697	1.000
HCI 2007	-0.717	-0.697	1.000
Variance	1.0270	.9730	2.0000
%Var	.514	.486	1.000
Factor Score Coefficients			
Variable	**Factor1**		**Factor2**
HIV/Capita 2017	0.698		-0.717
HCI 2017	-0.698		-0.717

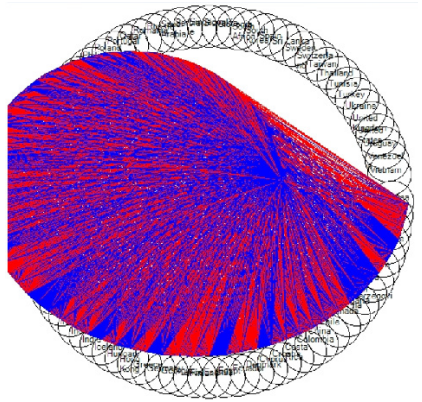

Figure 2. Synergistic Representation

Tabular values indicate that there are two features extracted. The first factor or feature is HIV Prevention Feature while the second factor or feature is Extensive HIV Prevention Feature.

Of the two factors, the first factor or feature accounted for 51.4%. For this reason, only the first feature is used in the analysis. However, the factor analysis is used solely for clustering the 79 countries but the data sets used in deriving the histogram were taken from the original source Numbeo.com and CIA world factbook. Using the factor 1 feature, the synergies were computed for pairs of countries from the results of the synergistic analysis in Figure 1.

A casual perusal shows that similarities are less prevalent than the dissimilarities as evidenced by preponderance of red rather than blue color. The countries involved in the study were disaggregated in order to highlight their positive synergy.

Table 2

Number otf Positive Synergies

Countries and No. of Positive Synergies							
Bangladesh	77	Nigeria	64	Philippines	35	Belgium	11
Egypt	77	Russia	55	Iceland	32	Denmark	11
Morocco	77	Macedonia	51	Hong Kong	30	Japan	11
Venezuela	77	Saudi Arabia	51	Italy	30	Thailand	11
Hungary	76	Tunisia	50	Colombia	29	South Korea	6
Ireland	76	Latvia	48	Lithuania	29	Taiwan	4
Cyprus	75	Slovakia	48	Malaysia	29	Portugal	23
Georgia	75	Pakistan	47	India	28	Singapore	23
Iran	75	Panama	43	Argentina	26	Sweden	23
Kazakhstan	75	Indonesia	42	Turkey	26	Ecuador	21
Ukraine	75	Poland	42	United States	26	Estonia	21
Serbia	70	Costa Rica	41	Mexico	25	Qatar	21
Bosnia and Herzegovina	68	Slovenia	39	Canada	23	Sri Lanka	21
Bulgaria	67	China	37	Switzerland	20	Finland	20
Brazil	66	Croatia	37	United Kingdom	19	Germany	20
Greece	66	Uruguay	36	Australia	14	Israel	20
Peru	66	South Africa	35	Spain	13	New Zealand	20
Romania	66	Chile	34	France	12	Norway	20
Nepal	59	Jordan	33	Netherlands	12		
Belarus	55	Lebanon	33	Austria	11		

These are summarized in the form of histogram as shown in Figure 2. Two clusters were derived. Cluster 1 are countries whose synergy is below 42 and the 2nd cluster are countries with synergy of 43 and above.

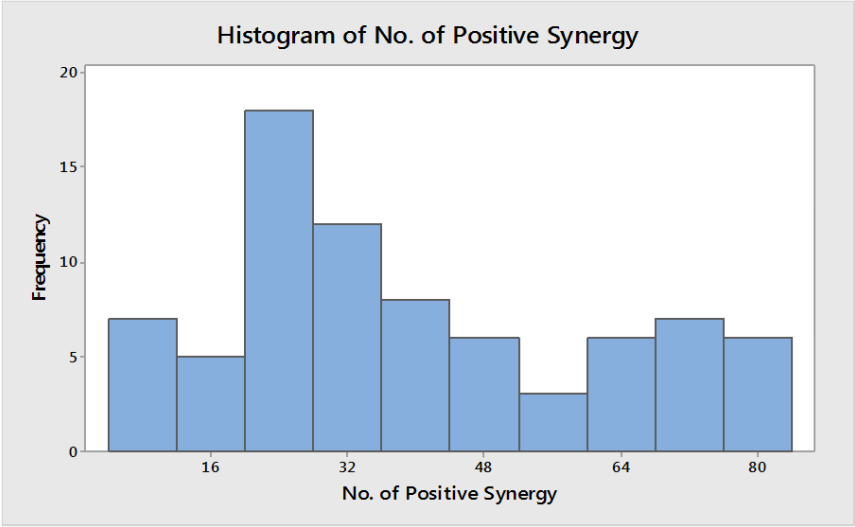

Figure 3. Histogram of No. of Positive Synergy

A scatterplot of the features in countries belonging to cluster 1 is shown in figure 3. The scatterplot shows that HIV per capita is well controlled by the Health care service from 36-61 except for Venezuela (HCI = 41.24, HIV/Capita = .0035), Ukraine (HCI = 50.95, HIV/Capita = .0080), Nigeria (HCI = 55.33, HIV/Capita = .0157), Russia (HCI = 57.63, HIV/Capita = .0069), Latvia (HCI = 59.71, HIV/Capita = .0052), and Panama (HCI = 61.41, HIV/Capita = .0053) where sudden jumps in HIV/capita are observed. While other countries belonging to cluster 1 are from 0-.002 in their HIV/Capita as shown in Table 3.

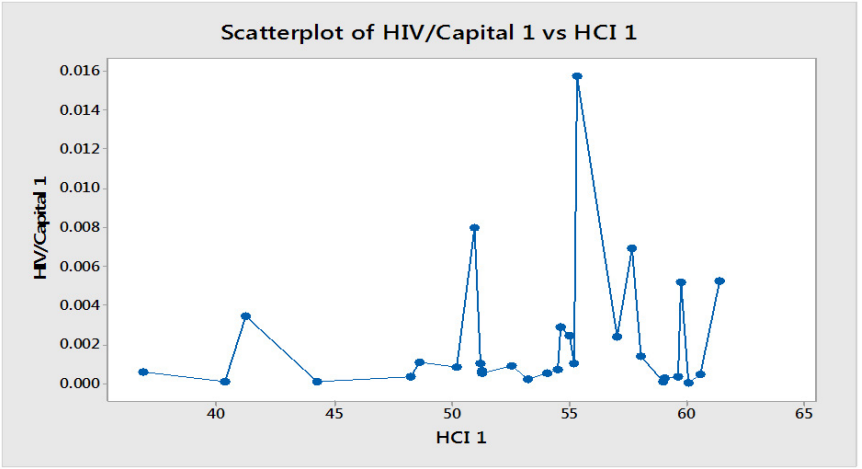

Figure 4. Scatterplot of Cluster 1

Venezuela, Ukraine, Nigeria, Russia, Latvia, and Panama had disproportionate responses showing steep increases in their HIV/Capita. Countries who maintained their HIV/capita from 0-0.002 are shown in Figure 4.

Table 3

Other Countries in Cluster 1

CLUSTER 1		
Bangladesh	Kazakhstan	Nigeria
Egypt	Ukraine	Nepal
Morocco	Serbia	Belarus
Venezuela	Bosnia and Herzegovina	Russia
Hungary	Bulgaria	Macedonia
Ireland	Brazil	Saudi Arabia
Cyprus	Greece	Tunisia
Georgia	Peru	Latvia
Iran	Romania	Slovakia
Pakistan	Panama	

In the space of HIV prevention feature, the emergent feature is the disproportionate responses of HIV/capita incidences, with countries (shown in Figure 4) Venezuela, Ukraine, Nigeria, Russia, Latvia and Panama having inconsistent responses. As shown in Table 3, it is observable that the countries which have disproportionate responses are from low to middle income economies.

According to a study by Shao, low income to middle-income countries bear the burden of being hit by the HIV epidemic due to a combination of modifiable factors such as: (1) poor socioeconomic conditions prompting economy-driven-migration and prostitution, (2) lack of access to health care, (3) political displacement of communities and, (4) gender inequalities (Shao, 2012). This is also reinforced by Pellowski's study which highlights HIV as a disease embedded in social and economic inequity because it affects those of lower socioeconomic status and impoverished area due to poverty, low educational attainment, lack of employment opportunities, and limited health care access among others (Pellowski, Kalichman, Matthews, & Adler, 2013). Further exacerbations to these countries are non-modifiable factors such as: (1) geography and (2) cultural practices. To aggregate the situation, high-income countries had reduced funding for the HIV response in low-income and middle-income countries when economic crisis hit 2008 (Avert.org, 2018). It is apparent therefore, that the root cause of the spread of HIV is economic in origin, enveloped by social factors. Geography and migration play a major role in the spread of HIV in these countries. In recent years a trend of migration flux from Venezuela arriving in Latin American countries has increased. This is a consequence of the existing political instability and the economic crisis in that country. National migration reports an increase in Venezuelans asking for refugee status in Panama with 4,615 Venezuelans lodged asylum applications as of 2017 report of the UN Migration Agency. The region is also a transit zone for African and Asian migrants trying to reach the United States or Canada. Such a situation is leading the migration to countries in Latin America and Europe, among other regions of the world. This forced displacement contributes to the spread of Human Immunodeficiency Virus (HIV) infection. The most direct consequences in public health are to countries of the Latin Americas, which are receiving the massive flux of migration from Venezuela to Panama (Tuite, 2018). On the other hand, the European Economic Area (EEA) is host to a large number of African migrants. Of the people living with HIV in Europe, around half (53%) of newly diagnosed people of non-native origin were from Sub-Saharan Africa (avert.org). This global mobility trend is also mirrored in a study by Cordova, H, et al, where he identified travel in increasing volume and refugee situations from areas of conflict as contributors to the spread of sexually transmitted diseases including HIV.

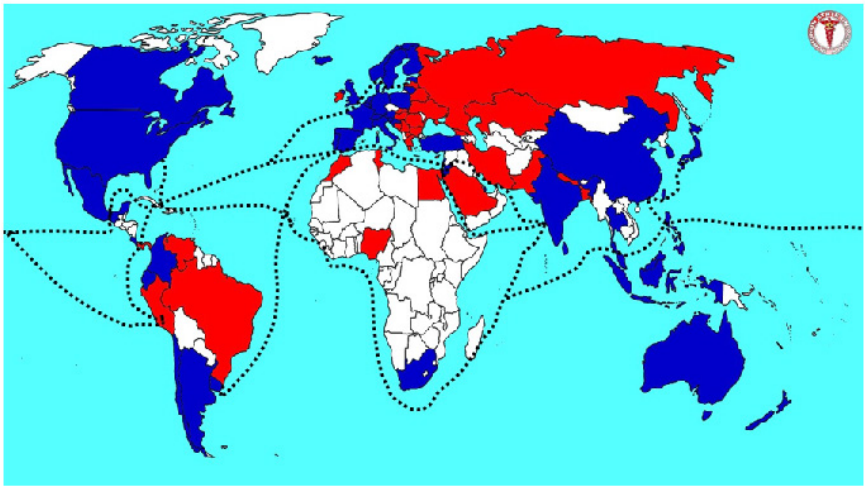

Figure 5. Major Global Trade Routes

Furthermore, it is interesting to note that the countries identified having inconsistent responses are located in the Northern Hemisphere as shown in Figure 5. According to Barroso et al. (2017), HIV cases is spreading towards the northeastern hemisphere because these are the direction of the global trade routes following the coastal area. This mobility among travelers increases the risk of HIV transmission to other countries.

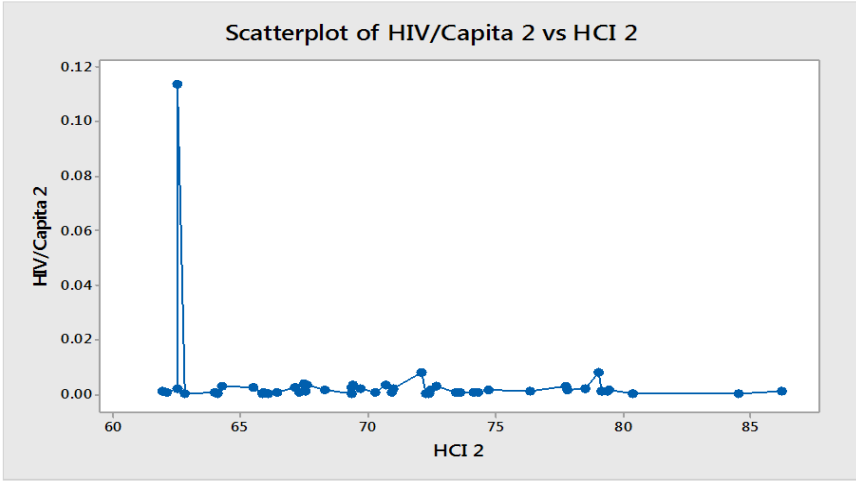

Figure 6. Scatterplot of Cluster 2

The scatterplot of Figure 5 shows that over the range of HCI 61.98-86.22, HIV/capita is within 0-1 range except for a sudden jump in South Africa (HCI=62.56, HIV/capita=.1138). The scatterplot suggests that as the country moves higher into the HCI continuum, the HIV epidemic remains low and controlled.

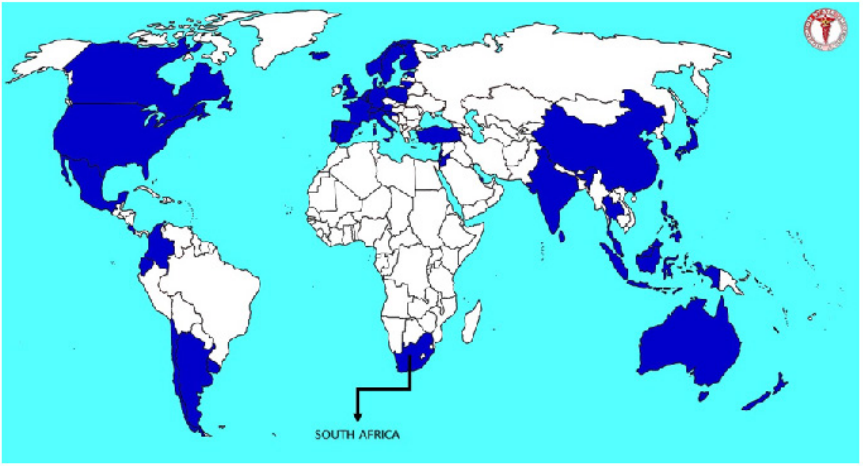

Figure 7. Countries in Cluster 2

Figure 6 are map of the countries from cluster 2. HIV epidemic are low and controlled in these countries except for South Africa. According to Worldbank data, South Africa has the biggest and most high-profile HIV epidemic in the world, with an estimated 7.2 million people living with HIV in 2017. South Africa exhibits the same characteristics with the countries from cluster 2 in terms of socio-economic landscape, migration, and mobility. With high levels of Poverty, many people struggle with illiteracy, unemployment, and discrimination. The Illiteracy, poverty, and discrimination drive women into the sex trade and sex worker cannot demand safe sex at all (Ackermann, 2002). These women lack not only money, but assets and skills. Information dissemination is underway but even if the poor understand the information and counseling activities regarding HIV, these messages are irrelevant and inoperable given the realities of their lives and therefore would not adopt recommended behaviors (Mbirimtengerenji, 2007).

Table 4

Other Countries in Cluster 2

CLUSTER 2			
Indonesia	Jordan	Turkey	Sri Lanka
Poland	Lebanon	United States	Finland
Costa Rica	Iceland	Mexico	Germany
Slovenia	Hong Kong	Canada	Israel
China	Italy	Portugal	New Zealand
Croatia	Colombia	Singapore	Norway
Uruguay	Lithuania	Sweden	Switzerland
Philippines	Malaysia	Ecuador	United Kingdom
South Africa	India	Estonia	Spain
Chile	Argentina	Qatar	Australia
France	Netherlands	Austria	Belgium
Denmark	Taiwan	Japan	Thailand
South Korea			

In Table 4, it is shown that culture plays a major role in the spread of HIV in South Africa. Heterosexual transmission is enhanced because of the widespread practice of female circumcision. Female circumcision has been claimed to increase the likelihood of AIDS transmission because of the increased chance of tearing in the mutilated vaginal canal increasing the absorption and secretion of the virus. Witchcraft and retribution to people engaged in immoral activities are perceived to be the cause of body wasting instead of the signs and symptoms of AIDS, promulgating a stigma on AIDS. The reluctance to talk about sex within marriages and between generations also has delayed health response to a sexually transmitted epidemic. One particular risk factor imbedded in their culture is attributed to gender inequality. In African societies' women have lower social and economic status simply because they are women. They were given to marriage early and they lack power and economic independence to negotiate safe sex and insist on condom use (Ackermann, 2002). Moreover, the threat of physical and sexual violence prevents women from refusing sex. Denying sexual encounters, asking about other sexual partners, or suggesting condom use have all been described as triggers for intimate partner violence (Kim, 2005).

The contribution of migration to the spread of HIV has long been recognized. Voluntary and involuntary migration connected with local and international travel, refugee movements, and army movements have emerged as major factors in the spread of the virus across countries, borders, and regions (Nyindo, 2005). In addition, South Africa and neighboring countries (as shown in figure 6), have high incidences of HIV because they were identified as the origin or source of trade

force (Barroso et al., 2017). Mobility in and outside these countries intensifies the spread of HIV. Poor people in rural areas migrate to urban areas in search of work, leaving their family and spouses for extended periods of time. These Male migrants may engage in high-risk behaviour with sex workers, thereby increasing their own susceptibility to HIV infection (A Buvé, 2002).

CONCLUSIONS

In the space of HIV prevention feature, the emergent feature is the disproportionate number of HIV incidence which can occur depending on the modifiable and non-modifiable conditionalities such as (1) poor socioeconomic conditions prompting economy-driven-migration and prostitution, (2) lack of access to health care, (3) migration and economic or political displacement of communities, and (4) gender inequalities and non-modifiable factors such as: (1) geography and (2)cultural practices. When these conditions are satisfied, there is a jump in the HIV incidences regardless of the health care index.

The rise and spread of HIV is therefore, multi-dimensional and not just a health care issue. Focusing on behavior change or therapy alone may not combat this epidemic. The approach needs to be multifaceted and interdisciplinary taking into consideration the context and the economic and social realities at multiple scales which may include: socio-economic, political, cultural, Gender equality, migration or mobility patterns, spirituality, and environment, among others. To eradicate or minimize the spread of HIV, there should be a holistic approach in attacking this epidemic.

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