Stigmatizing against PLHIV and HIV Prevalence in South Africa: A Linear Discriminant and Spatio-Temporal Analysis

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Abstract

Evidence from the South African National HIV Prevalence, Incidence, Behavior, and Communication Survey shows that the level of HIV prevalence in each province varies. Among the factors that account for this variation is the level of stigma meted out to people living with HIV (PLHIV). This social and sometimes economic discrimination against PLHIV not only poses a psychological threat to the victim but also undermines the effort made by the constituted authorities to reduce and manage cases of PLHIV in every province. The fear of being stigmatized can make it difficult for people who have developed signs and symptoms to make themselves available for testing and for PLHIV to make themselves available for treatment. The former will increase the rate of prevalence in provinces where stigma against PLHIV is high. This situation may result in the movement of persons who have developed signs and symptoms and are PLHIV to provinces with less likelihood of being stigmatized for testing and treatment. Based on the

Print ISSN 1023-1757; Electronic ISSN: 2519-5476; DOI https://doi.org/10.29086/2519-5476/2025/v32n1a5

preceding, the study, therefore, hypothesizes that: (i) there is significant variation in the level of stigma against PLHIV; (ii) an increase in stigma against PLHIV is likely to increase HIV prevalence; and (iii) a spatial-temporal pattern exists in the stigma against PLHIV and HIV prevalence in provinces in South Africa. Annual time series data for the periods 2005 2012, and 2017 for all the provinces were sourced for analysis. Insignificant variation (*F-stat. = 1.17*, *p-value = 0.33*) in behavior towards family members living with HIV and HIV prevalence (*F-stat. = 2.52, p-value = 0.10).* The linear discriminant analysis shows that gender plays an important role in the level of prevalence of HIV in all nine (9) provinces of South Africa. The positive coefficient of the spatial dependence variable (i.e., $\rho = 0.38$) confirms that space and time matter in the prevalence of HIV. The negative coefficient (i.e., -79.91, p-value 0.05) on the spatially weighted stigma against PLHIV by family members was also computed from the estimated spatial fixed effect (SFE) and the other models. Findings demonstrate that gender factors account for social behavior that affects stigmatization against PLHIV and the prevalence of HIV and that there is a spatial relationship between stigmatization against PLHIV and the prevalence of HIV. There is an urgent need to address the burden of social and economic stigma against PLHIV and its impact on HIV prevalence. A notable disparity in the degree of stigmatization towards people living with HIV (PLHIV) was observed throughout all nine provinces, except for instances of stigmatization originating from family members. The provinces of Kwazulu-Natal and the Northern Cape have demonstrated notable advancements in reducing the amount of stigmatization towards people living with HIV (PLHIV) within their respective business and workplace environments.

Keywords: HIV Prevalence, Stigma, Spatio-temporal, PLHIV, Linear Discriminant Analysis

1 Introduction

A prominent societal concern pertains to the stigmatization linked to contagious illnesses. When individuals experience stigmatization, their physical and psychological well-being is confronted and exposed to various forms of criticism and social condemnation (Rewerska-Juśko & Rejdak 2022). Stigma can impede the general population's adoption of health-promoting behaviors, utilization of healthcare services, and treatment adherence, among other repercussions (Yuan *et al.* 2021). HIV/AIDS, a contagious ailment, encom-

passes both health-related and societal ramifications; nonetheless, there exists a paucity of scholarly literature addressing its social dimensions. According to Dejman *et al.* (2015), individuals living with HIV/AIDS (PLHIV) face significant obstacles, with stigma and prejudice being identified as the most prominent issues. South Africa ranks fourth globally among the top ten nations exhibiting a high prevalence of HIV infection. Based on the findings of Statistics South Africa (2021), it has been determined that around 13.63 percent of the whole population is afflicted with the Human Immunodeficiency Virus (HIV). Furthermore, the prevalence rate of HIV among individuals aged 15 to 49 will be 19.50 percent in 2021. According to Statistics South Africa (2021), there has been a notable rise in the overall population affected by HIV/AIDS, with figures escalating from 3.8 million individuals in 2002 to 8.2 million individuals as of 2021. South Africa is widely recognized as the global hub of the HIV/AIDS pandemic. As an illustration, it is noteworthy that over 70 percent of those afflicted with HIV/AIDS are located on the continent of Africa, with Southern Africa alone accounting for approximately 30 percent of the global infected population. According to Statistics South Africa (2019), South Africa possesses the highest recorded population of individuals living with infections globally, with a reported figure of 7.97 million in 2018.

The stigma associated with HIV/AIDS is associated with specific gender identities, racial backgrounds, sexual orientations, impairments, and socioeconomic statuses. The stigmatization of individuals belonging to marginalized groups, such as gay men, impoverished black women, and those living in poverty, has resulted in a tendency to associate them with a higher prevalence of AIDS. This association is often based on the perception of their engagement in risky behaviors and their limited access to contraception and healthcare services. Furthermore, they have been held accountable for the dissemination of infectious diseases. According to Velloza *et al.* (2015), there is a significant prevalence of stigma in South Africa. However, in recent years, there has been a notable decrease in stigma due to the implementation of the HAART program and several social programs aimed at addressing this issue. Nevertheless, it is important to note that stigma persists in certain regions. South Africa has witnessed numerous instances of stigmatization, including the tragic murder of Gugu Dlamini in December 1998, who was targeted for openly disclosing her HIV-positive status (McNeil Jr. 1998). Another distressing incident involved the murder of Mpho Mtloung and her mother by Mtloung's husband, who subsequently took his own life (Treatment Action Campaign [TAC] 2000). Additionally, there have been cases of HIV-positive

children being denied access to schools, attempts to exclude individuals from employment, discrimination within military services, marginalization within local communities, and rejection by families. According to Skinner and Mfecane (2004), Lorna Mlofane, an activist with the Treatment Action Campaign (TAC), was subjected to sexual assault and subsequently killed in 2004 due to her HIV-positive status. Numerous instances, including the aforementioned incidents, have gained significant recognition and received extensive media coverage.

Several published papers have included stigma as a significant aspect of their research findings. For instance, studies conducted among university students and schoolchildren have documented the presence of stigma (Cloete, Simbayi, Kalichman, Strebel & Henda 2008; Kang'ethe 2015; Pebody 2012; Sanabria 2016; Visser, Makin, Vandormael, Sikkema & Forsyth 2009; Wilson & Fairall 2010). According to a study conducted by Volks *et al.* (2016), University of Cape Town (UCT) students expressed the belief that their social standing and educational background provided them with a safeguard against HIV infection, leading them to perceive themselves as less vulnerable compared to individuals residing in townships or rural areas.

The presence of stigma related to HIV has a significant impact on the behavior and testing outcomes of individuals who are seeking HIV testing in certain locations (Kumar & Jha 2006). Extensive literature exists on stigmatized behavior, although limited scholarly investigations have been undertaken about the mobility patterns of individuals, particularly women, who seek anonymity by venturing outside their residences to undergo testing in alternative locations. Potential hurdles to HIV testing include the presence of misinformation concerning attitudes towards HIV testing and stigmatizing sentiments towards individuals living with HIV (Kandwal *et al.* 2010). The present study aims to examine the implications of stigma on the incidence of HIV across the nine provinces of South Africa. Stigma can have wider implications at the international level too. For example, countries that effectively combat HIV stigma and promote inclusive health policies enhance their standing on the global stage and attract foreign aid, investment, and cooperation in other areas. Stigma can lead to barriers to collaboration as countries fear sharing data on HIV; it can impact tourism as well as world order in some ways. Section 2 of the document provides an overview of the materials and statistical methods employed in the study. The findings are provided in Section 3. Results are discussed in Section 4. The concluding remarks and recommendations are provided in Section 5.

2 Material and Statistical Methods

2.1 Material

The present study employed secondary data obtained from the South African National HIV Prevalence, Incidence, Behaviour, and Communication Survey conducted over many years, specifically 2005 2012, and 2017. The objectives of the survey were to uphold the monitoring of HIV infection and behavior in South Africa as well as enhance comprehension of the underlying factors fueling the HIV epidemic. Additionally, the survey aimed to gather data for the evaluation of the South African National HIV, AIDS, and STI Strategic Plan from 2012 to 2016 and to collect data necessary for monitoring the HIV indicators essential for preparing the country report for various international organizations. The analysis utilized a panel dataset comprising the nine provinces of South Africa, namely the Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, North-West, Northern Cape, and Western Cape. The dataset covered the years 2005, 2012, and 2017.

2.2 Statistical Methods

The study employed exploratory cross-sectional and panel analyses to investigate the relationship between stigma against people living with HIV (PLHIV) and HIV prevalence. The frequentist approach was utilized to examine various statistical measures such as mean, standard deviation, minimum, and maximum. Additionally, spatial autocorrelation analysis, specifically Moran I and Geary C, was employed to assess the spatial patterns of stigma and HIV prevalence. Furthermore, the study also employed a frequentist approach to conduct exploratory cross-sectional and panel analyses on two additional variables: sexual debut before the age of 15 and condom use during the last sexual encounter among individuals aged 15 years and older. Similar statistical measures, including mean, standard deviation, minimum, and maximum, were employed to analyse these variables. Furthermore, the acquired data was analysed through a predictive linear discriminant function and a spatial panel linear regression. The purpose of the discriminant analysis was to investigate potential disparities between groups in terms of stigmatisation towards people living with HIV (PLHIV) and the prevalence of HIV. On the other hand, the spatial panel linear regression analysis revealed a spatial correlation between stigma towards PLHIV and HIV prevalence across all provinces in South Africa.

3 Results

3.1 Exploratory Data Analysis

Table 1 shows summary statistics for the mean percentage responses to each perspective of stigmatisation against PLHIV relative to the periods under review. The mean percentage YES responses to the question on stigmatisation against business owners or staff living with HIV (i.e., If you knew that a shopkeeper or food seller had HIV, would you buy food from them?) in the nine provinces computed are 70.09, 79.20, and 84.40 for the years 2005 2012, and 2017, respectively. Also, standard deviation statistics of 4.34, 3.36, and 4.21 for the mean percentage YES responses to the question on stigmatisation against business owners or staff living with HIV are computed for the years 2005 2012, and 2017, respectively. While the minimum of 64.10, 74.30, and 78.80 were recorded as percentage YES responses to the question on stigmatisation against business owners or staff living with HIV for the years 2005 2012, and 2017, respectively, a maximum of 76.20, 84.60, and 89.60 were recorded as percentage YES responses to the question on stigmatisation against business owners or staff living with HIV for the years 2005 2012, and 2017, respectively.

Second, the mean percentage YES responses to the question (i.e., Would you be willing to care for a family member with AIDS?) on stigmatisation against family members living with HIV in the nine provinces computed are 90.38, 91.87, and 90.52 for the years 2005 2012, and 2017, respectively. Also, standard deviation statistics of 2.16, 2.03, and 2.60 for the mean percentage YES responses to the question on stigmatisation against family members living with HIV are for the years 2005 2012, and 2017, respectively. While the minimum of 87.50, 87.60, and 86.90 are recorded as percentage YES responses to the question on stigmatisation against family members living with HIV for the years 2005 2012, and 2017, respectively, a maximum of 94.80, 86.90, and 95.90 are recorded as percentage YES responses to the question on stigmatisation against business owners or staff living with HIV for the years 2005 2012, and 2017, respectively. Lastly, the mean percentage NO responses to the question (i.e., Is it a waste of money to train or give a promotion to someone with HIV/AIDS?) on stigmatisation against PLHIV at the workplace in the nine provinces computed are 73.73, 82.60, and 85.08 for the years 2005 2012, and 2017, respectively. Also, standard deviation statistics of 5.05, 5.51, and 2.70 for the mean percentage NO responses to the question on stigmatisation against PLHIV at the

workplace are computed for the years 2005 2012, and 2017, respectively. While the minimum of 67.90, 72.10, and 79.60 are recorded as percentage YES responses to the question on stigmatisation against PLHIV at the workplace for the years 2005 2012, and 2017, respectively, a maximum of 80.20, 89.40, and 89.10 are recorded as percentage YES responses to the question on stigmatisation against business owners or staff living with HIV for the years 2005 2012, and 2017, respectively.

Table 1: Descriptive Statistics on Stigma Against PLHIV for Individual Years 2005, 2012, and 2017

	Stigma_biz (% YES response)			Stigma_family (% YES response)			Stigma_work (% NO response)		
Statistics	2005	2012	2017	2005	2012	2017	2005	2012	2017
Mean	70.09	79.20	84.40	90.38	91.87	90.52	73.73	82.60	85.08
SD.	4.34	3.36	4.21	2.16	2.03	2.60	5.05	5.51	2.70
Min	64.1	74.30	78.80	87.50	87.60	86.90	67.90	72.10	79.60
Max	76.2	84.60	89.60	94.80	96.90	95.90	80.20	89.40	89.10

Source: Author's computation based on data collected from www.hsrcpress.ac.za.
Note: stigma_biz = stigma against PLHIV at their places of doing business; stigma_family = stigma against family members who are living with HIV; stigma_work = stigma against PLHIV at their place of work/employment

Table 2 shows summary statistics for the prevalence of HIV infection, sexual debut before the age of 15 years among youth aged 15–24 years, and condom use at the last sexual encounter among people aged 15 years and older relative to the periods under review. The average number of people living with HIV aged 2 years and older in the nine (9) provinces of South Africa computed is 1761, 2880, and 2580 for the periods 2005 2012, and 2017, respectively. Also, standard deviation statistics of 2.16, 2.03, and 2.60 are computed for the mean number of people living with HIV aged 2 years and older in the nine (9) provinces of South Africa during the periods 2005 2012, and 2017, respectively. While a minimum of 1056, 1923, and 1865 are recorded as the number of people living with HIV aged 2 years and older for the years 2005 2012, and 2017, respectively, a maximum of 2729, 6798, and 4621 are recorded as the number of people living with HIV aged 2 years and older for the years 2005 2012, and 2017, respectively, in all nine (9) provinces of South Africa.

Second, the average number of youths aged 15–24 years who had their sexual debut before the age of 15 years in the nine (9) provinces of South Africa computed is 323, 435, and 355 for the periods 2005 2012, and 2017, respectively. Also, standard deviation statistics of 134, 185, and 104 were computed based on the average number of youths aged 15–24 years who had their sexual debut before the age of 15 years in the nine (9) provinces of South Africa during the periods 2005 2012, and 2017, respectively. While the minimum of 156, 286, and 237 are recorded as the number of youths aged 15–24 years who had their sexual debut before the age of 15 years for the years 2005 2012, and 2017, respectively, a maximum of 535, 852, and 591 are recorded as the number of youths aged 15–24 years who had their sexual debut before the age of 15 years during the periods 2005 2012, and 2017, respectively, in all nine (9) provinces of South Africa. Lastly, the average number of people aged 15 years and older who confirmed using condoms during their last sexual encounter in the nine (9) provinces of South Africa computed is 1028, 1715, and 1325 for the periods 2005 2012, and 2017, respectively. Also, standard deviation statistics of 468, 806, and 514 were computed based on the average number of people aged 15 years and older who confirmed using condoms during their last sexual encounter in the nine (9) provinces of South Africa during the periods 2005 2012, and 2017, respectively. While the minimum of 469, 1085, and 934 were recorded as the number of people aged 15 years and older who confirmed using condom use during their last sexual encounter for the years 2005 2012, and 2017,

respectively, a maximum of 1805, 3550, and 2438 were recorded as the number of people aged 15 years and older who confirmed using condom use during their last sexual encounter during the periods 2005 2012, and 2017, respectively, in all nine (9) provinces of South Africa.

Table 2: Descriptive statistics on the prevalence of HIV infection, sexual debut before the age of 15 years among youth aged 15–24 years, and condom use at the last sexual encounter among people aged 15 years and older for each of the years 2005, 2012, and 2017

	HIV prevalence			Sex debut			Condom Use		
Statistics	2005	2012	2017	2005	2012	2017	2005	2012	2017
Mean	1761	2880	2580	323	435	355	1028	1715	1325
SD	681	1540	872	134	185	104	468	806	514
Min	1056	1923	1865	156	286	237	469	1085	934
Max	2729	6798	4621	535	852	591	1805	3550	2438

Source: Source: Authors' computation based on data collected from www.hsrcpress.ac.za.
Note: HIV prevalence = Prevalence of HIV Infection; Sex debut = Sexual Debut before age of 15 among youth aged 15–24 years; Condom use = Condom use at last sexual encounter among people aged 15 years and older.

The descriptive statistics results for the panel data are presented in Table 3. The observation column indicates that our study utilised a balanced panel consisting of nine (9) cross-sectional units and three (3) years of data. The total number of data points in the panel, denoted as N, is 27. The overall and within effects are computed based on a dataset spanning 27 province-years. The disparity is computed across a total of nine provinces. The panel's aggregate findings for the percentage of YES responses to the question on stigmatisation against company owners living with HIV are as follows: The mean was calculated as 77.90 percent, with a standard deviation of 7.18 percent. The minimum and maximum values recorded were 64.10 percent and 89.60 percent, respectively. The standard deviation for the between groups was calculated to be 3.35. The minimum and maximum values reported for this group were 72.60 and 82.57, respectively. In addition, the standard deviation for the inside group was calculated to be 6.42. The minimum and maximum values reported for this group were 65.26 and 87.30, respectively.

Furthermore, the panel's analysis revealed that the average percentage of negative replies (NO) regarding stigmatisation against people living with HIV (PLHIV) in the workplace was computed to be 80.47%, with a standard deviation of 6.64. The minimum and maximum values recorded for this question were 67.90% and 89.40%, respectively. The standard deviation for the between-group variable was calculated to be 2.59. The minimum value recorded was 77.27, while the maximum value recorded was 85.30. In addition, the standard deviation for the within-group group was calculated to be 6.16. The minimum and maximum values observed were 69.14 and 88.04, respectively. In relation to the comprehensive panel analysing the proportion of affirmative responses to the inquiry regarding stigmatisation towards individuals with HIV within their families, the mean and standard deviation were calculated as 90.92 percent and 2.29 percent, respectively.

Additionally, the minimum and maximum values were recorded as 86.90 and 95.90, respectively. The standard deviation for the variable "between" was calculated to be 1.17. The smallest value observed was 89.53, while the greatest value recorded was 92.50. Furthermore, the standard deviation for the inside group was calculated to be 2.00. Additionally, the minimum and maximum values within the dataset were recorded as 87.92 and 94.36, respectively. Furthermore, the mean value of 2407 was calculated as the average for individuals who are HIV-positive and are aged 2 years and older, encompassing the entire panel. The standard deviation was calculated as 1157, with the minimum and greatest values recorded as 1056 and 6798, respectively.

The standard deviation for the variable "between" was calculated to be 971. The least value observed was 1643, while the largest value recorded was 5716. In addition, the standard deviation for the within-group group was calculated to be 684. The minimum and maximum values observed were 420 and 4489, respectively. In the fifth instance, the average number of individuals between the ages of 15 and 24 who experienced their sexual debut prior to the age of 15 was calculated as 371 for the entire panel. The standard deviation was calculated to be 147, with the minimum and greatest values recorded as 156 and 852, respectively. The standard deviation for the between groups was calculated to be 133, with the minimum value recorded as 244 and the maximum value recorded as 659. In addition, the standard deviation for the inside group was calculated to be 684.

Furthermore, the minimum and maximum values were recorded as 228 and 564, respectively. Finally, the aggregate panel calculated that 1356 individuals, aged 15 years and older, reported using condoms during their most recent sexual experience, representing the average number. The standard deviation was calculated to be 656, with the minimum and greatest values recorded as 469 and 3550, respectively. The standard deviation for the between-group variable was calculated to be 577. The least value observed was 891, while the largest value recorded was 2597. In addition, the standard deviation for the within-group group was calculated to be 351. Furthermore, the minimum and maximum values reported for this group were 563 and 2308, respectively.

Table 3 also presents the computed F-statistics for different responses to questions on stigmatisation against business owners living with HIV, stigmatisation against PLHIV at the workplace, stigmatisation against family members living with HIV, and stigmatisation against people living with HIV aged 2 years and older. The computed F-statistics for YES and NO responses to the questions on stigmatization against business owners living with HIV and the NO question on stigmatization against PLHIV at the workplace, respectively, are greater than the F-critical value. However, the computed F-statistics for YES responses to the question on stigmatization against family members living with HIV and people living with HIV aged 2 years and older, respectively, are less than the F-critical value.

Table 3: Panel Data Descriptive Statistic and Analysis of Variance (ANOVA) Result

Panel A: Panel Data Descriptive Statistic Results						
Variable		Mean	Std. Dev.	Min	Max	Observation
stigma_biz	overall	77.90	7.18	64.1	89.60	N = 27
	between		3.35	72.6	82.57	n = 9
	within		6.42	65.26	87.30	T = 3
stigma_work	overall	80.47	6.64	67.90	89.40	N = 27
	between		2.59	77.27	85.30	n = 9
	within		6.16	69.14	88.04	T = 3
stigma_family	overall	90.92	2.29	86.90	95.90	N = 27
	between		1.17	89.53	92.50	n = 9
	within		2.00	87.92	94.36	T = 3
hiv_prevalence	overall	2407	1157	1056	6798	N = 27
	between		971	1643	4716	n = 9
	within		684	420	4489	T = 3
sex_debut	overall	371	147	156	852	N = 27
	between		133	244	659	n = 9
	within		684	228	564	T = 3
condom_use	overall	1356	656	469	3550	N = 27
	between		577	891	2598	n = 9
	within		351	564	2308	T = 3

Panel B: Analysis of Variance (ANOVA) Results			
	F-stat.	*p-value*	*F-critical*
stigma_biz	28.51	0.00	3.40
stigma_work	15.19	0.00	3.40
stigma_family	1.17	0.33	3.40
hiv_prevalence	2.52	0.10	3.40

Source: Authors' computation based on data collected from www.hsrcpress.ac.za

The correlation results for the selected variables in this investigation are presented in Table 4. A significant and positive correlation was observed between stigmatization towards business owners and stigmatization towards people living with HIV (PLHIV) in the workplace (r = 0.63, p = 0.00). Additionally, a strong correlation was found between the number of youths aged 15–24 who had their sexual debut before the age of 15 and the number of people living with HIV aged 2 years and older (r = 0.87, p = 0.00).

Table 4: Panel Data Pairwise Correlation Result

	1	2	3	4	5	6
1	1.00					
	-					
2	0.63**	1.00				
	[0.00]	-				
3	0.30	0.04	1.00			
	[0.13]	[0.84]	-			
4	0.32	0.26	0.15	1.00		
	[0.11]	[0.18]	[0.46]	-		
5	0.22	0.21	0.21	0.87**	1.00	
	[0.26]	[0.30]	[0.29]	[0.00]	-	
6	0.32	0.30	0.30	0.93**	0.95**	1.00
	[0.11]	[0.13]	[0.13]	[0.00]	[0.00]	-

Source: Author's computation based on data collected from www.hsrcpress.ac.za.
Note: 1 = stigma_biz, 2 = stigma_work, 3 = stigma_family, 4 = hiv_prevalence, 5 = sex_debut, and 6 = condom_use

Furthermore, a highly significant correlation was observed between the number of youths aged 15–24 who had their sexual debut before the age of 15 and both the number of people living with HIV aged 2 years and older (r = 0.93, p = 0.00) and the number of people aged 15 years and older who reported using condoms during their last sexual encounter (r = 0.95, p = 0.00).

3.2 Exploratory Spatial Data Analysis (ESDA)

The maps depicted in Figure 1 illustrate the presence of varying levels of stigmatisation against people living with HIV (PLHIV) at their respective business locations throughout South African provinces during the years 2005 2012, and 2017, with the exception of Gauteng. However, it is important to highlight the observed progress in reducing the degree of stigmatisation faced by People Living with HIV (PLHIV) within their workplace environments in the province of Kwazulu-Natal.

The maps depicted in Figure 2 illustrate the presence of varying degrees of stigmatisation against people living with HIV (PLHIV) by their family members throughout different provinces in South Africa during the years 2005 2012, and 2017. However, it is important to acknowledge that each province displayed distinct variations in the degree of stigmatisation against people living with HIV (PLHIV) in their respective business environments.

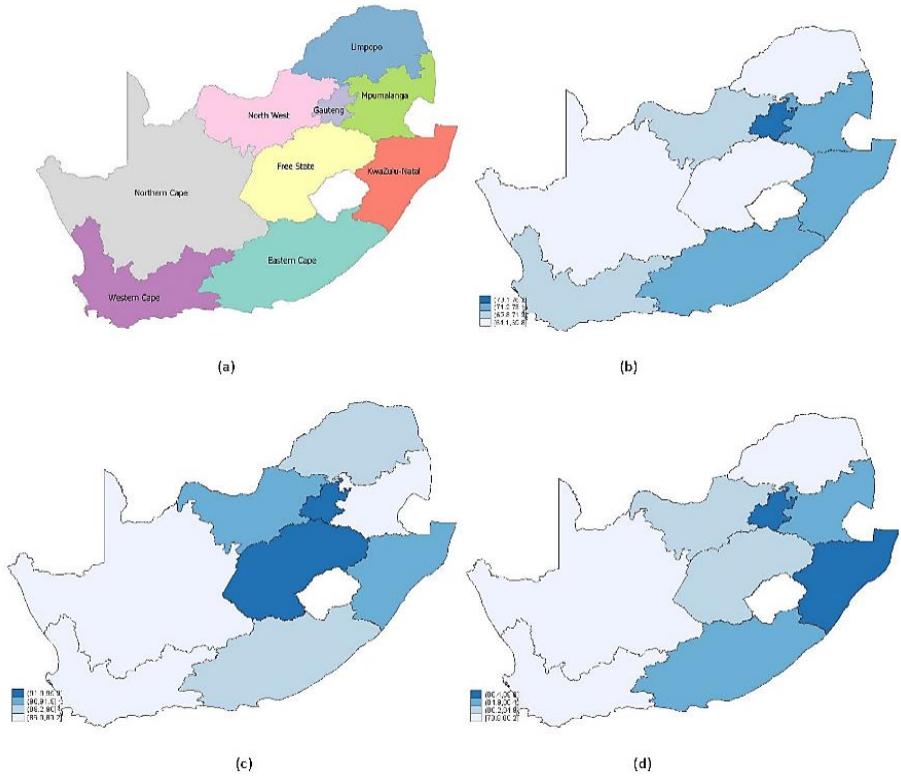

Figure 1: Maps showing the spatial distribution pattern of responses to the question on stigmatisation against PLHIV at their places of doing business during the periods 2005 (i.e., map b) 2012 (i.e., map c), and 2017 (i.e., map d).

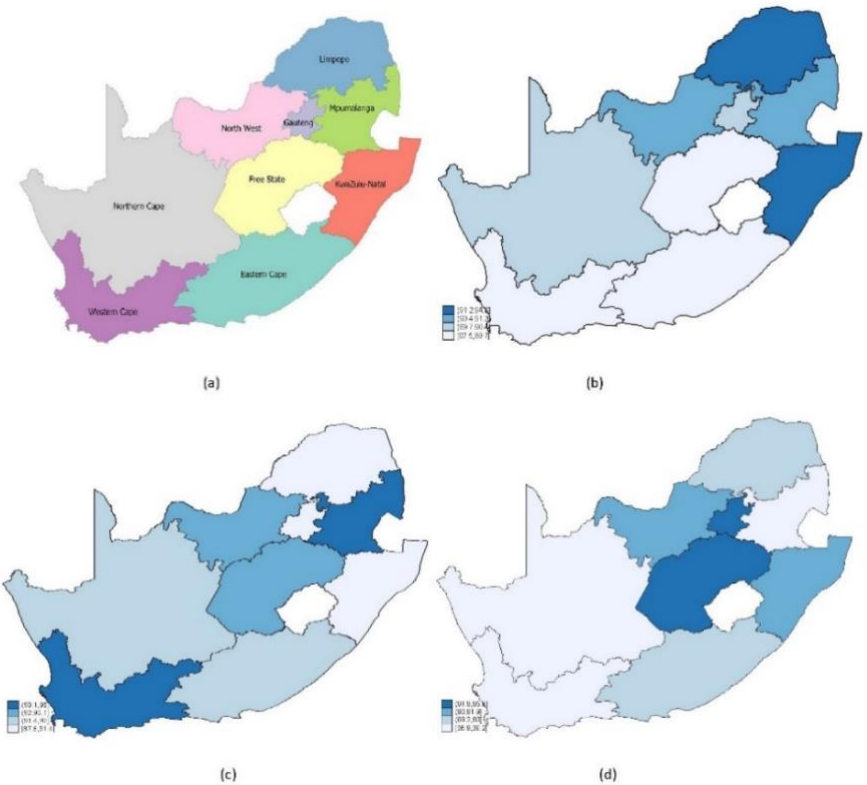

Figure 2: Maps showing the spatial distribution pattern of responses to question on stigmatization against PLHIV by family members during the periods 2005 (i.e., map *b*) 2012 (i.e., map *c*), and 2017 (i.e., map *d*).

The maps presented in Figure 3 illustrate the observed variations in the level of stigmatisation against people living with HIV (PLHIV) in their respective workplaces throughout different provinces in South Africa over the years 2005 2012, and 2017, with the exception of Gauteng. However, it is important to highlight the progress made in reducing the level of stigmatisation against people living with HIV (PLHIV) in their workplace settings in the Northern Cape region between the years 2005, 2012, and 2017.

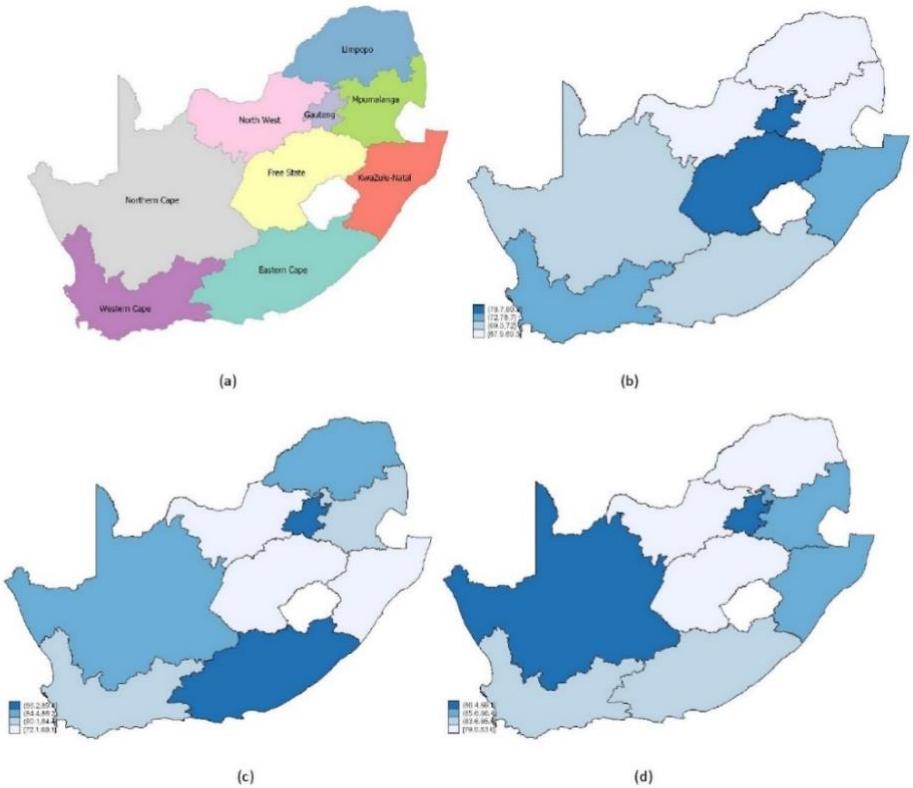

Figure 3: Maps showing the spatial distribution pattern of responses to question on stigmatization against PLHIV at their place of Work (e.g., In Private and Public Establishments) during the periods 2005 (i.e., map *b*) 2012 (i.e., map *c*), and 2017 (i.e., map *d*).

Table 5: Spatial Autocorrelation: Moran I

Variables	Moran I statistics [p-value]			Geary C statistic [p-value]		
	2005	2012	2017	2005	2012	2017
hiv_prevalence	-0.122	-0.167	-0.136	1.025	0.913	0.924
	[0.989]	[0.682]	[0.935]	[0.886]	[0.733]	[0.742]
stigma_biz	-0.287	-0.082	0.044	1.190	0.989	0.718
	[0.360]	[0.805]	[0.342]	[0.291]	[0.733]	[0.113]
stigma_work	-0.284	-0.159	-0.437**	1.184	1.237	1.549***
	[0.381]	[0.838]	[0.045]	[0.288]	[0.229]	[0.009]
stigma_family	-0.179	-0.356	-0.013	1.054	1.094	0.932
	[0.723]	[0.117]	[0.467]	[0.797]	[0.665]	[0.745]

Source: Author's computation based on data collected from www.hsrcpress.ac.za
Note: *, **, *** implies significance at 10% (i.e., 0.10), 5% (i.e., 0.05), and 1% (i.e., 0.01)

The results of the spatial autocorrelation tests, namely Moran's I and Geary's C, for each year, are displayed in Table 5. As stated by Górniak (2016), there exists a distinction in the interpretation of the Moran I and Geary C statistics. In the context of the Moran I statistic, a positive spatial autocorrelation is observed when the value of distance d is similar ($I > 0$). Conversely, a negative spatial autocorrelation is observed when the value of distance d is dissimilar ($I < 0$). When $I = 0$, the value of distance d is considered random.

Furthermore, in the context of the Geary C statistic, when the value of C falls between 0 and 1, it indicates a positive spatial autocorrelation, suggesting that values at a certain distance d exhibit similarity. Conversely, when C ranges between 1 and 2, it signifies a negative spatial autocorrelation, indicating that values at distance *d* are dissimilar. The findings presented in Table 5 indicate that, for each variable of interest across all years, the Moran I statistic (i.e., $I<0$) and Geary C statistic (i.e., $1<C<2$) suggest the presence of negative spatial autocorrelation. However, it is noteworthy that these statistics were found to be statistically significant (i.e., $p = 0.045 < 0.05$ and $p = 0.045 < 0.05$) only in the case of stigmatization against PLHIV at the workplace in the year 2017.

3.3 Discriminant Function Analysis

The results obtained from the discriminant function analysis undertaken in this study are presented in Table 6. Panel A shows the canonical linear discriminant analysis outcomes for HIV prevalence disaggregated by gender across several age groups. It also displays the results of stigmatization against people living with HIV (PLHIV) based on three established views, also stratified by age groups. The estimated canonical correlations for dimensions one and two about HIV prevalence are 0.9341 and 0.7539, respectively. The F-statistics, namely 6.8547 and 3.2196, along with the corresponding p-values of 0.00 and 0.012, indicate that the computed canonical correlations for dimensions one and two are statistically significant at a 5% significance level (i.e., $p < 0.05$). Furthermore, in stigmatization against people living with HIV (PLHIV), the computed canonical correlations for the first and second dimensions are 0.9778 and 0.2221, respectively. The F-statistics, namely 5.1954 and 0.12967, along with the corresponding p-values of 0.02 and 0.88, indicate that only the computed canonical correlations for dimension one exhibit statistical significance at the 5% level (i.e., $p < 0.05$).

Panel B displays the standardized canonical discriminant function coefficient outcomes for HIV prevalence by gender across various age groups, as well as stigmatization against people living with HIV (PLHIV) from three established perspectives across distinct age groups. An increase of one standard deviation in HIV prevalence among males is associated with a predicted rise of 0.9950448 standard deviations on discriminant function 1 and 0.008556

standard deviations on discriminant function 2. Furthermore, an increase of one standard deviation in HIV prevalence among females is associated with a predicted rise of -0.7120348 standard deviations on discriminant function 1 and an increase of 1.223534 standard deviations on discriminant function 2.

Moreover, in the context of stigmatization towards people living with HIV (PLHIV), an increase of one standard deviation in stigmatization against business owners is associated with a predicted rise of -1.141463 and 1.560969 standard deviations on discriminant functions 1 and 2, respectively.

Moreover, an increase of one standard deviation in stigmatization towards a family member who is living with HIV is associated with a decrease of -1.699982 standard deviations in the predicted values on discriminant function 1 and a decrease of -0.418699 standard deviations in the predicted values on discriminant function 2.

Finally, it can be observed that a one-unit increase in stigmatization against people living with HIV (PLHIV) at the workplace is associated with a 2.315041 standard deviation rise in the predicted values on discriminant function 1 and a -0.446396 standard deviation increase in the predicted values on discriminant function 2.

The discriminant functions under HIV prevalence are:

(i) discriminant_score_1 = 0.9954*male + 0.0086*female; and

(ii) discriminant_score_2 = 1.2235*female – 0.7120*male.

Also, the discriminant functions under stigmatization against PLHIV are:

(i) discriminant_score_1 = 2.3150*Work -1.1414*Business-1.7000*Family; and

(ii) discriminant_score_2 = 1.5610* Business -0.4187*Family -0.4464Work.

Table 6: Linear Discriminant Analysis (Canonical linear discriminant, Standardized Canonical discriminant function coefficient, Canonical Structure, and Group means on canonical variables) Results

Panel A: Canonical linear discriminant								
Fcn	HIV Prevalent among Male and Female [Group = Age]			Fcn		Stigmatization against PLHIV (work, business, and by family members) [Group = Age]		
	CC Stat.	F-stat.	Prob > F			CC Stat.	F-stat.	Prob > F
1	0.9341***	6.8547	0.00	1		0.9778**	5.1954	0.02
2	0.7539**	3.2196	0.012	2		0.2221	0.12967	0.88
Panel B: Standardized Canonical discriminant function coefficient								
Prevalence by Gender	Function 1	Function 2		Perspective of Stigmatization	Function 1	Function 2		
male	0.9950448	-0.7120348		Business	-1.141463	1.560969		
female	0.008556	1.223534		Family	-1.699982	-0.418699		
				Work	2.315041	-0.446396		

Source: Author's computation using STATA 17.
Note: CC = Canonical Correlation

3.3 Spatial Linear Panel Regression (SLPR) Analysis

Panels A and B of Table 7 present the results of the estimated Spatial Durbin Model (SDM) and Spatial-Autoregressive Model (SARM). Table 7 also shows that Spatial Random Effects (SRE), Spatial Fixed Effects (SFE), Time Fixed Effects (TFE), Spatial and Time Fixed Effects (STFE), and Without Direct,

Indirect and Total Effects (No-DITE) variants of the SLPR models were estimated. First, while the spatial variable (i.e., *rho*) appeared to be statistically significant at 5% under STFE in panel A, it also appeared to be statistically significant at 5% under SFE in panel B. Moreover, a test was conducted to choose the most appropriate spatial model between SDM and SARM for discussion and prediction. Panel C shows the result of the test to determine the model to adopt for discussion. From the result and application of the stated decision rule, the SARM is considered the most appropriate spatial model for discussion and prediction. Hence, the SARM result will be the focus hereafter.

Table 7: Spatial Durbin Model (SDM) and Spatial-Autoregressive Model (SAR) for HIV Prevalence

Panel A: Spatial Durbin Model (SDM)					
	SRE	**SFE**	**TFE**	**STFE**	**No-DITE**
Main					
stbiz	30.53	39.93	-7.22	23.84	30.53
stwork	-13.57	-11.45	-2.15	-7.37	-13.57
stfam	-78.84**	-71.71	-70.68***	-71.63***	-78.84**
sex_debut	-2.42	-5.93***	-4.40	-8.88***	-2.42
condumuse	2.13***	2.52***	-2.93***	3.46***	2.13***
const.	8794.68	-	-	-	8794
Wx					
stbiz	29.55**	29.83	-33.29	26.15	29.55
stwork	23.28	67.53***	26.42	16.78	23.28
stfam	-74.21	-	3.77	-	-74.21
sex_debut	-1.69	139.45**	-6.36	163.54***	-1.69
condomuse	0.36	-2.89	2.74**	-16.84***	0.36
		0.411		3.56***	
Spatial					
rho	0.09	0.24	-0.35	-0.76**	0.09
Panel B: Spatial-Autoregressive Model (SARM)					
	SRE	**SFE**	**TFE**	**STFE**	**No-DITE**
Main					
stbiz	17.86	27.71	12.11	23.67	17.86
stwork	-16.76	-18.90	-13.01	-19.02	-16.76

stfam	-88.81**	-79.91**	-80.08**	-83.61**	-88.81**
sex_debut	-2.13	-4.89***	-1.80	-5.94***	-2.13
condomuse	2.19***	2.44***	2.12	2.75***	2.19***
const.	7872.522	-	-	-	7872.52
Spatial					
rho	0.17	0.38**	0.13	0.31	0.17
Panel C: Testing for SDM OR SARM					
chi2(5) = 8.38 Prob > chi2 = 0.1366 Decision Rule: H0: Fail to reject the null hypothesis, with a p-value greater than ten percent, use SAR. H1: Reject the null hypothesis, with a p-value less than five percent, use SDM.					

Source: Author's Computation. Note: **, *** implies significance at 5% (i.e., 0.05), and 1% (i.e., 0.01) respectively. SRE= Spatial Random Effects; SFE= Spatial Fixed Effects; TFE= Time Fixed Effects; STFE = Spatial and Time Fixed Effects; No-DITF = Without Direct, Indirect and Total Effects

The results presented in panel B show that only the coefficients (i.e., -88.81, -79.91, -80.08, -83.61, and -88.81) of stigmatising family members who are living with HIV (i.e., stfam) appeared with a negative sign and were also statistically significant at the 5% level under all the variants of models estimated. While the coefficients of sexual debut before the age of 15 years appeared with negative signs under SFE and STFE and were also statistically significant at the 1% level, the coefficient of the number of people aged 15 years and older who confirmed using condoms during their last sexual encounter appeared with positive signs under SRE, SFE, STFE, and No-DITE and was also statistically significant at the 1% level.

4 Discussion

The exploratory analysis of the data conducted shows that while the level of different perspectives on stigmatisation has reduced over the years, specifically, the variation in the stigmatisation of PLHIV by family members is low. This is so because the mean response result and the ANOVA result

suggest insignificant variation in behaviour towards family members and individuals living with HIV. An insignificant variation shows that the behaviour of family members towards a relative who is living with HIV has remained almost the same over the period under consideration. This finding is in line with findings made by Karim *et al.* (2008), who revealed that it would be easier to disclose HIV status to sexual partners and family members. And this may not be unconnected to the love and care they expect to receive from family members as opposed to strangers, friends, colleagues, and acquaintances. Our finding also aligns with the findings of a study in India where the authors confirmed that family members were informed first about HIV positive status as family is considered the primary support system in Indian culture (Yadav *et al.* 2006; Serovich, Craft, Reed & STDs 2012).

The result from the standardised canonical discriminant analysis shows a consistent positive linear relationship between the male gender and HIV prevalence. This finding proves to be consistent with the findings by Maughan-Brown *et al.* (2016) who associated the sexual behaviour of male partners with popularly held beliefs and culture in Sub-Saharan Africa with respect to men being considered superior and not answerable to women, which has led to leading a reckless life of having multiple sexual partners and engaging in unprotected sex (Ramjee & Daniels 2013; Rankin, Brennan, Schell, Laviwa & Rankin 2005). This study found a relatively improved level of HIV prevalence among the female gender over the years. This is in line with the findings of a study conducted in Soweto and Vulindlela, which found that despite the male dominance and gender violence that exist and prevent women from disclosing to their partners or acquiring VCT, more women were likely to get tested than men and held less AIDS-related stigma beliefs than men (Katirayi *et al.* 2017).

The spatial exploratory data analysis result shows a negative spatial autocorrelation in the level of discrimination against PLHIV at their places of work across the nine (9). This implies that the values of distance across the nine (9) are not similar. This may not be unrelated to the situation of varying levels of educational attainment, race, and urbanisation in the country. This factor may have contributed to the attitude towards PLHIV. This finding aligns with a previous study that showed that countries do not exhibit the same disposition towards PLHIV, even if they are spatially close or neighbours. For example, Maman *et al.* (2009) described the variation that exists in the behaviour of people towards PLHIV in South Africa and Zimbabwe.

The correlational analysis conducted shows a positive but insignificant correlation between each of the perspectives of stigma and HIV prevalence. Moreover, our study found that a spatial relationship exists between stigmatisation against PLHIV and the prevalence of HIV. The positive ρ coefficient is consistent with omitted provincial factors that vary over time and affect HIV prevalence. The negative coefficient on the spatially weighted stigma against PLHIV by family members in neighbouring provinces indicates a clear and consistent effect by which a decrease in stigma against PLHIV by family members in one province encourages a decrease in stigma against PLHIV by family members in neighbouring provinces. A behavioural spillover was confirmed in this regard. Our finding aligns with that of Muleia *et al.* (2020), whose study revealed the presence of spatial patterns of HIV infection and prevalence in Mozambique.

Conclusion

A notable disparity in the degree of stigmatization towards people living with HIV (PLHIV) was observed throughout all nine provinces, except for instances of stigmatization originating from family members. The provinces of Kwazulu-Natal and the Northern Cape have demonstrated notable advancements in reducing the amount of stigmatization towards people living with HIV (PLHIV) within their respective business and workplace environments. Furthermore, it was underscored that gender-related factors play a significant role in shaping social behaviors that contribute to the stigmatization of people living with HIV (PLHIV) and the overall prevalence of HIV. Furthermore, our research has revealed the presence of a spatial correlation between the phenomenon of stigmatization towards people living with HIV (PLHIV) and the overall prevalence of HIV. There is a pressing global concern, particularly in developing nations, to effectively tackle the issue of stigmatization towards people living with HIV (PLHIV) and its implications on the prevalence of HIV. This trend of reduced stigmatization forebodes South Africa well in terms of its reputation worldwide and helps promote collaborations with countries.

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Appendix

id	Province	Stigma against PLHIV at their places of doing business (%)			Stigma against PLHIV by family members (%)			Stigma against PLHIV at their place of work/employment (%)		
		2005	2012	2017	2005	2012	2017	2005	2012	2017
1	EC	73.1	79.5	85.2	87.5	92	90	87.5	92	90
2	FS	65.8	84.6	84.9	87.7	92.1	92.3	87.7	92.1	92.3
3	GP	76.2	81.9	89.6	90.1	91.4	95.9	90.1	91.4	95.9
4	KZN	73.1	76.3	88.8	94.8	90.8	91.9	94.8	90.8	91.9
5	LP	64.5	74.3	79	91.5	87.6	89.5	91.5	87.6	89.5
6	MP	73	83.3	88.4	91.2	95	89.2	91.2	95	89.2
7	NW	71.2	78.3	84.7	90.5	93.1	90.5	90.5	93.1	90.5
8	NC	64.1	79.7	80.2	90.4	91.6	86.9	90.4	91.6	86.9
9	WC	69.8	74.9	78.8	89.7	93.2	88.5	89.7	93.2	88.5

Source: South African National HIV Prevalence, Incidence, Behaviour and Communication Survey (2005, 2012, & 2017). Available online: www.hsrcpress.ac.za. Note: EC, FS, GP, KZN, LP, MP, NW, NC, WC under the province column denotes Eastern Cape, Free State, Gauteng, KwaZulu-Natal, Limpopo, Mpumalanga, North West, Northern Cape, and Western Cape provinces respectively.

Data on Condom use at last sexual encounter among people aged 15 years and older for each of the years 2005 2012, and 2017.

id	Province	2005	2012	2017
1	Eastern Cape	1267	1842	1045
2	Free State	590	1217	992
3	Gauteng	1613	2139	1887
4	KwaZulu-Natal	1805	3550	2438
5	Limpopo	856	1190	934
6	Mpumalanga	721	1116	1104
7	North West	726	1085	1140
8	Northern Cape	469	1235	970
9	Western Cape	1209	2065	1417

Source: South African National HIV Prevalence, Incidence, Behaviour and Communication Survey (2005 2012 & 2017). Available online: www.hsrcpress.ac.za.

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