RUFORUM Working Document Series (ISSN 1607-9345)2019, No. 18 (1): 895 - 905.
Available from httpp://repository.ruforum.org

Research Application Summary

The association between cancer incidence, HIV prevalence, and Gross Domestic Product in Uganda

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Abstract

This study examined the association of cancer incidence, HIV prevalence and Gross Domestic Product (GDP) in Uganda. The study utilised secondary data where Cancer data were obtained from the Kampala Cancer Registry, Department of Pathology, College of Health Sciences, Makerere University. GDP data was obtained from IMF's World Economic Outlook and AIDs data was obtained from the global AIDs epidemic reports of UNAIDS 2017. Multivariate time series analysis method was used covering a period from 1993 -2014. The variables were tested for stationarity, co-integration, autocorrelation and optimal lag length was determined. The findings indicate that the Non-AIDs defining cancers, that is, stomach (p=0.000), eye (p=0.000), liver (p=0.000) cancer and prostate cancer (p=0.000) had a long run positive significant relationship with HIV prevalence while colon (p=0.002), lung (p=0.00) and breast cancer (p=0.004) had a negative significant relationship with HIV prevalence. These cancers, that is, breast (p=0.00) and prostate (p=0.001) had a positive significant relationship with GDP while cancer of the lung (p=0.000) had a negative significant relationship with GDP in Uganda. AIDS defining cancers such as Non-Hodgkin cancer (p=0.001) had a long run positive significant relationship with HIV prevalence while cervical cancer (p=0.000) had a negative significant relationship with HIV prevalence. Cervical cancer (p=0.014) had a positive significant relationship with GDP in Uganda. The study recommended that the Government of Uganada should strengthen policies that reduce HIV since it was observed that HIV had a significant relationship with cancer. In addition, the Government should encourage HIV patients to screen for non- AIDs defining cancers since they are also at a risk for such cancers as well as educate the masses that some of the lifestyle habits could lead to cancer.

Key words: Cancer incidence, GDP, HIV prevalence, Time series analysis, Uganda

Résumé

Cette étude a examiné l'association entre l'incidence du cancer, la prévalence du VIH et le produit intérieur brut (PIB) en Ouganda. L'étude a utilisé des données secondaires où les données sur le cancer ont été obtenues du registre du cancer de Kampala, du département de pathologie, du collège des sciences de la santé de l'université de Makerere. Les données sur le PIB ont été obtenues à partir du World Economic Outlook du FMI et les données sur le SIDA ont été obtenues à partir des rapports mondiaux sur l'épidémie de SIDA de l'ONUSIDA 2017. La méthode d'analyse multivariée des séries chronologiques a été utilisée pour couvrir une période allant de 1993 à 2014. Les variables ont été testées pour la stationnarité, la co-intégration, l'autocorrélation et la longueur optimale du décalage a été déterminée. Les résultats indiquent que les cancers non liés au SIDA, à savoir le cancer de l'estomac (p=0,000), de l'œil (p=0,000), du foie (p=0,000) et de la prostate (p=0,000) ont une relation

significativement positive à long terme avec la prévalence du VIH, tandis que le cancer du côlon (p=0,002), du poumon (p=0,00) et du sein (p=0,004) ont une relation significativement négative avec la prévalence du VIH. Ces cancers, c'est-à-dire le cancer du sein (p=0,00) et de la prostate (p=0,001) avaient une relation significative positive avec le PIB alors que le cancer du poumon (p=0,000) avait une relation significative négative avec le PIB en Ouganda. Les cancers characteristiques du SIDA tels que le cancer non hodgkinien (p=0,001) ont une relation significativement positive à long terme avec la prévalence du VIH, tandis que le cancer du col de l'utérus (p=0,000) a une relation significativement négative avec la prévalence du VIH. Le cancer du col de l'utérus (p=0,014) avait une relation positive significative avec le PIB en Ouganda. L'étude recommande au gouvernement ougandais de renforcer les politiques de réduction du VIH, car il a été observé que le VIH avait une relation significative avec le cancer. En outre, le gouvernement devrait encourager les patients séropositifs à se soumettre à un dépistage des cancers non liés au SIDA, car ils sont également exposés à ce type de cancer, et sensibiliser les populations au fait que certains styles de vie peuvent conduire au cancer.

Mots clés : Incidence du cancer, PIB, prévalence du VIH, analyse des séries chronologiques, Ouganda.

Introduction

According to the American Cancer Society and National Cancer Institute (2009), cancer is an abnormal growth of cells which tend to grow in an uncontrolled way and can spread to other parts of the body. In a study about spectrum of cancers among HIV-infected persons in Africa, Mbulaiteye *et al*. (2006) stated that little is known about cancer risk among people living with human immunodeficiency virus (HIV). This is despite more than 25 million people in sub-Saharan Africa having human immunodeficiency virus (HIV) infection (Wabinga *et al*., 2006).

Many studies conducted in USA and Europe have shown that there is a correlation between cancer and the level of gross domestic product (Ferlay *et al.*, 2010). Life style , urbanization and economic development have also been shown to have an effect on cancer (Jemal *et al.,* 2012). Furthermore in Europe studies have concluded that HIV infected persons have a higher risk for certain types of cancers than the general population (Yang *et al*., 2017). Cancer is an emerging public health problem in Africa because about 715,000 new cancer cases and 542,000 cancer deaths occurred in 2008 on the continent, with these numbers expected to double in the next 20 years. In Uganda particularly there has been an overall increase in the risk of cancer during the period 1991-2010 in both sexes, with incidence rates of major cancers such as breast and prostate showing particularly marked increases, that is, 3.7% and 5.2% annually, respectively, (Jemal *et al*., 2012).

Several studies have described major declines in the occurrence of non-Hodgkin lymphoma and other cancers such as Kaposi's sarcoma and cervical cancer among HIV-infected persons and have attributed these major declines to the introduction of HAART. Furthermore HIV-infected persons, including those who have developed AIDS, have higher risk for some non- AIDS-defining cancers, such as cancers of the stomach, liver and anus, and Hodgkin lymphoma (Ferlay *et al*., 2010; Juan, 2013). While these cancers are an important source of morbidity, little has been researched about them in Uganda. In addition, few reports of cancer incidence have thoroughly investigated cancer incidence among adults aged 15-49 after the introduction of HAART.

In addition to the above, with little information available regarding how gross domestic product (GDP) and HIV prevalence affect incidence of cancer, this study examines the association between cancer incidence, HIV prevalence and GDP in Uganda by (i) establishing the relationship between incidence of non-AIDS defining cancers and prevalence of HIV, (ii) determining the relationship between incidence of non-AIDS defining cancers and GDP, and (iii) as well as analyzing the relationship between incidence of AIDS defining cancers and GDP in Uganda.

Methodology

Source of data. Cancer data were obtained from the Kampala Cancer Registry, Department of Pathology, College of Health Sciences, Makerere University. Data collected were in terms of cases of cancer recorded from 1993-2014. The GDP data were obtained from GDP data by country from IMF's World Economic Outlook (IMF, 2017).The World Economic Outlook (WEO) database contains selected macroeconomic data series from the statistical appendix of the World Economic Outlook report, which presents the IMF projections of economic developments at the global level, in major country groups and in many individual countries. The WEO is released in April and September/ October each year. GDP data collected were in terms of US dollars (billions) from 1993-2014. AIDS data were obtained from report on the global AIDS epidemic (UNAIDS/WHO, 2017).

Variables and their measurements. The variables were cancer incidence, estimates of prevalence of HIV measured in terms of percentages, gross domestic product (GDP) which measured in terms of US dollars and time measured in terms of years. The 10 selected cancers were divided into two groups, the first one being the AIDS defining cancer that is cervical cancer, and non-Hodgkin lymphoma [NHL], the second group was the non-AIDS-related cancers that is breast, prostate, stomach, eye, colon, Hodgkin Lymphoma, Lung, liver.

Data analysis. The study was retrospective studying 10 selected cancers, prevalence of AIDS and GDP from 1993-2014. Data were obtained and imported in STATA 13.O for analysis which involved Multivariate time series analysis. A model for each of the 10 cancer types was run to find out the association of Cancer incidence, HIV prevalence and GDP in Uganda. Each variable was endogenous and was a function of its lagged value and the lagged values of other variables.

The Variables were tested for stationarity using the Augmented Dickey-Fuller test. The null hypothesis was that variables were non-stationary against the alternative that variables were stationary. When the absolute test statistic was greater than the 5 % critical value, we rejected the null hypothesis otherwise we failed to reject the null hypothesis (Zou, 2018).

The three variables were also tested for co-integration using the Johansen co-integration test and in case of no co-integration a Vector Autoregressive model (VAR) was used. Otherwise in the presence of co-integration a vector error correction model (VECM) was used to find out the association of cancer incidence, HIV prevalence and GDP (Zou, 2018). The study also estimated the optimal number of lags using Akaike information criterion (AIC), Hannan-Quinn information criterion (HQIC) and SBIC criteria, all variables had equal number of lags and were estimated by ordinary least squares.

Autocorrelation. Residuals were tested for autocorrelation using the Lagrange-multiplier test. The null hypothesis was that there was no autocorrelation against the alternative that there was autocorrelation. The model was well specified with the absence of autocorrelation.

The Vector Autoregressive Model (VAR). VAR model is a multi-equation system where all the variables are treated as endogenous. A system of linear regression equations was derived based on the three study variables with each variable as dependent variable, the right-hand side of each equation includes lagged values of all dependent variables considered.

$$Cancer_t = \sigma + \sum_{j=1}^{k} \beta_j Cancer_{t-j} + \sum_{j=1}^{k} \Phi_j HIV_{t-j} + \sum_{j=1}^{k} \varphi_j GDP_{t-j} + \varepsilon_{1,t} \quad (1)$$

$$HIV_t = \alpha + \sum_{j=1}^{k} \rho_j Cancer_{t-j} + \sum_{j=1}^{k} \Theta_j HIV_{t-j} + \sum_{j=1}^{k} \varepsilon_j GDP_{t-j} + \varepsilon_{2,t} \quad (2)$$

$$GDP_t = d + \sum_{j=1}^{k} \omega_j Cancer_{t-j} + \sum_{j=1}^{k} \tau_j HIV_{t-j} + \sum_{j=1}^{k} \eta_j GDP_{t-j} + \varepsilon_{3,t} \quad (3)$$

The Vector Error Correction Model (VECM). A vector error correction (VEC) model is a restricted VAR that has co-integration restrictions built into the specification and is designed for use with non-stationary series that are known to be co-integrated. This model is derived as follows:

$$\Delta Cancer_t = \sigma + \sum_{j=1}^{k-1} \beta_j \Delta Cancert_{-1} + \sum_{j=1}^{k-1} \Phi_j \Delta HIV_{t-j} + \sum_{j=1}^{k-1} \varphi_j \Delta GDP_{t-j} + \lambda_1 ECT_{t-1} + \varepsilon_{1,t} \quad (4)$$

$$\Delta HIV_t = \alpha + \sum_{j=1}^{k-1} \rho_j \Delta Cancert_{-1} + \sum_{j=1}^{k-1} \Theta_j \Delta HIV_{t-j} + \sum_{j=1}^{k-1} \varepsilon_j \Delta GDP_{t-j} + \lambda_2 ECT_{t-1} + \varepsilon_{2,t} \quad (5)$$

$$\Delta GDP_t = d + \sum_{j=1}^{k-1} \omega_j \Delta Cancert_{-1} + \sum_{j=1}^{k-1} \tau_j \Delta HIV_{t-j} + \sum_{j=1}^{k-1} \eta_j \Delta GDP_{t-j} + \lambda_3 ECT_{t-1} + \varepsilon_{3,t} \quad (6)$$

Δ

Where: k-1 = the lag length reduced by 1; $\beta i,$, $\Phi\Phi_j$, $\varphi\varphi_j$, ρj, Θ_j, ε_j, ω_j, τ_j, η_j = Short run dynamic coefficients of the model's adjustment long-run equilibrium; λi = Speed of adjustment parameter with a negative sign with i=1, 2,3; ECTt-1 = the error correction term is the lagged value of the residuals obtained from the co-integrating regression of the dependent variable on the regressors and $\varepsilon i,t$ = residuals (stochastic error terms).

Results

Data were analyzed to identify, describe and explore the relationship between cancer incidence, HIV prevalence and GDP in Uganda.

Distribution of Cancer incidence, HIV Prevalence and GDP. The graph below shows the distribution of the three variables that is cancer incidence, HIV prevalence and GDP. We can see that there is a down ward trend and an upward trend for HIV prevalence and GDP, respectively. From the graph we can see that the variables are non-stationary since there is a trend.

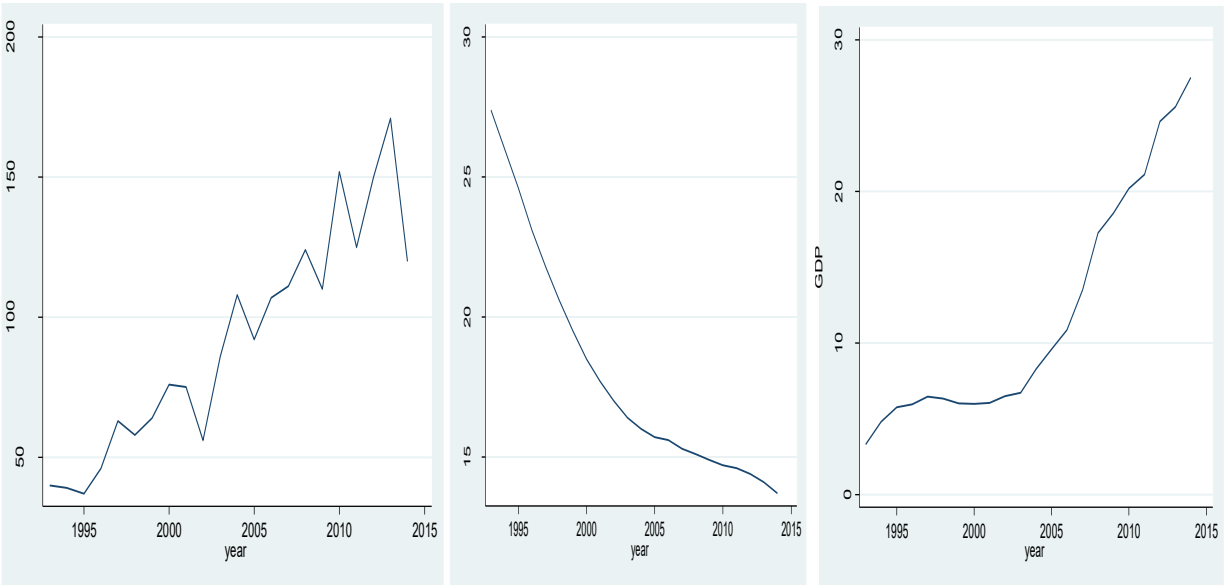

Figure 1. Distribution of cancer incidence, HIV Prevalence and GDP

Test for stationarity. Variables were tested for stationarity using the Augmented Dickey-Fuller test. The null hypothesis was that variables were non-stationary against the alternative that variables were stationary. When the absolute test statistic was greater than the 5 % critical value, we rejected the null hypothesis otherwise we failed to reject the null hypothesis.

Table 1. Non-stationary variables

Variables	Test Statistic	5% Critical value	p-value
GDP	1.612	-3.000	0.9979
HIV Prevalence	-2.71	-3.000	0.0723
Incidence of Cancer	-0.778	-3.000	0.8256

From Table 1, the absolute values of the test statistic for all variables that is GDP, prevalence of HIV and incidence of cancer were less than the 5% critical value, hence we failed to reject the null hypothesis and concluded that all the variables were Non-stationary. Further, From Table 2, the absolute values of the test statistic for all variables that is GDP, prevalence of HIV and incidence of cancer after differencing were greater than the 5% critical value, hence we rejected the null hypothesis and concluded that all the variables were Stationary after differencing. Figure 2 shows that Cancer incidence, HIV prevalence and GDP were stationary at first differencing.

Table 2. Stationary Variables after differencing

Variables	Test Statistic	5% Critical value	p-value
Dgdp	-4.364	-3.000	0.0003
DHIVprevalence	-4.623	-3.000	0.0001
DIncidencecancer	-7.153	-3.000	0.0000

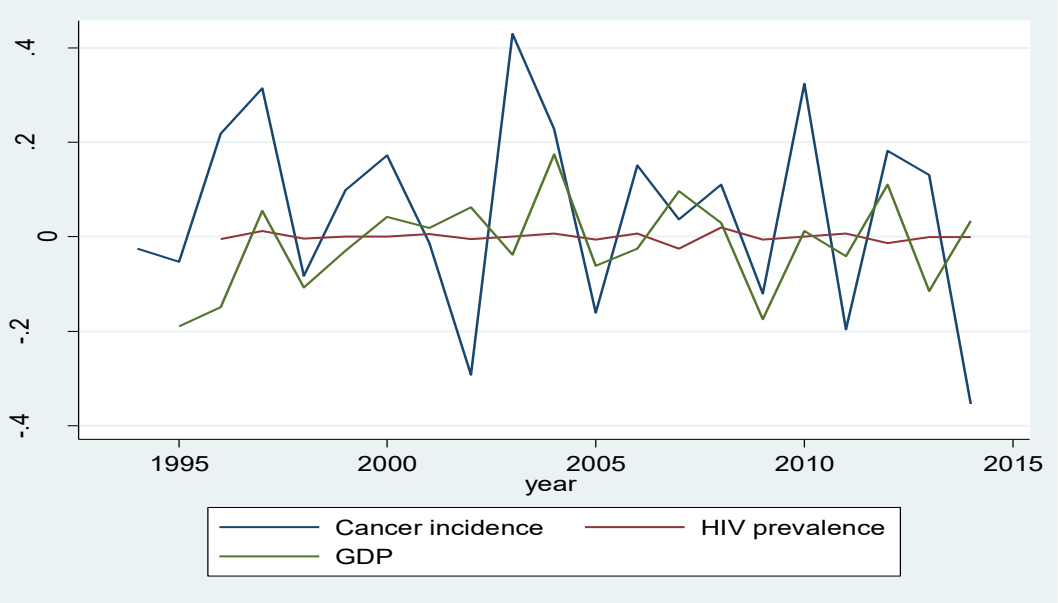

Figure 2. Graph showing stationary variables after differencing

Co-integration Test of the variables.Each of the 10 cancer models were tested for Co-integration using the Johansen test with the null hypothesis being that there was no co-integration against the alternative that there was co-integration. From Table 3 we can see that for breast, cervical, eye, Liver, Lung, Non-Hodgkin, Prostate and stomach cancer the trace statistic was greater than the critical value therefore we rejected the null hypothesis and conclude that there was co-integration hence we ran the VECM model. For Colon cancer and Hodgkin cancer the trace statistic was less than the critical value, therefore we failed to reject the null hypothesis and concluded that there was no co-integration hence we ran the VAR model.

Table 3. Johansen tests for co-integration.

Cancer Type	Max Rank	Trace Statistic	5% critical Value
Breast	0	43.2301	29.68
Cervical	0	43.3939	29.68
Colon	0	29.2976	29.68
Eye	0	41.1769	29.68
Hodgkin	0	24.0869	29.68
Liver	0	40.0616	29.68
Lung	0	35.9854	29.68
Non-Hodgkin	0	37.0643	29.68
Prostate	0	36.0881	29.68
Stomach	0	37.3164	29.68

Optimal Lag selection. The number of lags to be used in the models were determined using the optimal lag selection criteria and Table 4 shows that criteria AIC, HQIC and SBIC all suggested that 2 lags be used in the models.

Table 4. Selection order criteria

Lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	-178.21				14875.7	18.1209	18.1500	18.2702
1	-75.432	205.55	9	0.000	1.27882	8.7432	8.8598	9.3406
2	-54.554	41.756	9	0.000	0.420796	7.5554*	7.7595*	8.6009

Test for residual autocorrelation. The residual for each model were tested for autocorrelation using the Lagrange -multiplier test. The null hypothesis was that there was no autocorrelation against the alternative that there was autocorrelation. Since the p values as shown in Table 5 are greater than 0.05, we failed to reject the null hypothesis and concluded that there was no autocorrelation.

Relationship between cancer, GDP and HIV prevalence in Uganda. Since there was co-integration for breast, cervical, eye, liver, Lung, Non-Hodgkin, Prostate and stomach cancer, we used the VECM model to find out the effect of HIV prevalence, GDP on cancer incidence as shown in Table 6.

The results in Table 6 indicate that in the long run HIV had a negative significant effect on breast and cervical cancer while GDP had a positive effect on both breast and cervical since the p values were less than 5% level of confidence keeping other factors constant. Furthermore, in the long run GDP has a positive significant effect on eye, Non-Hodgkin and prostate cancer since the p-values were less than 5%. However, in the long run GDP had a negative significant effect on Lung cancer at 5% level of confidence keeping other factors constant. HIV had a long run positive significant relationship on eye, liver, Non-Hodgkin, Prostate and Stomach cancer at 5% level of confidence keeping other factors constant.

Relationship between colon cancer, GDP and Prevalence of HIV in Uganda. Results in Table 7 show the relationship between incidence of colon cancer, Lagged GDP and lagged prevalence of HIV in Uganda after running a vector autoregressive model. From Table 7 the third lag of HIV prevalence had a negative significant relationship with incidence of Colon cancer since the p-values was less than 0.05.

Discussion

From Table 6, there was a long run negative significant relationship between HIV prevalence and incidence of breast cancer since the p value was less than 0.05. Furthermore, there was also a long run positive significant relationship between GDP and breast cancer. Yang *et al*., 2017 noted that wealthier countries tended to have higher breast cancer incidence with the age-standardized incidence rate in more developed countries being two times as high as in less developed countries . In China, positive correlation between breast cancer mortality rate and GDP was found. In addition Ferlay *et al*.(2010) stated that as longevity improves in HIV-positive patients with the use of HAART, their risk for developing breast cancer continues to increase, similar to the general population.

There was a long run negative significant relationship between HIV prevalence and incidence of cervical cancer since the p value was less than 0.05. Furthermore, there was a long run positive significant relationship between GDP and cervical cancer since the p-value is less than 0.05. This is in line with (Ghebre *et al.,* 2017) who indicated that HIV-infected women as a special population, are at increased risk for cervical cancer. Overall risk of co-morbid conditions will increase with aging of the HIV-positive population. In addition Polesel *et al*. (2008) stated that cervical cancer mortality was associated with poverty-related factors, including lack of formal education, unemployment, low socio-economic level, rural residence and insufficient access to healthcare. From Table 7 there was a significant relationship between all lagged HIV prevalence and incidence of colon cancer since the p value was less than 0.05. Furthermore, there was also a significant relationship between GDP and colon cancer since the p-value was less than 0.05. Also, both HIV and GDP jointly cause colon cancer. This is in line with (Jemal *et al*., 2012) who stated that the incidence of many types of non–AIDS-defining cancers such as cancer of the colon was higher among HIV-infected persons than among the general population. Yang *et al*. (2017) notes that Colon cancer, nevertheless, showed a positive association, with high-GDP Per Capita areas having the highest age standardized incidence rate (ASIR). In our analysis olon cancer showed a positive association with GDP level.

Table 5. Test for residual autocorrelation

Cancer Type	Lag	Chi2	df	Prob>chi^2
	1	7.4813	9	0.58714
Breast	2	6.8137	9	0.65651
	1	14.6635	9	0.1006
Cervical	2	12.1736	9	0.2037
	1	9.0363	9	0.43393
Colon	2	7.2786	9	0.60813
	1	10.6262	9	0.3022
Eye	2	4.877	9	0.8449
	1	8.2309	9	0.51106
Hodgkin	2	4.3709	9	0.88535
	1	16.2102	9	0.06262
Liver	2	7.1946	9	0.616886
Lung	1	4.8843		0.84428
	2	6.8807		0.64953
	1	10.302	9	0.32659
Non-Hodgkin	2	10.6609	9	0.29967
	1	14.6978	9	0.09958
Prostate	2	4.5106	9	0.87472
	1	7.2761	9	0.6084
Stomach	2	3.2264	9	0.95464

Table 6. Relationship between cancer, GDP and prevalence of HIV in Uganda

Cancer	beta	Coef.	Std. Err.	z	P>z	[95% Conf.	Interval]
Breast	incidence	1.0000					
	HIV	2.6353	0.9247	2.85	0.004	0.8229	4.4477
	GDP	-3.0400	0.2069	-14.69	0.000	-3.4455	-2.6345
	_cons	-116.3527					
cervical	incidence	1.0000					
	HIV	17.7586	3.1158	5.7	0.000	11.6517	23.8655
	GDP	-1.7942	0.7316	-2.45	0.014	-3.2280	-0.3603
	_cons	-448.1500					
Eye	incidence	1.0000					
	HIV	-11.1217	2.0002	-5.56	0.000	-15.0421	-7.2013
	GDP	-0.5541	0.4535	-1.22	0.222	-1.4430	0.3348
	_cons	122.6458					
Liver	incidence	1.0000					
	HIV	-23.6435	4.8901	-4.83	0.000	-33.2279	-14.0591
	GDP	-0.1710	1.1956	-0.14	0.886	-2.5143	2.1724
	_cons	173.1006					
Lung	incidence	1.0000					
	HIV	4.4834	0.7575	5.92	0.000	2.9988	5.9681
	GDP	0.9453	0.1687	5.6	0.000	0.6146	1.2760
	_cons	-94.4508					
Non-Hod-gkin	incidence	1.0000					
	HIV	-15.5867	4.6327	-3.36	0.001	-24.6666	-6.5068
	GDP	-0.7649	1.1315	-0.68	0.499	-2.9825	1.4528
	_cons	62.8046					
Prostate	incidence	1.0000					
	HIV	-34.7054	7.7975	-4.45	0.000	-49.9883	-19.4225
	GDP	-6.2960	1.8304	-3.44	0.001	-9.8834	-2.7085
	_cons	378.2316					
stomach	incidence	1.0000					
	HIV	-4.7094	0.9498	-4.96	0.000	-6.5709	-2.8478
	GDP	-0.0579	0.2175	-0.27	0.790	-0.4841	0.3683
	_cons	8.6790					

Table 7. Relationship between Lagged incidence of Colon cancer, lagged GDP and lagged prevalence of HIV in Uganda.

Cancer Type	Variable	Coef.	Std. Err.	z	P>z
	incidence				
	L1.	-0.0564515	0.261179	-0.22	0.829
	L2.	-0.1095475	0.254604	-0.43	0.667
	L3.	-0.4595162	0.199317	-2.31	0.021
COLON	HIV				
	L1.	18.01392	18.03881	1.00	0.318
	L2.	3.837686	24.06409	0.16	0.873
	L3.	-43.62502	21.98242	-1.98	0.047
	All				
					0.002
	GDP				
	L1.	-0.651691	1.939951	-0.34	0.737
	L2.	1.516871	1.585659	0.96	0.339
	L3.	0.0366541	2.340541	0.02	0.988
	All				
					0.018
	_cons	15.00393	30.31018	0.5	0.621

There was a long run positive significant relationship between HIV prevalence and cancer of the eye since the p value was less than 0.05. This is in line with (Yang *et al*., 2017) who stated that Squamous cell carcinoma of the conjunctiva was associated with the human immunodeficiency virus and was thus a marker for the disease in Benin City, Nigeria.There was a long run positive significant relationship of HIV prevalence, GDP and Liver cancer since the p value was less than 0.05. Juan (2013) observed that people co-infected with HIV and viral hepatitis tended to experience more rapid liver disease progression and responded less to treatment than those with hepatitis B virus (HBV) or hepatitis C virus (HCV) alone. As antiretroviral therapy has reduced mortality due to AIDS, liver diseases including hepatocellular carcinoma has become a growing cause of death among people with HIV.

There was a long run positive significant relationship between HIV prevalence and Non-Hodgkin cancer since the p value was less than 0.05. Furthermore, there was also a long run positive significant relationship between GDP and Non-Hodgkin cancer since the p-value was less than 0.05. Polesel *et al*. (2008) noted that the incidence of NHL declined gradually in patients initiating HAART and even at persistent severe immune deficiency, HAART protects against NHL. The natural history including the clinical prognosis of NHL has not changed after the introduction of HAART. In the era of HAART, patients at highest risk of developing NHL are those who did not respond adequately to HAART, that is, remained at low CD4 cell count and insufficiently suppressed viral replication. There was a long run positive significant relationship between HIV prevalence and Prostate cancer since the p value was less than 0.05. Furthermore, there was also a long run positive significant relationship between GDP and Prostate cancer since the p-value was less than 0.05. Chebre *et al*., 2017 stated that Prostate cancer was a common malignancy in HIV-positive men. With improved therapies for HIV and increasing survival, the importance of screening and treating prostate cancer is increasing. Furthermore in a study about comparison of cancer incidence and mortality in three GDP per capita levels in China Yang *et al*.

(2017) stated that Prostate cancer had the highest age-standardized incidence rate (ASIR) in all cancer types for men in more developed areas and was the second most common cancer for men worldwide.

There was a long run positive significant relationship between HIV prevalence and stomach cancer since the p value was less than 0.05. Furthermore, GDP had a long run positive significant relationship with stomach cancer. This is in line with (Wabinga *et al*., 2016) who indicated that overall, people with AIDS are at higher risk for stomach and esophageal cancer than the general population. This could be due to more frequent use of tobacco and alcohol, or perhaps obesity, among people with AIDS. There was a long run negative significant relationship between HIV prevalence and Lung cancer since the p value was less than 0.05. Furthermore, GDP had a long run negative significant relationship with Lung cancer. This is in line with Sigel *et al.* (2017) who stated that Lung cancer was a leading non-AIDS defining cancer (NADC) and is the most frequent cause of cancer deaths in HIV infected persons. This is largely related to higher smoking rates among HIV infected persons, but also due to independent HIV-related increased lung cancer risk. With improved HIV disease control, larger numbers of patients are surviving long enough. Furthermore (Chebre *et al*., 2017) stated that lung cancer was also the leading cause of cancer deaths, regardless of gender and gross domestic product per capita (GDPPC) level. Negative associations with GDPPC level were found for the age-standardized incidence rate (ASIRs) of lung cancer.

Conclusions

The purpose of this study was to determine the association of cancer incidence, HIV prevalence and GDP in Uganda. Non-AIDS defining cancers that is stomach, eye, liver cancer and prostate cancer had a long run positive significant relationship with HIV prevalence while colon, lung and breast cancer had a negative significant relationship with HIV prevalence. These cancers (breast cancer and prostate) had a positive significant relationship with Gross Domestic Product while cancer of the lung had a negative significant relationship with Gross Domestic Product in Uganda. AIDS defining cancers that is, Non-Hodgkin cancer had a long run positive significant relationship with HIV prevalence while cervical cancer had a negative significant relationship with HIV prevalence. These cancers (Non-Hodgkin and cervical cancer) had a positive significant relationship with Gross Domestic Product in Uganda.

In line with the findings of this study, the following recommendations are provided towards reducing the incidence of cancer and prevalence of HIV in Uganda; (i) Government should focus on reducing the prevalence of HIV in the population since it has been observed that there is a relationship between HIV and cancer, and (ii) Government should focus on sensitizing and making available cancer screening centers in both rural and urban areas for HIV infected patients for NON-AIDS defining cancers.

Acknowledgement

We thank Kampala Cancer Registry, Department of Pathology, College of Health Sciences, Makerere University for providing us with cancer data. This paper is a contribution to the Fifteenth RUFORUM Annual General Meeting held 2-6 December 2019 in Cape Coast, Ghana.

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