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Economic Tertiarization and Environmental Quality in Togo: An Empirical Investigation Using Vector Error Correction Models (VECM) and Dynamic Ordinary Least Squares (DOLS)

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Abstract

Given the importance of environmental issues and the sustainability of economic growth, reconciling these two issues is one of the major challenges facing governments. Many developing countries, including Togo, have undergone a structural transformation that has been felt most acutely in the service sector. This research falls within the same framework, by analyzing the relationship between economic tertiarization and environmental quality in Togo. More specifically, this research assesses the impact of the value added of tertiary activities on environmental degradation resulting from economic activities. Using a vector error correction model and dynamic ordinary least squares estimation, this paper investigates the effects of service sector contributions to gross domestic product on environmental quality in Togo over the period 1980-2022. The results reveal that a 1% increase in the value added of the services sector to GDP reduces carbon dioxide emissions by 0.59% over the long term. Thus, economic growth reduces carbon dioxide emissions by 0.25% in the long term, with no significant impact in the short term. These results are a wake-up call to Togo's political authorities on the importance of promoting sustainable practices within the service sector to achieve long-term environmental objectives while not leaving other sectors behind.

Keywords

Economic Tertiarization, Economic Growth, Carbon Dioxide, Ecological Footprint, Togo

1. Introduction

The deterioration in the quality of the environment has led to a great deal of interest and concern among both the international community and political authorities. Since the signing of international commitments by States, including the Paris Agreement[1] aimed at taking primordial measures to combat climate change, notably for low-carbon emissions, the political authorities of developing countries have begun to integrate into their development programs reform measures aimed at combating the degradation of environmental quality. How to reconcile strong economic growth with environmental sustainability are therefore the major challenge facing political decision-makers. The need to ensure sustainable growth to satisfy urgent needs has led to overheating of the economy, accompanied by environmental degradation due to increased energy consumption for the production of basic necessities, on the one hand, and emissions of harmful substances, on the other.

Environmental problems are caused by emissions of greenhouse gases (GHGs) into the atmosphere, the main gas being carbon dioxide (CO_2). CO_2 is generated by various human activities such as the combustion of fossil fuels, industrial processes, livestock farming and waste treatment, agricultural fertilizers and the use of solvents. According to the Global Footprint and Biocapacity Forecast Report (Lin & Wambersie, 2023), the total ecological footprint increased by 0.2% year-on-year, while total biocapacity rose by 0.3% over the same period. Global biocapacity in 2023 is estimated at 1.5 global hectares per person, while humanity's ecological footprint is 2.6 global hectares per person, of which 60% is carbon footprint.

According to the latest report by the Intergovernmental Panel on Climate Change (GIEC, 2022), the next two decades will see a number of unavoidable climatic hazards, with global warming of 1.5˚C (2.7˚F). This warming will have serious consequences for society, including food insecurity. The report also states that multiple heat waves, droughts and floods have exceeded the tolerance thresholds of plants and animals, causing massive mortality of trees and other species. To avoid loss of life, biodiversity and infrastructure, ambitious measures are required to adapt to climate change while rapidly and significantly reducing greenhouse gas emissions.

Togo, like other developing countries, is not spared these environmental problems. Data from Global Footprint Network (2023) reveal a very worrying trend over the period 2000-2022. Over this period, the country saw an average annual growth in ecological footprint of 1.7% and biocapacity of 0.8%. The carbon footprint (CO_2) over the same period grew by an annual average of 4.0%. In 2022, thanks to the efforts made by the Togolese government, the country's ecological footprint fell by 2.5% compared with 2021, to 7902880.8 global hectares (gha) in 2022. In the same vein, the carbon footprint fell by 11.9% compared with 2021, to

[1]The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at COP 21, the United Nations Climate Change Conference in Paris, France, on December 12, 2015. It entered into force on November 4, 2016.

1551147.7 global hectares (gha) in 2022.

In recent years, the structure of the economies of developing countries has undergone a remarkable sectoral change. These economies have evolved with a high level of value added by the services sector in gross domestic product (GDP). In the case of Togo, over the period 2000~2023, the value added of services in GDP averaged 57.4%. On the other hand, over this period, value added in the primary sector and industry came out at 21.7% and 20.9% respectively. These results reveal the Togolese government's efforts to structurally transform its economy, with an emphasis on exploiting the potential of service activities. In its economic development program (Togo 2025 Government Road Map), Togo has included structural transformation based on a strategy of industrialization and tertiarization of its economy, while not neglecting the agricultural sector. The country's priority projects also include responses to major climatic risks.

Given Togo's economic structure and the crucial challenges facing the country, one of which is the quality of the environment as enshrined in its economic development plan, our research follows this same logic by determining the relationship between the emergence of tertiary activities and the quality of the environment in the country. To this end, the main research question of this paper is: how does the value added of services to GDP influence the impact of economic activity on environmental quality in Togo? The aim of the study is to examine the relationship between economic tertiarization and environmental quality in Togo by quantifying the impact of the economic sector on environmental degradation. More specifically, the study aims to: 1) assess the impact of the service sector's contribution to environmental degradation resulting from economic activities, 2) verify the existence of a cointegrating (long-term) relationship between the service sector and environmental quality.

The methodological approach adopted in this study is based on statistical and econometric analysis. The statistical analysis traces the evolution of the study variables in the case of Togo. For the econometric analysis, we start with tests for the presence of unit roots and end with econometric estimation, using two approaches: 1) the Vector Error Correction Model (VECM) approach to identify short- and long-term effects, 2) the Dynamic Ordinary Least Squares (DOLS) approach, to check the robustness of the empirical results. The VECM and DOLS approaches are used to examine cointegration in time series. DOLS estimation takes account of any endogeneities that may exist between the explanatory and dependent variables.

This study contributes to the existing literature by focusing specifically on the case of Togo, and sheds light on the interactions between economic growth, structural transformation (assessed by the service sector) and environmental quality. To our knowledge, in the existing literature, there is no research that explains this relationship in the context of Togo. Many previous studies in the economic literature have examined the Kuznets environmental curve (Kuznets, 1955) and the general relationship between economic activities and environmental degradation, but they have not investigated the effect of the sector contributing most to economic growth on environmental outcomes. As Togo has undergone a structural transformation of its economy and is continuing this struggle by including it in the Togo 2025 Government Roadmap, it is crucial to analyze how changes the service sector influence environmental quality.

The present work is organized as follows: Section 2 deals with the literature review. Section 3 deals with the methodology employed in the study. Section 4 presents the main findings of the study. Section 5 provides the conclusion and some policy recommendations based on the results of the study.

2. Literature Review

In this section, we present the works that have studied the relationship between economic growth and environmental degradation in the economic literature.

The first pioneering works on the relationship between economic growth and environmental degradation were those by (Grossman & Krueger, 1991; Shafik & Bandyopadhyay, 1992) for the World Bank's Global Development Report and (Panayotou, 1995) for the Development Working Paper as part of a study for the International Labour Organization. These various studies discovered an inverted U-shaped relationship (curve) between the emission of several environmental pollutants and economic growth. This curve has been dubbed the Kuznets Environmental Curve (KEC). The Kuznets environmental curve relates per capita income to society's degradation of the environment. Two phases make up the CEK curve. The first phase is most commonly attributed to developing countries, where per capita income has not yet reached a certain threshold. The second phase is attributed to the economies of developed countries, where per capita income has reached its threshold.

The theory behind the Kuznets environmental curve is that, regardless of their impact on the environment, the least-developed economies give priority to meeting primary needs such as nutrition, housing and health. To this end, economic development manifests itself in the intensification of agriculture and the extraction of other resources. Pollutant waste increases in quantity, leading to a deterioration in environmental quality as income rises. Once the economy has developed sufficiently to meet vital needs, society begins to seek a healthier environment. As the economy continues to grow, more and more resources are allocated to sustainable production. In developed countries, however, the opposite is true, with pollution decreasing as a function of per capita income. This situation is observed in Europe, the United States, and Japan, where the technical effects outweigh the scale and composition of several pollutants.

(Grossman & Krueger, 1991), studying the environmental impacts of a North American free trade agreement, showed that a reduction in trade barriers will generate environmental effects by widening the scale of economic activity, altering the composition of economic activity and bringing about a change in production techniques. On a panel of 42 countries made up of low-income and high-income countries, the authors show that for pollutants such as sulfur dioxide and smoke, concentrations increase with GDP per capita at low national income levels, but decrease with GDP growth at higher income levels.

In economic literature, the prevailing perception is that economic growth is often accompanied by adverse effects on the environment. These effects result from production activities in the three sectors of the economy (agriculture, industry, and services). (Horii & Ikefuji, 2014), examining the mutual causality between environmental quality and economic growth in Asian countries, come to the conclusion that economic growth deteriorates the environment through high carbon dioxide emissions during the production process, and that environmental degradation limits the possibility of achieving sustainable and inclusive economic growth.

(Alam, 2014), examines the relationship between economic growth (GDP per capita) and CO_2 emissions in Bangladesh World Bank data, for the period 1972-2010. His work does not test the environmental Kuznets curve hypothesis. He finds that a faster structural shift from agriculture to other sectors and the emergence of services as a dominant part of the economy lead to an upward trend in CO_2 emissions.

(Senzele, 2022), analyzing the relationship between economic growth and environmental degradation in Côte d'Ivoire over the period 1990-2020, uses the STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology) model to detect the effects of macroeconomic variables on the environment. His study confirms the Kuznets environmental curve hypothesis for the Ivorian economy, with a GDP per capita threshold of 2008 US dollars, and that the main determinants of carbon dioxide emissions are energy consumption, urbanization and industry. The author also reveals that trade openness and the share of services in GDP have a negative impact on CO_2 emissions.

Based on a sample of 20 low-income sub-Saharan African countries (Awad, 2021) reveals a non-significant effect of industrialization on environmental quality. The author justifies this result on the basis of the underdevelopment of the industrial sector in these countries and the structural transformation of the economies of underdeveloped countries, where labor migrates mainly from the agricultural sector to the service sectors. The labor force used in the industrial sector is very small.

(Keho, 2015) examined the long-term determinants of CO_2 emissions in Côte d'Ivoire on data covering the period from 1970 to 2010. The author reveals that the results obtained support the environmental Kuznets curve, and the main variables determining CO_2 emissions are per capita income, the share of the industrial sector in GDP and trade openness. It reveals that the effect of trade openness on CO_2 emissions is linked to the structure of the economy, and increases as the country industrializes. Furthermore, trade openness and industrialization are complementary in the deterioration of environmental quality in Côte d'Ivoire.

NOUNAGNON (2022) using the Autoregressive Staggered Lag (ARDL) model, analyzed the effects of economic growth on environmental quality in Benin, as measured by carbon dioxide emissions. It reveals that, in the short term, economic growth has no effect on CO_2 emissions. In the long term, however, economic growth leads to an increase in CO_2 emissions.

By estimating the Kuznets Environmental Curve in the context of the Beninese economy, (Dossa, 2024) has shown that the inverted U-shape of the CEK is verified and achieves a relatively unpolluted environment for 500 US dollars per capita per year, with a turning point of 250 US dollars.

Kouton et al. (2024), exploring how structural changes in the agricultural, industrial and service sectors have seen an impact on environmental quality in Ivory Coast, over the period 1961 to 2021, reveal that positive changes in the share of the agricultural, industrial and service sectors reduce the ecological footprint by 0.222%, 0.178% and 0.368% respectively in the long term. In the short term, there is no significant impact for the agricultural and industrial sectors, while a 1% increase in the added value of the service sector reduces the ecological footprint by 0.288%.

3. Econometric Methodology and Data

In this section, we present the data sources used, the econometric model and the estimation techniques.

3.1. Data Used

The study uses annual time series for Togo, a member country of the Economic Community of West African States (ECOWAS), over the period from 1980 to 2022. These data come from a variety of sources, such as the World Bank's latest World Development Indicators database (World Bank, 2023) and public data from the Global Ecological Footprint Network's National Ecological Footprint and Biocapacity Accounts (Global Footprint Network, 2023) (**Figure 1**, **Table 1**).

The variables used are:

➢ ***Dependent variable***

- **the logarithm of carbon dioxide emissions (LnCO_2)** measured in global hectares (gha[2]) is the dependent or explained variable used as a proxy to measure environmental quality.

➢ ***Variable of interest***

- **the logarithm of service-sector value added (LnSERVICE)**, measured as a percentage of gross domestic product (GDP), is the variable of interest used to capture the importance of service-sector activities in GDP.

➢ ***Other explanatory variables***

- **the logarithm of gross domestic product per capita (LnPIBTETE)** is a proxy used to measure a country's economic activity, and gives an indication of the level of average per capita income in a given year. It is the variable used to

[2]The global hectare is the unit of measurement for both ecological footprint and biocapacity. These biologically productive hectares, weighted according to productivity, enable researchers to account for both the biocapacity of the Earth or a region, and the demand for biocapacity (the ecological footprint).

categorize countries according to income level. In our data, we use GDP per capita in constant 2015 US dollars.

- **-the logarithm of gross fixed capital formation (LnFBCF)** measured as a percentage of GDP, is used to measure the level of investment. Investment remains an essential element in a country's production process, with effects on carbon dioxide levels.
- **-the logarithm of the working population (LnTRAVAIL)** measured as a percentage of the total population and representing labor capital (population aged 15 to 64).

Table 1. Descriptive statistics and correlation matrix.

	$LnCO_2$	LnSERVICE	LnPIBTETE	LnFBCF	LnTRAVAIL
		Summary Statistics			
Moyenne	13.305	3.852	6.583	2.818	14.829
Médiane	13.526	3.918	6.583	2.848	14.845
Std. Dev.	0.905	0.140	0.101	0.341	0.372
Minimum	11.586	3.493	6.325	2.189	14.189
Maximum	14.447	4.020	6.794	3.541	15.431
		Correlation Matrix			
$LnCO_2$	1.000				
LnSERVICE	0.639*	1.000			
LnPIBTETE	0.024	−0.272**	1.000		
LnFBCF	−0.001	−0.552*	0.487*	1.000	
LnTRAVAIL	0.961*	0.645*	0.124	0.027	1.000

Notes: * and ** indicate significance at the 5% and 10% level, respectively. **Source**: Authors, based on data from the World Bank (World Bank, 2023) and the Global Ecological Footprint Network (Global Footprint Network, 2023).

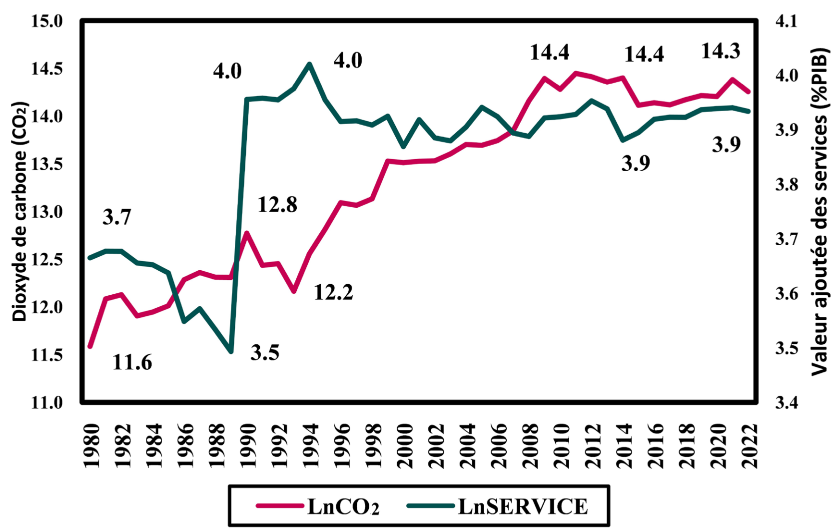

Figure 1. Evolution of carbon dioxide emissions and value added in the tertiary sector. **Source**: Authors, based on data from the World Bank (World Bank, 2023) and the Global Ecological Footprint Network (Global Footprint Network, 2023).

3.2. Model Specification

To investigate the long-term impact of the service sector on environmental quality, the study draws on the economic literature and specifies an empirical model linking environmental quality to the service sector, economic growth, physical capital and the active workforce in the Togolese economy. These variables have all been included.

$$CO_{2t} = f\left(\text{SERVICE}_t, \text{PIBTETE}_t, \text{FBCF}_t, \text{TRAVAIL}_t\right) \quad (1)$$

where t is the time period.

3.3. Econometric Methodology

To examine the relationship between environmental quality and the tertiarization of economic activities, a number of econometric steps need to be taken following the study of a time series. The first step is to test for the presence of unit roots in the series. In the economic literature, it has been shown that the presence of a unit root in a series is likely to create spurious regressions in the estimates, leading to poor results. In this work, we performed the unit root tests of Augmented Dickey-Fuller (Dickey & Fuller, 1981; Philips & Perron, 1988; Kwiatkowski et al., 1992). These tests are well documented in the economic literature. When the dependent or explained variable is stationary in the first difference, an error-correction model (ECM) is estimated. On the other hand, if it is stationary in level, then we estimate the empirical model using the heteroscedasticity-robust ordinary least squares (OLS) method. In the second approach, we test for the presence of cointegration between the series of the empirical model using the Johansen test (Johansen, 1995). Cointegration is the presence of a long-term relationship between several non-stationary variables. For a cointegrating relationship to exist between two variables, two conditions must be met. Firstly, the variables must be non-stationary and integrated of the same order. Secondly, there must be at least one linear combination of these variables that is stationary. In the presence of cointegration, we estimate a vector error correction model (VECM), also known as a cointegrated vector autoregression (cointegrated VAR). The Johansen cointegration test a multivariate generalization of the augmented Dickey-Fuller test. To determine the number of cointegrating vectors, Johansen proposed two alternatives: the Trace test and the maximum eigenvalue test.

The following general model is used:

$$\begin{aligned} \ln CO_{2t} = \beta + \alpha_1 \ln \text{SERVICE}_t + \alpha_2 \ln \text{PIBTETE}_t \\ + \alpha_3 \ln \text{FBFC}_t + \alpha_4 \ln \text{TRAVAIL}_t + \varepsilon_t \end{aligned} \quad (2)$$

To perform the Johansen cointegration test, we begin by determining the optimal number of lags to incorporate into the autoregressive process. This number is determined according to the AIC (Akaike Information Criterion), FPE (final prediction error), SBIC (Schwarz's Bayesian information criterion) and HQIC (Hannan and Quinn information criterion) criteria. VAR models characterized by their dynamic structures, modeling each endogenous variable in the system as a function of the lagged values of all other endogenous variables in the system.

The VAR(p) model in equation 2 is presented as follows:

$$Y_t = A_0 + A_1 Y_{t-1} + A_2 Y_{t-2} + \cdots + A_P Y_{t-p} + \varepsilon_t \quad (3)$$

Avec $\varepsilon_t \sim N(0, \Sigma)$. Y_t contains the endogenous variables

The VAR can be rewritten as VECM:

$$\Delta Y_t = \Pi Y_{t-1} + \Gamma_i \Delta Y_{t-i} + A_0 + \varepsilon_t \quad (4)$$

Cointegration relationships are determined by the Π matrix, which describes the adjustment towards equilibrium following an exogenous shock.

If the matrix Π has reduced rank $r < k$ (k denotes the number of variables), then there exist two matrices ($k * r$), α et β each of rank r such that Π = αβr where:

- The β matrix contains the coefficients of the r (long-term) cointegration relationships;
- theα matrix contains coefficients that measure the speed of adjustment towards the equilibrium relationship;
- the elements Γ_i are matrices ranging from 1 to p - 1 that capture the dynamics of short-term adjustments.

Johansen's cointegration test is based on estimating the rank r of the matrix Π, which designates the number of cointegration vectors.

Three cases can be distinguished:

- if rank(Π) = 0, then there is no cointegrating relationship. Thus, estimating a VECM model is not appropriate. We estimate a VAR model on the first difference (stationarity);
- if rank(Π) = k, then there is no cointegrating relationship. Thus, estimating a VECM model is not appropriate. We can estimate a VAR model directly on level;
- if rank(Π) = r where 0 < r < k, then there are r cointegrating relationships. We estimate a VECM model on the first difference.

Two statistics are defined for the Johansen test: the trace statistic and the maximum eigenvalue statistic.

- The trace statistic is: $\lambda_{trace}(r) = -T \sum_{i=r+1}^{n} \ln\left(1 - \hat{\lambda}_i\right)$ with null hypothesis (H0): Number of cointegrating vectors ≤ r, against the alternative hypothesis (Ha): Number of cointegrating vectors > r;
- The maximum eigenvalue statistic is: $\lambda(r, r+1) = -T \ln\left(1 - \hat{\lambda}_{r+1}\right)$ with null hypothesis (H0): Number of cointegrating vectors r, against the alternative hypothesis (Ha): Number of cointegrating vectors r + 1.

We use a powerful modeling procedure called dynamic ordinary least squares (DOLS) proposed by Stock & Watson (Stock & Watson, 1993) to check the robustness of the VECM results. The Stock Watson method is a robust approach that corrects for the endogeneity of the explanatory variables by incorporating initial values and first-difference lags of these variables, as well as serially correlated errors through a GLS procedure. The DOLS estimator improves on ordinary least squares (OLS) estimates by taking into account dynamic sources of bias and small sample sizes.

4. Empirical Results and Discussion

4.1. Results of Unit Root Presence Tests

The application of unit root tests indicates that all variables are stationary in the first difference. To this end, all variables are integrated of order 1 (I(1)). The results are shown in Table 2.

Table 2. Unit root test results

	Level			Primary difference			Decision
Variables	ADF	PP	KPSS	ADF	PP	KPSS	I(d)
$LnCO_2$	−1.061 (0.730)	−1.689 (0.436)	0.294 (0.146)	−7.556*** (0.000)	−7.696*** (0.000)	0.040*** (0.216)	I(1)
LnSERVICE	−1.934 (0.316)	−2.030 (0.273)	0.253 (0.146)	−6.848*** (0.000)	−6.873*** (0.000)	0.038*** (0.216)	I(1)
LnPIBTETE	−1.733 (0.414)	−1.936 (0.315)	0.363 (0.146)	−5.387*** (0.000)	−5.370*** (0.000)	0.045*** (0.146)	I(1)
LnFBCF	−1.967 (0.301)	−2.541 (0.105)	0.398 (0.146)	−4.468*** (0.000)	−7.920*** (0.000)	0.051*** (0.216)	I(1)
LnTRAVAIL	−1.218 (0.665)	−1.394 (0.584)	0.182 (0.146)	−4.366*** (0.000)	−4.197*** (0.000)	0.045*** (0.216)	I(1)

Note: Values in brackets are p-values for the ADF and PP tests. For the KPSS test, on the other hand, they are the Z-statistics of the decision thresholds (10%: 0.119; 5%: 0.146 2.5%: 0.176; 1%: 0.216). The optimal lag length for each variable was determined using the varsoc function. For the ADF and PP tests, $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$ indicate rejection of the unit root null hypothesis at the 10%, 5% and 1% significant levels, respectively. For the KPSS test, $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$ indicate acceptance of the null hypothesis of series stationarity at significant levels of 10%, 5% and 1%, respectively. I(d) denote the order of integration of the variable. **Source**: Authors, based on data from the World Bank (World Bank, 2023) and the Global Ecological Footprint Network (Global Footprint Network, 2023).

Table 3. Results for determining the optimum VECM offset length.

Lag	LL	LR	df	P	FPE	AIC	HQIC	SBIC
0	80.960				1.4e−08	−3.895	−3.818	−3.682
1	316.729	471.540	25	0.000	2.9e−13	−14.704	−14.244	−13.424*
2	335.590	37.723	25	0.049	4.2e−13	−14.389	−13.547	−12.043
3	369.438	67.694	25	0.000	3.2e−13	−14.843	−13.618	−11.430
4	425.864	112.850*	25	0.000	9.3e−14*	−16.4545*	−14.847*	−11.975

Note: AIC (Akaike Information Criterion), FPE (final prediction error), HQIC (Hannan and Quinn information criterion), and SBIC (Schwarz's Bayesian information criterion). *Indicates the optimum VECM offset length. **Source**: Authors, based on data from the World Bank (World Bank, 2023) and the Global Ecological Footprint Network (Global Footprint Network, 2023).

4.2. Determining the Optimum VECM Offset Length

The FPE, AIC and HQIC information criteria indicate an optimal VAR lag length of 4. This leads to the estimation of a VECM with three (3) lags, as for the cointegration test. (Table 3)

4.3. Results of the Cointegration Test

Johansen's cointegration test is applied, taking the constant trend and three lags. At rank 1, the trace statistic is below the critical value at the 5% threshold, indicating the presence of a cointegrating relationship. The same is true of the maximum eigenvalue test. There is, therefore, a cointegrating relationship between tertiary activities and carbon dioxide emissions in Togo. The results are presented in Table 4.

Table 4. Results of Johansen's cointegration test.

Rank	Eigen value	Trace statistic	Valeur critique at 5%	Valeur critique at 1%
0		75.346***	68.52	76.07
1	0.585	40.089**	47.21	54.46
2	0.433	17.335	29.68	35.65
3	0.270	4.715	15.41	20.04
4	0.111	0.000	3.76	6.65
5	0.000			
Rank	Eigen value	Max statistic	Valeur critique à 5%	Valeur critique à 1%
0		35.257***	33.46	38.77
1	0.585	22.753**	27.07	32.24
2	0.433	12.619	20.97	25.52
3	0.270	4.715	14.07	18.63
4	0.111	0.000	3.76	6.65
5	0.000			
Observations	40			
Lags	3			
Trend	Constant			

Note: *** and ** indicate the presence of a cointegrating relationship at rank *i* at the 1% and 5% significant levels, respectively. Null hypothesis (H0) is the absence of cointegration. **Source**: Authors, based on data from the World Bank (World Bank, 2023) and the Global Ecological Footprint Network (Global Footprint Network, 2023).

4.4. Results of the Long-Term Effect of Increasing Value Added in Tertiary Activities on Carbon Dioxide Emissions

- **Vector error correction model (VECM) results**

As Johansen's cointegration test revealed a cointegrating relationship, we are therefore interested in the first equation, which contains our variable of interest, and we estimate the long run block of the chosen model by the maximum likelihood method as follows (Table 5):

Table 5. Long-term relationship estimation results (VECM).

Variables	CointEq1
	Coefficients
$LnCO_2$	1
LnSERVICE	1.703** [1.96]
LnPIBTETE	3.927*** [6.46]
LnFBCF	0.278 [0.99]
LnTRAVAIL	−3.058*** [−11.19]
Constante	−1.562
Prob > chi2	0.0042
Chi2	28.845
R2	0.51
RMSE	0.155
Observations	40
AIC	−14.336
HQIC	−13.359
SBIC	−11.634

Note: *$p < 0.10$; **$p < 0.05$; ***$p < 0.01$ indicate significance of coefficients at the 10%, 5% and 1% significant levels, respectively. Values in brackets [] indicate Z-statistics associated with these coefficients. **Source**: Authors, based on data from the World Bank (World Bank, 2023) and the Global Ecological Footprint Network (Global Footprint Network, 2023).

Estimation of the cointegration relationship leads to the following long-term equation:

$$\begin{aligned}\ln CO_{2t} = {} & 1.562 - 1.703 \ln \text{SERVICE}_t - 3.927 \ln \text{PIPTETE}_t \\ & - 0.278 \ln \text{FBCF}_t + 3.058 \ln \text{TRAVAIL}_t\end{aligned} \tag{5}$$

A 1% increase in the value added of tertiary sector activities to GDP (lnSERVICE) generates a 0.587% reduction in carbon dioxide (CO_2). There is also a negative effect on gross domestic product per capita (lnPIBTETE) and gross fixed capital formation (lnFBCF). In fact, a 1% increase in gross domestic product per capita and gross fixed capital formation respectively generates a 0.255% and 3.597% drop in CO_2. On the other hand, the workforce in the Togolese economy, represented by the active population, has a positive impact on carbon dioxide emissions.

- **Dynamic ordinary least squares (DOLS) estimation results**

Robustness estimates using dynamic ordinary least squares reveal a negative and significant effect of the value added of tertiary activities to GDP on carbon dioxide emissions. Thus, in the long term, the value added of tertiary activities to GDP leads to a reduction in carbon dioxide emissions. This result confirms that of the VECM. (Table 6)

Table 6. Long-term relationship estimation results (DOLS).

Variables	Dependent: $LnCO_2$
	Coefficients
LnSERVICE	−0.513*** [−5.43]
LnPIBTETE	−2.890*** [−62.16]
LnFBCF	0.039 [1.48]
LnTRAVAIL	2.687*** [93.82]
Constante	−6.821*** [−19.99]
R^2	**0.99**
R^2 Ajusted	**0.97**
Long run S.e.	**0.014**
Observations	**39**
Kernel	**qs**

Note: $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$ indicate significance of coefficients at the 10%, 5% and 1% significant levels, respectively. Null hypothesis (H0) is the absence of cointegration. Values in brackets [] indicate the Z-statistics associated with these coefficients. The kernel used is the quadratic function (qs). **Source**: Authors, based on data from the World Bank (World Bank, 2023) and the Global Ecological Footprint Network (Global Footprint Network, 2023).

4.5. Results of the Short-Term Effect of Increasing Value Added in Tertiary Activities on Carbon Dioxide Emissions

Short-term results show that the effect of value added in the service sector is not significant on environmental quality. The results are presented in Table 7.

Table 7. Short-term estimation results (VECM).

Variables	Dependent: $DLnCO_2$
	Coefficients
$DLnCO_2(-1)$	0.111 [0.56]
$DLnCO_2(-2)$	0.060 [0.38]
DLnSERVICE(−1)	−0.499 [−1.06]
DLnSERVICE(−2)	−0.140 [−0.35]
DLnPIBTETE(−1)	0.595 [0.92]
DLnPIBTETE(−2)	0.687 [1.09]
DLnFBCF(−1)	0.045 [0.26]
DLnFBCF(−2)	−0.125 [−0.72]
DLnTRAVAIL(−1)	−2.540 [−0.49]
DLnTRAVAIL(−2)	0.126 [0.03]
Constante	−0.0477 [−0.27]
CointEq(−1)	**−0.352*** [−3.39]**

Note: $^*p < 0.10$; $^{**}p < 0.05$; $^{***}p < 0.01$ indicate significance of coefficients at the 10%, 5% and 1% significant levels, respectively. Null hypothesis (H0) is the absence of cointegration. Values in brackets [] indicate Z-statistics associated with these coefficients. **Source**: Authors, based on data from the World Bank (World Bank, 2023) and the Global Ecological Footprint Network (Global Footprint Network, 2023).

4.6. VECM Validation Test

Validation tests of the VECM model show no evidence of violation of the assumptions of the classical linear regression model (Table 8). Figure 2 also shows that all eigenvalues are below unity, and the cointegrating relationship exists on the unity circle. The model is therefore stable.

Table 8. Model validation tests.

Test d'autocorrélation de Breusch-Godfrey (H0: Pas d'autocorrélation)	
Lags(1) (Chi2 = 42.534)	Prob. (Chi2) = 0.015
Lags(2) (Chi2 = 33.882)	Prob. (Chi2) = 0.110*
Test de Normalité de Jarque-Bera (H0: Normalité)	
Test-statistic= 6.615	Prob. (Chi2) = 0.036**

Notes: *indicates acceptance of the null hypothesis. **Source**: Authors, based on data from the World Bank (World Bank, 2023) and the Global Ecological Footprint Network (Global Footprint Network, 2023).

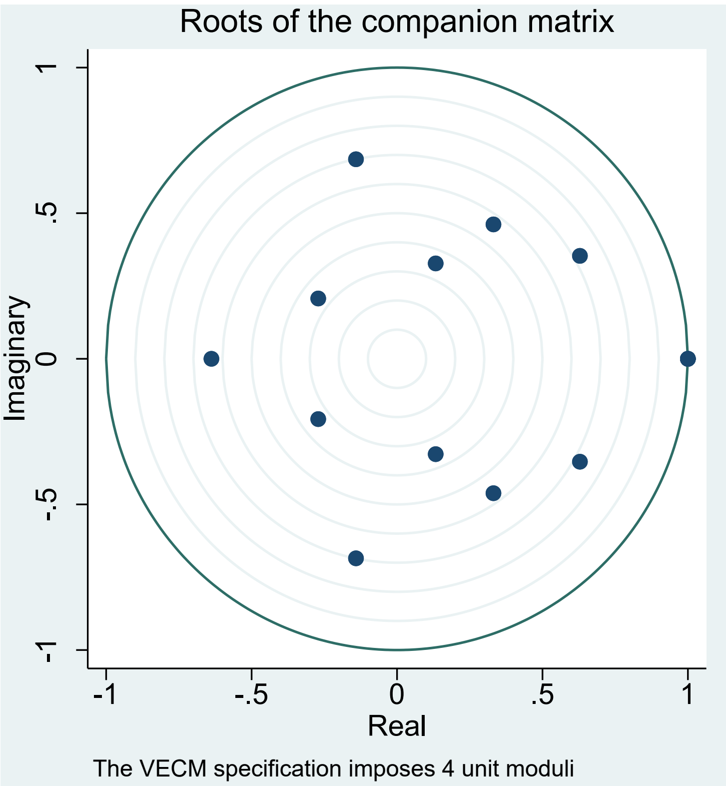

Figure 2. VECM Stability test. **Source**: Authors, based on data from the World Bank (World Bank, 2023) and the Global Ecological Footprint Network (Global Footprint Network, 2023).

4.7. Discussions

The empirical results of this study show that increasing the value added of the tertiary sector relative to GDP leads to a reduction in carbon dioxide emissions.

This is a major result that underlines the importance of the tertiarization of a country's economy in wealth production, and remains consistent with the findings of Kouton *et al.* (Kouton et al., 2024) and Senzele (Senzele, 2022). Thus, the greater the importance of tertiary activities in a country's wealth production, the fewer CO_2 emissions there are, and therefore the less air pollution there is. On the other hand, per capita gross domestic product has a negative effect on carbon dioxide emissions. There are two reasons for the negative effect of per capita income on CO_2. The first is that economic growth in developing countries is driven more by tertiary activities, which contribute more to growth. Empirical research by Awad (Awad, 2021) has shown that the structural transformation of economies in underdeveloped countries is mainly due to the migration of labor from the agricultural sector to the service sector. The second reason is linked to the use of per capita income in developing countries. This income is used more by households for consumption expenditure on goods and services, housing expenditure, healthcare expenditure, etc. This result is in line with that of Keho (Keho, 2015). The positive effect of the labor force (active population) used in the Togolese economy on CO_2 emissions could be explained by the dynamics of their fuel consumption. Indeed, with a fast-growing population and rapid urban development, workers generally use two or four-wheeled vehicles that consume fossil fuels to get to their place of work. What's more, given their low incomes, Togolese workers generally opt for older vehicles when purchasing a means of transport, which are cheaper but consume more fuel. According to a diagnostic report (SSATP, 2019)[3] on sustainable mobility and accessibility policies in Togolese cities, the number of private cars (excluding two-wheelers) in circulation in Togo in 2015 was estimated at 140,000 units, or 19 cars/1000 inhabitants. And this rate has grown exponentially since 2005 (+7% between 2005 and 2010, then +30% between 2010 and 2015). This rate is higher in Togo than in neighboring countries such as Burkina Faso and Mali, which have more than twice the population of Togo. Furthermore, these factors of the capital component of the workers' share combined with the technological effect or the productivity rate improve the impact on CO_2. In this respect, the capital used is increasingly clean, as is technology, which justifies its negative effects outweighing the positive effect of labor. The effect of investment measured by gross fixed capital formation on CO_2 emissions is insignificant.

Comparative analysis of Togo's results with those of studies such as Kouton et al. (2024), who worked on the case of Ivory Coast, reveal the same similarity as that of Ivory Coast in terms of the service sector's high share of value added in GDP and the improvement in the rise of tertiary activities in reducing CO_2 emissions. Thus, the relationship between the tertiarization of activities and environmental quality in Togo is the same as in Côte d'Ivoire. An analysis of the added value of the agricultural, industrial and service sectors in WAEMU countries reveals that these countries have the same economic structure, i.e., the service sector

[3]The Southern Africa Transport Policy Program (SSATP) is an international partnership aimed at facilitating policy development and related capacity building in the African transport sector.

is the biggest contributor to growth, and the workforce migrates more to this sector, to the detriment of the others. This already gives us an intuition of the relationship between the tertiarization of activities and the quality of the environment that may exist in these countries. Empirical studies are needed in these other countries to confirm exactly the similar relationship found in Togo and Côte d'Ivoire.

5. Conclusion

This study attempted to empirically examine the effect of increasing tertiary activities in GDP on carbon dioxide (CO_2) emissions in Togo over the period 1980 to 2022. Given the presence of unit root and cointegration in the series, we used a vector error correction method (VECM) and a dynamic ordinary least squares (DOLS) modelling procedure proposed by Stock & Watson (1993) to check the robustness of the results. Indeed, DOLS estimation is a robust approach that corrects for the endogeneity of explanatory variables by incorporating initial values and first-difference lags of these variables, as well as serially correlated errors. It improves ordinary least squares (OLS) estimates by taking into account dynamic sources of bias and small sample sizes. In this study, environmental quality was measured by the emission of carbon dioxide into the atmosphere.

The results show that there is a cointegrating relationship between the value added of tertiary activities to GDP and carbon dioxide emissions. The increase in tertiary activities reduced CO_2 emissions. This result shows that the more a country's wealth is based on the predominance of tertiary sector activities, the less CO_2 is emitted, and therefore the less the atmosphere is polluted. The results also show that the level of per capita income has a significant negative impact on carbon dioxide emissions. Labour capital, as measured by the working population, has a positive and significant influence on carbon dioxide emissions. This is due to its importance in a country's production process. The use of labor in an economy increases the country's wealth, while at the same time polluting the atmosphere.

This study contributes to the economic literature by providing empirical data on the value added of the tertiary sector influencing environmental quality in Togo, highlighting the importance of tertiary activities in achieving sustainable development goals. The results suggest that policymakers should prioritize the service sector by promoting the growth of activities in this sector to improve environmental quality. This must be done with an eye to other sectors, so that they are not neglected. We also need to define a national low-carbon strategy (SNBC), as in the case of France, which adopted this strategy by decree in April 2020. This strategy sets out guidelines for reducing the carbon footprint and emissions of other pollutants in all sectors of activity. It is also necessary to create a High Council for Climate (HCC) to steer climate policy and evaluate the implementation of the SNBC.

While this study provides essential insights into the dynamics of tertiary activities affecting environmental quality in Togo, other future studies could focus on the link between the expansion of service sectors such as renewable energies and environmental sustainability.

Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this article.

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