World Journal of Agricultural Research, 2017, Vol. 5, No. 1, 9-20
Available online at http://pubs.sciepub.com/wjar/5/1/3

DOI:10.12691/wjar-5-1-3

Econometric Modeling of the Epidemic Cost of Cape Saint Paul Wilt Disease on Coconut Cultivation in Ghana: A Case Study of MYD x VTT Hybrid Coconuts

Danyo G.[1,*], M.A. Anyiwe[2], Q.E. Osemwegie[3]

[1]Plant Protection Division, Coconut Research Programme, Oil Palm Research Institute, P. O. Box 245, Sekondi, Ghana
[2]Department of Economics and Statistics, University of Benin, Benin City, Edo State, Nigeria
[3]Agricultural Economics Division, Nigerian Institute for Oil Palm Research, P.M.B. 1030, Benin City, Edo State, Nigeria
*Corresponding author: bertdanyo@gmail.com

Abstract Cape Saint Paul Wilt Disease has destroyed several thousands of hectares of coconut plantings in the main coconut producing regions of Ghana namely, Western, Central, and Volta Regions. The capacity of the disease to decimate coconut populations in active disease foci threatens the coconut industry rehabilitation programmes in Ghana. This study critically evaluates the effect of Cape Saint Paul Wilt Disease on coconut yield, and verifies economic cost of the disease on coconut cultivation in Ghana, using robust econometric models and statistical analytical tools. Disease data from selected Coconut Sector Development Project's Malayan Yellow Dwarf x Vanuatu Tall hybrid coconut farms spanning eight consecutive years (2008-2015) were used for this important study. Ordinary least squares regression of the data indicates, the disease has significant effect on coconut yield and that expected annual yield of diseased palms and price per unit nut are significant determinants of the economic cost of Cape Saint Paul Wilt Disease on coconut cultivation in Ghana. The disease can cause 100% crop losses if appropriate containment strategies are not implemented in time. These findings confirm the assertion of Danyo that, Cape Saint Paul Wilt Disease of coconut has a significant economic cost. An assertion corroborated much later by Osemwegie. However, compared to the latter, the economic cost of CSPWD on coconut yield is lesser; accentuating the knowledge that hybrid coconuts are less susceptible to the CSPWD than the pure lines.

Keywords: *coconut, cape saint paul wilt disease, epidemic cost, econometric modeling*

Cite This Article: Danyo G., M.A. Anyiwe, and Q.E. Osemwegie, "Econometric Modeling of the Epidemic Cost of Cape Saint Paul Wilt Disease on Coconut Cultivation in Ghana: A Case Study of MYD x VTT Hybrid Coconuts." *World Journal of Agricultural Research*, vol. 5, no. 1 (2017): 9-20. doi: 10.12691/wjar-5-1-3.

1. Introduction

Coconut (*Cocos nucifera* L) exists throughout the humid intertropical zone, but it is mostly grown along the coasts [1]. It is planted up to a height of 1 000 metres above sea level. The economic life span is estimated at 50 years, but the plant can live for more than a century. The palm is variously referred to as: 'tree of life', 'tree of paradise', 'symbol of the tropics', 'milk bottle at the door step of mankind', tree of a thousand uses', etc. [1].

Although, there are several varieties and hybrids of coconut in cultivation across the world, the exact origin of the coconut palm is unknown. The palm is believed, however, to be disseminated by fruits floating on sea currents and much later, by human migration. The coconut palm is believed to have been brought to West Africa by the Portuguese missionaries some 500 years ago [2].

Few plants are as versatile as the coconut (tree of a thousand uses). Every part of the coconut palm; from the roots to the fronds and the many value-added products from them is useful to man. The coconut endosperm (meat) is a source of food and nutritional supplement for body fluids and minerals, particularly potassium. The liquefied endosperm is a medium for *in-vitro* storage of seeds and also a growth regulator of plants [4]. The dehydrated endosperm, copra, is an important source of oil used for food and in premium cosmetics and pharmaceutical industries. Coconut cake from extracted gritted copra is used as animal feed especially in pig farming.

The coconut shell is used directly as fuel, filler, and extender in the synthesis of plastics and produces activated charcoal, household articles and artifacts, numerous distillation products such as tar, wood-spirit and pitch. The coconut coir, a coarse fibre from the coconut husk has many important domestic (such as bristles, brushes, and foot mats) and industrial (twines and ropes in the haulage and shipping operations) utility.

Medical experts claim coconut is important in the clinical treatment of asthma, baldness, bruises, burns, colds, constipation, cough, dropsy, dysentery, fever, flu, gonorrhea, menstrual pains, kidney stones, malnutrition, nausea, rash, skin infections, sore throat, stomach, typhoid, ulcers and tuberculosis, among others [5]. Brewed coconut root is used in folk medicine, for example, as a cure for dysentery.

Agro-forestry uses of the coconut palm include coastal stabilization and windbreaks. Horticulturally, the palm is used to beautify landscapes and homes. The fronds are also used for roofing, fencing, matting and the shell for industrial products and craft items. In fact, the economic uses of the coconut palm, is almost inexhaustible. The flow chart (Figure 1) succinctly depicts the versatility and the global economic importance of the coconut palm.

In Ghana, an estimated 5.35% of Ghana's population (estimated at 28 million as at October, 2016) depends on coconut for their livelihood. It is cultivated both as cash crop and as food crop. Its cultivation, processing and marketing, offers employment opportunities to disadvantaged groups such as the landless poor, street children and rural women.

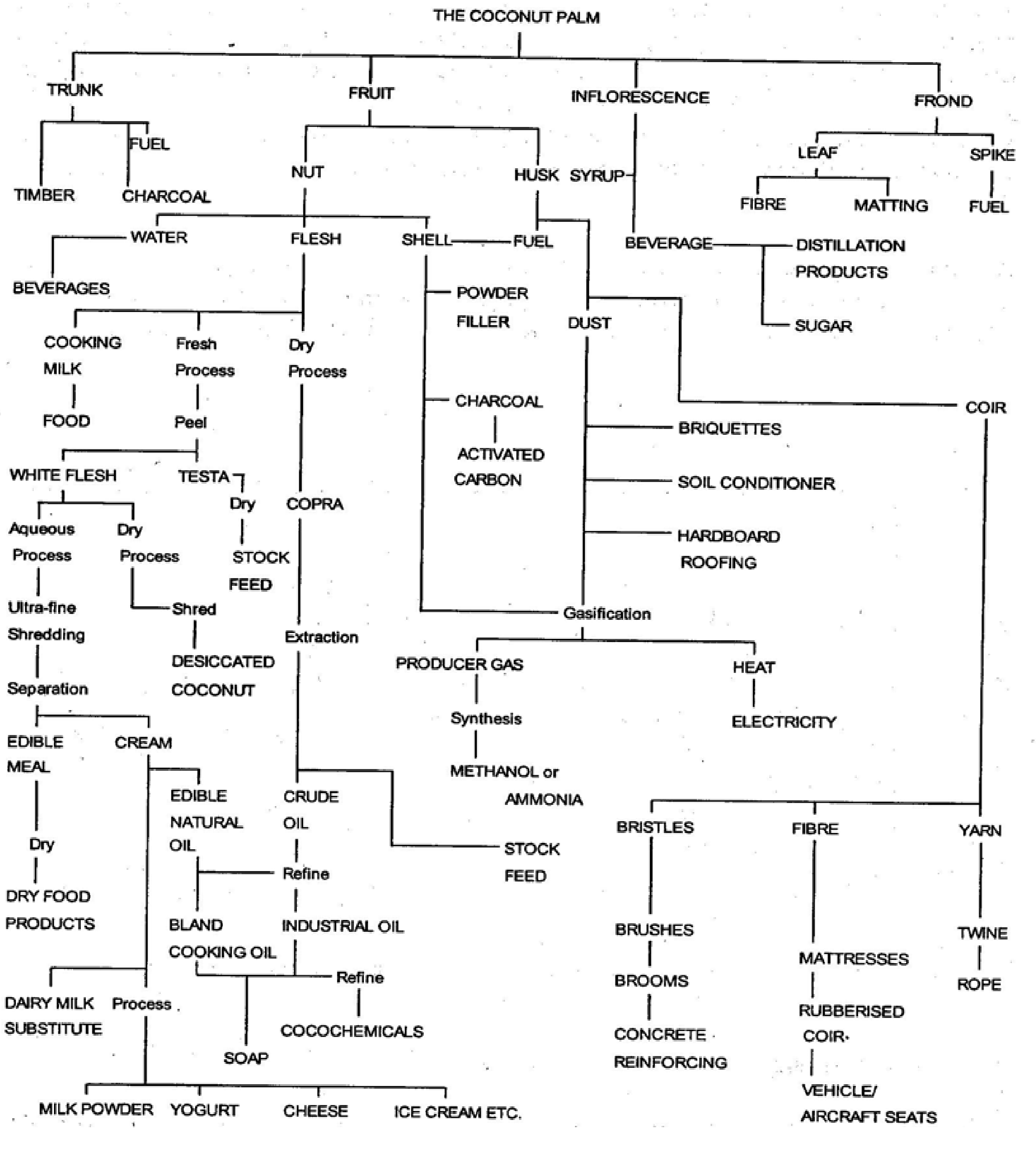

Figure 1. Potential products from the coconut palm [2] (Source: Anonymous)

Figure 2. (A)Cell wall-less pleomorphic bacteria (B) Putative Vector (C) Diseased Palms

Lethal yellowing (LY) is a disease that affects about 40 species of palm world-wide. Many of the disease symptoms are caused by plant pathogens called phytoplasmas. Phytoplasmas are cell wall-less and phloem-limited organisms that can neither be cultured *in-vitro* or viewed by light microscopy [6]. They are transmitted by insect vectors (Figure 2B). Phytoplasmas are generally present in the sieve tubes of host plants and in the salivary glands of insect vectors. Known vectors of phytoplasma diseases are species of leafhoppers, plant hoppers and psyllids (Tsai, 1979).

A planthopper, *Myndus crudus* van Duzee (Homoptera: Cixiidae), had been shown to be the vector of lethal yellowing disease in Florida (Howard et al. 1983). *M. crudus* was also found to transmit the palm lethal disease responsible for the decline of the Christmas palm *Veitchia* sp. (Howard et al., 1980). *Myndus* species has been found to be the vector of foliar decay of coconut in Vanuatu (Julia, 1982). Yet, to date, the vector(s) of the phytoplasma responsible for coconut lethal yellowing-like disease in West Africa is unknown (Philippe, 2007).

The Ghanaian form of lethal yellowing-like disease (LYD) of coconut is known as the Cape Saint Paul Wilt Disease (CSPWD). The disease was first recorded in Ghana in 1932 at Cape Saint Paul, Woe, in the Ketu-South district of the Volta Region, hence the local name. The disease is caused by *Candidatus phytoplasma palmicola,* and transmitted by insects. The symptoms include: pre-mature nut drop with or without yellowing of fronds. This is followed by progressive yellowing or, sometimes browning of the crown from the older fronds at the base of the crown to the younger fronds up crown. Eventually, the whole crown turns yellow, dries up and then falls off, leaving only the stipe standing. In some of them, including the MYD x VTT hybrids, the leaves may take a bronze colouration instead of yellow [7].

The history, occurrence, and epidemiology of the disease in Ghana have widely been reported by Addison (1974, 1978), Ofori and Nkansah-Poku (1995), and Dery et al. (1999). Attempts by Researchers to find a cure to the disease have been going on for decades. For instance, in 1942, investigations into the nature, causes and control of the disease, was initiated by the Crops Research Institute (CRI) of Ghana. But there was no breakthrough at that time (Chona and Andoh, 1970).

There still no cure for the disease presently. Limited prevention is achieved through breeding coconut germplasms for CSPWD-resistance/tolerance and by the adoption of farm hygiene. Control of disease spread is by felling of diseased palms, immediately upon confirmation of visual diagnosis by Polymerase Chain-Reaction (PCR) assay [3].

Several thousands of hectares (about 12 000 Ha) of coconut plantings in the main coconut producing regions namely, Western, Central, and Volta Regions have been devastated by the disease, and it is still spreading [7]. Between April 1999 and the end of 2004, 1,300 hectares of Malayan Yellow Dwarf × Vanuatu Tall (MYD x VTT) hybrids coconuts on 1,012 farms were planted in the Central (360 ha) and Western (940 ha) regions as part of a project assigned to the Coconut Sector Development Project (CSDP) with funding from Agence Française pour le Développement (AFD). The MYD × VTT hybrid had been recommended for the replanting (rehabilitation of CSPWD-devastated coconut plantations) project because of its good agronomic performance and assumed resistance to CSPWD. It subsequently proved susceptible to the disease.

A new coconut hybrid developed from a genetic cross between the Sri Lanka Green Dwarf (SGD) and the Vanuatu Tall (VTT) parents have under experimental conditions, proven more resistant to the CSPWD than all hybrids tested so far. The superiority of this hybrid is established, both by resistance values from a predictive additive genetic model (GLM) and observed/ actual field data on CSPWD tolerance/resistance. The hybrid has since 2008, been released to coconut farmers for large scale cultivation in Ghana (replacing the MYD x VTT hybrids).

Nevertheless, the MYD x VTT hybrid coconuts still constitute about 60 % of all commercial varieties in the Western and Central regions of Ghana. These farms were used for the CSPWD epidemic survey to select diseased coconut farms for this econometric analysis.

1.1. Objective

A healthy plant is one capable of optimum growth (efficient utilization of soil resources), reproduction and yield leading to significant economic gains to the farmer. A plant disease is a deviation from normal functioning of physiological processes, and as a consequence, inhibits optimum growth, reproduction and yield of plants. Theoretically therefore, Cape Saint Paul Wilt Disease (CSPWD) of coconut must result in losses in yield, palm population, the expenditure of money, time and efforts for cultivation. That is to say, the disease causes economic injury and therefore, has economic cost.

The research imperative is to empirically determine the economic cost of CSPWD epidemic and ascertain its impacts on coconut cultivation in Ghana, to constitute a strong basis to compel a comprehensive integrated management of CSPWD epidemiology in Ghana. The specific objectives of this study therefore, are:

1. To evaluate the effect of Cape Saint Paul Wilt Disease on coconut yield, so as to determine the economic cost of the disease epidemic on coconut cultivation in Ghana;
2. To verify significance of the economic cost of Cape Saint Paul Wilt Disease of coconut in Ghana, using robust econometric models and statistical analytical tools.

2. Background

Cape Saint Paul Wilt Disease (CSPWD) completes its cycle within six months from the date of manifestation of first symptoms [3]. Under normal physiological and growth conditions, a mature coconut palm produces one inflorescence per month. A fruiting diseased palm aborts on the average 8 buttons per opened inflorescence per month, depending on the stage and severity of the disease. This will amount to 48 coconut buttons per palm per CSPWD cycle, all things being equal. The standard standing crop (number of palms per hectare) is 160 coconut palms per hectare (for MYD x VTT hybrids). At a conservative CSPWD infection rate of 5%, 8 fruiting palms per hectare will have been affected, giving a total of 384 coconut buttons per CSPWD cycle (i.e. 8 buttons x 8 diseased palms x 6 month-disease cycle). A mature fresh coconut fruit costs approximately GHC 1.20. Therefore, 384 mature fresh fruits will cost GHC 1.20 x 384 = GHC 460.80 (or 111.52 USD) per hectare per disease cycle. The estimated economic cost (EC) at different infection rates is presented in Table 1.

An estimated 5.35% of Ghana's population (estimated at 28 million as at August, 2016) depends on coconut for their livelihood. Assuming half or 2.67% are direct coconut farmers, each cultivating at least 1ha coconut farm, the computed financial loss will be 749,000 farmers x GHC 460.80 per hectare per disease cycle. That is a whooping GHC 345 139 200 (USD 90 532 900 at 1USD: 4GHC rate of exchange). The socioeconomic cost is dire considering the fact that, loss of coconut palm to CSPWD is not just the fruits or their derivatives but also cost of labour and man-hours employed in the production process.

3. Material and Methods

A questionnaire survey of the CSDP MYD x VTT hybrid coconut farms was conducted to obtain information on every farm. Categories of data included: farm identity, hydrography, topography, soil properties, agronomic and ecological condition, and disease situation around the farm. The survey covered six districts: two in the Central Region (Abura-Asebu-Kwamankese, and Komenda-Edina-Ebrim-Aguafo), and four in the Western Region (Nzema East, Wassa West, Ahanta West, and Shama Ahanta East Metropolis, SAEMA).

Each of the six agricultural technical officers (T.O.) was assigned one administrative district within a region. Each farm was visited by a technical officer; to spot the precise geographical location with a hand-held Global Positioning System Receiver (Garmin GPS 60). Phytosanitary data including total number of coconut palms planted and the number diseased were collected in addition to the questionnaire. Figure 3 shows the spatial distribution of diseased MYD x VTT hybrid coconuts farms of the CSPD in the Western and Central regions of Ghana.

3.1. Study Area

At the end of the phytosanitary survey of the CSDP MYD x VTT hybrid coconut farms in 2007, 45 hectares (Western region, 27 ha and Central region, 18 ha) were found diseased (Table 2). About a third (16 ha) of these diseased farms were used for the econometric analysis of the economic cost of Cape Saint Paul Wilt disease of coconut (Table 3).

Table 1. Economic Cost of CSPWD of Coconut at Different Epidemic Rates (%)

No. of Palms Per Hectare	Rate of Infection	Diseased Palms Per Hectare	Aborted Nuts Per Disease Cycle	Price Per Unit Nut	Economic Loss (GHS)
160	1	2	96	1.20	115.20
160	5	8	384	1.20	460.80
160	10	16	768	1.20	921.60
160	20	32	1 536	1.20	1 843.20
160	50	80	3 840	1.20	4 608.00
160	100	160	7 680	1.20	9 216.00

Price per Unit Nut: Average of farm gate and open market prices of fresh nut as at 31 August, 2016. Source: Authors'.

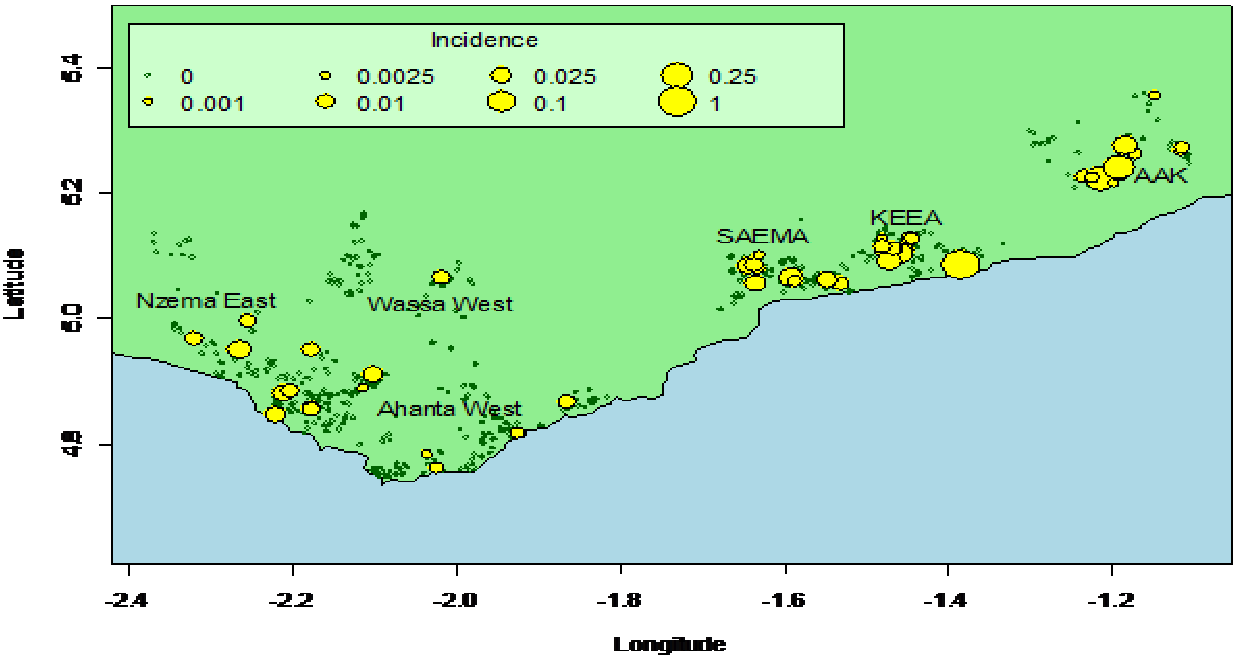

Figure 3. Spatial distribution of CSDP farms infected by CSPWD in the Western and Central Region of Ghana (2007). Each yellow circle represents an infected farm [9]

Table 2. Phytosanitary audit on the 1 300 ha CSDP MYD x VTT hybrid farms in 2007

Region	Healthy Farms (ha)	Diseased Farms (ha)	Neglected Farms (ha)	Unsurveyed Farms (ha)
Western	868	27 (3.11 %)	81	45
Central	342	18 (5.26 %)	24	0
Total	1,210	45 (3.72 %)	105	45

N.B.: A diseased farm is a farm in which there is at least, one diseased coconut palm. (*) Percentage Diseased Farms.

Table 3. Annual CSPWD incidence, Coconut Yield and Price per Unit Nut of MYD x VTT Hybrid Coconuts for the Indicated Period (2008-2015)

Year	Total No. of palms	No. of diseased palms	Coconut yield	Price per Unit nut (GHC)
2008	1 404	57	161 907	0.70
2009	1 347	79	143 115	0.70
2010	1 268	93	130 316	1.00
2011	1 175	57	128 605	1.00
2012	111	75	122 814	1.20
2013	1 043	65	112 814	1.20
2014	978	84	103 678	1.50
2015	894	109	92 196	1.50

3.2. Study Design

The degree of Cape Saint Paul Wilt Disease (CSPWD) incidence and severity among the Malayan yellow dwarf x Vanuatu tall (MYD x VTT) hybrid coconuts of the Coconut Sector Development Project were used for the research study.

3.3. Study Duration

The study analyzed CSPWD epidemic data on MYD x VTT hybrid coconut farms in the Western and Central regions of Ghana from 2008-2015 research year of the Coconut Research Programme Division of the Oil Palm Research Institute (Table 3).

3.4. Data Collection

On-field assessment of diseased palms was by visual observation of palms according to the known symptoms described in the introduction. Field data were taken through monthly field visits. Visual diagnosis was confirmed by subjecting suspect diseased palms to Polymerase Chain Reaction (PCR) assay. Table 3 shows the annual incidence of CSPWD in MYD x VTT hybrid coconut palms of the CSDP for the indicated period.

3.5. Data Analysis

Sampled epidemic data were analysed using Eview 8 software. The economic model was estimated using Ordinary Least Squares (OLS) method.

3.6. Model Specification

Raw data from epidemic studies are difficult to interpret and use, unless they can be synthesized into a quantitative relationship, commonly a model [8]. A model is a simplification of reality, usually focusing on a particular aspect of the whole. It may be descriptive, predictive, or conceptual. The model used for this study was proposed recently by Osemwegie, Anyiwe and Odewale (2016) to consider the economic cost of lethal yellowing disease (LYD) on coconut yield in Nigeria. Following the model with slight modifications, this study specifies the following relationships to investigate the economic cost of Cape Saint Paul Wilt Disease (CSPWD) on coconut yield in Ghana.

3.6.1. Linear Models

Model 1.1: Economic Cost (EC); EC = f (EAYDP, PUN, RDPTNP)

Model 1.2: Actual Coconut Output (AO); AO = f(NHP, NDP, PUN).

3.6.2. Non-Linear Models (Logarithm)

Model 2.1: Log of Economic Cost, LNEC = f(LNEAYDP, LNPUN, LNRDPTNP).

Model 2.2: Log of Actual Coconut Output, LNA = f(LNNHP, LNNDP, LNPUN), where:

EC = Economic cost;

EAYDP = Expected Annual Yield of Diseased Palms;

PUN = Price per Unit Nut;

RDPTNP = Ratio of Diseased Palms to Total Number of Palms;

AO = Actual Output of Coconut Palms;

NHP = Number of Healthy Palms;

NDP = Number of Diseased (CSPWD) Palms.

In econometric form, the models are expressed as follows:

$$EC_t = \alpha_o + \alpha_1 EAYDP_t + \alpha_2 PUN_t + \alpha_3 RDPTNP_t + U_{1t} \quad (1)$$

$$AO_t = \beta_0 + \beta_1 NHP_t + \beta_2 NDP_t + \beta_3 PUN_t + U_{2t} \quad (2)$$

$$\begin{aligned} \text{Ln } EC_t = a_o + a_1 \ln EAYDP_t + a_2 \ln PUN_t \\ + a_3 \ln RDPTNP_t + U_{3t} \end{aligned} \quad (3)$$

$$\text{Ln } AO_t = b_0 + b_1 \ln NHP_t + b_2 \ln NDP_t + b_3 \ln PUN_t + U_{4t} \quad (4)$$

where:

U_{it} is stochastic error term;

$\alpha_{1,}$ α_2 and $\alpha_{3\ >\ 0;}$ $\beta_{\ 1}$ and $\beta_{3\ >}0$, $\beta_{2<}$ 0; α_i' and b_i' are elasticities.

From *a priori* consideration, an increase in expected annual yield of diseased palms, price per unit nut and the ratio of diseased palms to total number of palms are expected to increase economic cost (EC); while increase in the number of healthy palms and price per unit nut will increase output but increase in the number of diseased palms is expected to decrease actual coconut output (AO).

3.7. Estimation Technique

The Ordinary Least Squares (OLS) econometric technique is adopted for the estimation of the models of this study. The test for multicollinearity is carried out using correlation matrix and the presence of multicollinearity is checked by using the first difference values of the variables for re-estimation.

4. Results and Discussion

The Descriptive Statistics of the variables used for the models of this study (Table 4) show that, the mean of Economic cost (EC) over the sample period is 10156.30 GHC (Ghana Currency) with a standard deviation of 4767.64 and the mean of the Number of Diseased Palms (CSPWD) is 77.37 with standard deviation of 18.04. The import of this is that, on the average, about 77 palms are infected annually in the sample-area of Ghana by Cape Saint Paul Wilt Disease (CSPWD) and as a result, Ghana incurs an economic cost of about 10156.30 GHC annually due to the impact of (CSPWD) on Coconut (*Cocos nucifera* L.) yield.The correlation matrix of the variables (Table 5) show high correlation coefficients (r > 0.5), implyingthat all the variables are highly (positively or negatively) correlated and this is an indicator of the problem of multicollineraity. The problem of multicollinearity is addressed in this study by the use of first-difference forms of the variables used in the models and the results are reported in Table 7. Regression results for the four models of this study are reported in the Table 6.

The four models recorded adequate goodness of fit (R^2) of above 97 percent each and the F-statistics (Fstat) which indicate the adequacy of models are found to be significant at 1 percent level of significance. By implication, the three independent variables in each model have explained over 97 per cent of the systematic variations in Economic Cost (EC) and Actual Output (AO), both in the linear and log-linear models.

In the linear models (1.1 and 1.2), the *a priori* expectations are upheld, implying that increases in Expected Annual Yield of Diseased Palms (EAYDP), Price per Unit Nuts (PUN) and Ratio of Diseased Palms to Total Number of Palms (RDPTNP) will bring about increases in Economic Cost (EC) arising from the impact of CSPWD on coconut yield in Ghana. The Price per Unit Nut (PUN) and Ratio of Diseased Palms to Total Number of Palms (RDPTNP) are found to be significant explanatory variables of Economic Cost at 5% and 20% respectively in Model 1.1, (as reported in Table 6). The results show that unit changes in PUN and RDPTNP will bring about 6331 and 874 unit changes in Economic Cost respectively.

The Remedial Model 1.1R (Table 7) also confirms that PUN and RDPTNP are positively and significantly related to Economic cost, indicating 1% and 5% levels of significance respectively. The results therefore, suggest that the Price per Unit Nut (PUN) and Ratio of Diseased Palms to Total Number of Palms (RDPTNP) are positive and significant determinants of Economic cost. In terms of Actual Output (AO) of coconuts in Ghana, increases in the Number of Healthy Palms (NHP) and Price per Unit Nut (PUN) will elicit increases in Actual Output, while increases in the Number of Diseased Palms (NDP) will reduce Actual Output (AO) as indicated by the signs of the regression coefficients.Only Number of Healthy Palms (NHP) is, however, found to be significant at 5% level of significance.

The results (Model 1.2) show that a unit increase in NHP will bring about 122.92 units increase in Actual Output. The Remedial Model 1.2R also confirms similar results in terms of *a priori* signs but Number of Healthy Palms (NHP) was only significant at 20% level of significance. The indication here is that, while the Number of Healthy Palms (NHP) positively and significantly determines the Actual Output of coconuts, the Number of Diseased Palms (NDP) and Price also affect the output, though insignificantly.

The Log-Linear (or Constant Elasticity) Models (2.1 and 2.2) in Table 6 show that the *a priori* expectations for signs are correct for the variables except for LNRDPTNP in Economic Cost model and LNPUN in Output model. But these variables turned out to be insignificant at 5% level thereby reducing their relevance. In Model 2.1, LNEAYDP and LNPUN are positive and significant explanatory variables for the log of Economic Cost at 1% level of significance. As the results indicate, the elasticity of Economic Cost (EC) with respect to EAYDP and PUN are about 1.00 each; suggesting that if Expected Annual Yield of Diseased Palms (EAYDP) or Price per Unit Nut (PUN) goes up by 1% on the average, then Economic Cost (EC) will go up by 1.00% on the average. Thus, Economic Cost (EC) is significantly responsive to changes in EAYDP and PUN by equal amounts or proportions (unitary elasticity) in the same direction.

Table 4. Descriptive Statistics of Variables

STAT	EC	EAYDP	PUN	RDPTNP	AO	NHP	NDP
Mean	10156.30	8933.37	1.10	6.97	124399.30	1076.00	77.37
Median	9646.50	8888.50	1.10	6.47	125709.50	1080.50	77.00
Maximum	19129.50	12753.00	1.50	12.19	161907.00	1347.00	109.00
Minimum	4788.00	6555.00	0.70	4.05	92196.00	785.00	57.00
Std. Dev.	4767.64	2047.66	0.32	2.53	22099.89	189.12	18.04
Skewness	0.77	0.59	-3.33E-16	1.03	0.22	-0.08	0.44
Kurtosis	2.56	2.53	1.78	3.34	2.32	1.94	2.20
Jarque-Bera	0.86	0.54	0.50	1.46	0.22	0.38	0.47
Probability	0.65	0.76	0.78	0.48	0.90	0.83	0.79
Sum	81250.40	71467.00	8.80	55.83	995194.0	8608.00	619.00
Sum Sq. Dev.	1.59E+08	29350442	0.68	44.81	3.42E+09	250368.0	2279.87
Observations	8	8	8	8	8	8	8

Source: Eview 8 Result Outputs of Analyses of Sample Data.

Table 5. Correlation Matrix for Variables

Model 1.1: Correlation of Variables (Test for Multicollinearity)				
Variables	**EC**	EAYDP	PUN	RDPTNP
EC	1.00	0.87	0.90	0.98
EAYDP	0.87	1.00	0.59	0.94
PUN	0.90	0.59	1.00	0.80
RDPTNP	0.98	0.94	0.80	1.00
Model 1.2: Correlation of Variables (Test for Multicollinearity)				
Variables	**AO**	NHP	NDP	PUN
AO	1.00	0.99	-0.62	-0.95
NHP	0.99	1.00	-0.57	-0.97
NDP	-0.62	-0.57	1.00	0.55
PUN	-0.95	-0.97	0.55	1.00

Table 6. Regression Results for the Four Models

Model 1.1							
Dependent Variable	Independent Variable	Coefficient	t-Stat	Probability	R^2	F-stat	DW
EC	Constant	-6935.36	-3.39^{+}	0.03			
	EAYDP	0.45	1.13	0.32			
	PUN	6331.49	4.16^{+}	0.01			
	RDPTNP	873.60	2.01^{ψ}	0.12			
	Test Statistics				0.99	225.85	2.18

Model 1.2							
Dependent Variable	Independent Variable	Coefficient	t-Stat	Probability	R^2	F-stat	DW
AO	Constant	-8934.49	-0.14	0.90			
	NHP	122.92	3.34	0.03			
	NDP	-103.60	-0.97	0.39			
	PUN	8254.43	0.37	0.73			
	Test Statistics				0.98	64.18	1.43

Model 2.1							
Dependent Variable	Independent Variable	Coefficient	t-Stat	Probability	R^2	F-stat	DW
LnEC	Constant	$-1.79E^{-11}$	-1.9217^{ψ}	0.13			
	Ln EAYDP	1.00	$7.9E^{+11*}$	0.00			
	LnPUN	1.00	$1.7E^{+12*}$	0.00			
	Ln RDPTNP	$-1.95E^{-12}$	-1.70^{ψ}	0.16			
	Test Statistics				1.00	$2.57E^{+25*}$	1.43

Model 2.2							
Dependent Variable	Independent Variable	Coefficient	t-Stat	Probability	R^2	F-stat	DW
LnAO	Constant	6.22	4.24^{+}	0.01			
	LnNHP	0.83	4.27^{+}	0.01			
	LnNDP	0.07	-1.23	0.28			
	LnPUN	0.06	-0.54	0.61			
	Test Statistics				0.99	95.47*	2.23

Notes: * shows 1% level of significance; + shows 5% level of significance; ψ shows 20% level of significance; all at two-tailed tests.

Table 7. Multicollinearity-Remedial Models with Variables' First Difference Form

Model 1.1R							
Dependent Variable	Independent Variable	Coefficient	t-Stat	Probability	R^2	F-stat	DW
DEC	Constant	-501.05	-1.69^{ψ}	0.17			
	DEAYDP	0.07	0.19	0.86			
	DPUN	9489.65	6.82*	0.00			
	DRDPTNP	1271.25	2.81^{+}	0.05			
	Test Statistics				0.99	121.78*	2.21

Model 1.2R							
Dependent Variable	Independent Variable	Coefficient	t-Stat	Probability	R^2	F-stat	DW
DAO	Constant	-1298.73	-0.28	0.79			
	DNHP	110.94	1.65^{ψ}	0.17			
	DNDP	-121.80	-1.14	0.32			
	DPUN	11706.8	0.80	0.47			
	Test Statistics				0.63	2.28	1.70

In the Log-linear Output Model (2.2), LNAO and LNNHP are found to be positively and significantly related (at 5% level); whereas LNNDP and LNPUN are negatively but insignificantly related to LNAO. The elasticity of Actual Output (AO) with respect to Number of Healthy Palms is 0.8327, which is less than one (inelastic). By implication a 10% increase in the Number of Healthy Palms (NHP) will bring about 8.3% increases in Actual Output. Thus, even though the Number of Healthy Palms (NHP) is a positive and significant determinant of Actual Output, the increases in the Number of Healthy Palms (NHP) would bring fewer amounts of increases in the output. This is quite informative, since it suggests that extra efforts or inputs may be needed for greater output. That is to say, higher total number of palms planted by farmers translates into greater prospects of higher yield. Similarly, higher unit prices of nuts imply higher income for the coconut farmers, thereby empowering them to better manage their farms (hire labour to weed farms and to harvest nuts; buy crop protection chemicals, etc.). At any rate, higher income from coconut cultivation on its own will motivate the farmers to increase cultivation since they see it as lucrative. The converse is true for higher number of diseased palms; corresponds to lower actual output of coconut, and therefore, lower income.

5. Conclusion

The coconut palm is not just of interest to millions of small holders, to whom it supplies food and drink, receptacles, fibres braided into rope, frond roofs, and even fuel for cooking, but also, of a global economic importance as a source of fats and oils and numerous industrial products. In summary, the following conclusions are made from the discussion of results above:

- That on the average, about 77 palms are diseased annually in the sample-area of Ghana arising from Cape Saint Paul Wilt Disease (CSPWD) and that Ghana incurs an economic cost of about 10156.30 GHs annually due to the impact of (CSPWD) on Coconut (*Cocos nucifera* L.) yield;
- That the Price per Unit Nuts (PUN) and Ratio of Diseased Palms to Total Number of Palms (RDPTNP) are positive and significant (at 5% and 20% respectively) determinants of Economic cost of the impact of (CSPWD) on Coconut (*Cocos nucifera* L.) yield in Ghana;
- In addition, it was found that Economic Cost (EC) is significantly responsive to changes in Expected Annual Yield of Diseased Palms (EAYDP) and the Price per Unit Nuts (PUN) by equal amounts or proportions (unitary elasticity) in the same direction;
- That while the Number of Healthy Palms (NHP) positively and significantly determines the Actual Output of Coconuts, the Number of Diseased Palms (NDP) and Price also affects the output, though insignificantly;
- That, even though the Number of Healthy Palms (NHP) is a positive and significant determinant of Actual Output, the increases in the Number of Healthy Palms (NHP) would bring fewer amounts of increases in the output, since it's elasticity is less than one which suggests that extra efforts or inputs are needed for greater output.

These findings confirm the assertion of Danyo (2011) that, Cape Saint Paul Wilt Disease (CSPWD) of coconut has a significant economic cost. An assertion corroborated much later by Osemwegie et al. (2016). However, compared to the latter (Osemwegie et al., 2016), the economic cost of CSPWD on coconut yield is lesser; accentuating the knowledge that hybrid coconuts are less susceptible to the CSPWD than the pure lines. The disease can cause 100% crop losses if appropriate containment strategies are not implemented timeously. Typically, if infected, a one-hectare coconut farm (160 coconut palms) can die out within two years of manifestation of first disease symptoms, if no control measures are at all carried out.

Poor economic returns from coconut production resulting largely from Cape Saint Paul wilt Disease have impoverished over 50 000 households that depend upon the coconut industry for their livelihoods, and is a major disincentive for maintenance of existing coconut farms, replanting ageing plantations as well as acquisition of improved disease-tolerant coconut hybrids for cultivation. The coconut palm is listed as an important crop in Ghana's Tree Crop Policy, but unless the menace of CSPWD is curtailed, the coconut industry faces a sure demise!

This affirms Cape Saint Paul Wilt Disease of coconut as an economic disease that must be contained, if not eradicated, to maintain the profitability of coconut cultivation and its competitive position on the vegetable oils market. This may be accomplished through aggressive scientific research, especially breeding coconut germplasms for CSPWD resistance/tolerance.

The government of Ghana and her donor partners need to do more by investing heavily in research efforts aimed finding a lasting cure to the disease. This is crucially important to the attainment of the Sustainable Development Goals (SDGs), especially Goal1 (eradication of poverty), and the developmental objectives specified in the Growth and Poverty Reduction Strategy II (GPRS II) and the Food and Agriculture Sector Development Policy II (FASDEP II) of Ghana consistent with ECOWAS Agriculture Policy and NEPAD's Comprehensive Africa Agricultural Development Programme (ECOWAP/CAAPD).

Having demonstrated empirically, the economic cost of CSPWD on coconut yield, further experimental studies are necessary (epidemiological studies) to estimate potential yield loses at different epidemic rates. This will facilitate the setting of reliable economic thresholds in the integrated management of CSPWD epidemic of coconut in Ghana.

Acknowledgements

The authors are grateful to the Coconut Sector Development Project (CSPD) and the French Agency for Development (Agence Française pour le Développement - AFD) for funding the original French Special Projects (FSP) on the epidemiology of Cape Saint Paul Wilt Disease of coconut in Ghana (2006-2009), from which the sequel study leading to this analysis is made.

Competing Interests

There are no competing interests.

Authors' Contributions

All authors read and approved the final manuscript

References

[1] Addison EA (1980). Varietal resistance screening trials with some dwarf coconut palms against the Cape St. Paul Wilt Disease in Ghana. Afr. J. Plant Prot., 1(2): 129-141.

[2] Ahiabor, G. Coconut: The Status Changer in Agbozume. Special Feature Article, *Daily Graphic, Tuesday, July 30, 2014:*pp. 40-41

[3] Bonnot, F., Danyo, G., Dery, S.K., Philippe, R., Arthur, R. (2009). Preliminary Results on the Epidemiology of Coconut Lethal Yellowing in Ghana. Oleaginaux Gras Lepides, Vol. 6 (2), (2009) pp. 116-122.

[4] Bourdeix, R., Konan, J.L., N'Cho, Y.P. Coconut: A guide to traditional and improved varieties. Editions Diversiflora, Barcelona, Spain, (2005). p. 104.

[5] Chatterjee, P.B. Plant Protection Techniques. Bharati Bhawan, Kadamkuan, India, (1997). pp. 133-158.

[6] Chona BL, Andoh PG (1970). Cape St. Paul Wilt - the present position.In: Chona B.L., and Adansi M. A. (eds). Coconut in Ghana. Bull No. 3; Crops Research Institute, CSIR-Ghana, p. 20.

[7] Danyo, G. Review of Scientific Research into the Cape Saint Paul Wilt Disease (CSPWD) of Coconut in Ghana. African Journal of Agricultural Research (AJAR) Vol. 6(19), (2011). pp. 4567-4578.

[8] Dery, S.K., Arthur, R. Rehabilitation of the coconut industry in Ghana: a strategy. Report submitted to the Western Region Deputy Minister for Agriculture. September (1996).

[9] Dollet, M., Quaicoe, R., and Pilet, F. Overview of the Lethal Yellowing Type Disease of Coconut: Diversity, Variability, and Diagnosis. Proceedings of the International Workshop on Lethal Yellowing Disease of Coconut, Accra, Ghana, June (2008). p. 8.

[10] Harries, H.C. Growing coconuts in Africa: resistance to Lethal Yellowing-like Diseases. In: Eden-Green, S.J., Ofori, F. (eds) (1997). Proceedings of an International Workshop on Lethal Yellowing-like Diseases of Coconut, Elmina, Ghana, November, 1995. NRI, Chatham, UK, (1995). p. 139.

[11] Howard FW, Norris RC, Thomas DL (1983). Evidence of transmission of palm lethal yellowing agent by a planthopper, Myndus crudus (Homoptera: Cixiidae). Trop. Agric. Trin., 60: 166-17.

[12] Iyoha MA. Applied econometrics, 2nd edition, Mindex Publishers, (99), (2003). pp, 139-140.

[13] Julia JF (1982). Myndus taffini (Homoptera: Cixiidae); vector of foliar decay of coconut in Vanuatu. Oleagineux, 40: 19-27.

[14] Ofori F, Nkansah-Poku J (1995). The Cape Saint Paul Wilt Disease of coconut in Ghana: history of its occurrence and spread. In: Eden-Green SJ, Ofori, F. (eds). Proceedings of an international workshop on lethal yellowing-like diseases of coconut, Elmina, Ghana. NRI, Chattam, UK, pp. 27-32.

[15] Osemwegie, Q.E., Anyiwe, M.A., Odewale, J.O. Econometric Analysis of the Economic Cost of Lethal Yellowing Disease (LYD) on Coconut (*Cocos nucifera* L.) Yield in LYD Endemic Area of Nigeria: A Case Study of Nigerian Institute for Oil Palm Research (NIFOR). American Journal of Experimental Agriculture, Vol. 11 (5), (2016). pp1-10.

[16] Philippe R, Nkansah-Poku J, Fabre S, Quaicoe R, Pilet F, Dollet M. (2007). Search for the vector of Cape St. Paul Wilt of coconut (coconut lethal yellowing) in Ghana. First international phytoplasmologist working group meeting, Bologna, Italy, 12-15 November 2007. Bull Insectol., 60(2): 179-180.

[17] Tsai JH (1979). Vector transmission of mycoplasma agents of plant diseases. In: The mycoplasmas III. Plant and Insect mycoplasmas. Ney York, San Francisco and London. Academic Press, p. 35.

[18] Woodroof, J.G. Coconut Production, processing, products. The AVI Publishsing Company, Inc. 1970: 241.

APPENDIX 1

RESULT OUTPUTS

MODEL 1.1: EC = ƒ (EAYDP, PUN, RDPTNP)
MODEL 1.2: AO = ƒ (NHP, NDP, PUN)
MODEL 2.1: LNEC = ƒ (LNEAYDP, LNPUN, LNRDPTNP)
MODEL 2.2: LNAO = ƒ (LNNHP, LNNDP, LNPUN)
DESCRIPTIVE STATISTICS OF VARIABLES

STAT	TNP	NDP	AO	EAYDP	PUN	EC	RDPTNP	NHP
Mean	1153.37	77.37	124399.3	8933.37	1.1000	10156.30	6.97	1076.00
Median	1146.50	77.00	125709.5	8888.50	1.1000	9646.50	6.47	1080.50
Maximum	1404.00	109.00	161907.0	12753.00	1.5000	19129.50	12.19	1347.00
Minimum	894.00	57.00	92196.00	6555.00	0.7000	4788.00	4.05	785.00
Std. Dev.	179.43	18.04	22099.89	2047.66	0.3116	4767.64	2.53	189.12
Skewness	0.0075	0.4394	0.2214	0.5907	-3.33E-16	0.7730	1.03	-0.0818
Kurtosis	1.75	2.20	2.3153	2.5328	1.7785	2.5635	3.34	1.94
Jarque-Bera	0.5163	0.4703	0.2216	0.5381	0.4973	0.8603	1.46	0.3823
Probability	0.7724	0.7904	0.8951	0.7640	0.7798	0.6503	0.48	0.8259
Sum	9227.00	619.00	995194.0	71467.00	8.8000	81250.40	55.83	8608.00
Sum Sq. Dev.	225375.9	2279.87	3.42E+09	29350442	0.6800	1.59E+08	44.81	250368.0
Observations	8	8	8	8	8	8	8	8

CORRELATION MATRIX FOR VARIABLES:

MODEL 1.1: CORRELATION OF VARIABLES (TEST FOR MULTICOLLINEARITY)

VARIABLES	EC	EAYDP	PUN	RDPTNP
EC	1	0.8727	0.8993	0.9765
EAYDP	0.8727	1	0.5901	0.9375
PUN	0.8993	0.5901	1	0.8002
RDPTNP	0.9765	0.9375	0.8002	1

MODEL 1.2: CORRELATION OF VARIABLES (TEST FOR MULTICOLLINEARITY)

VARIABLES	AO	NHP	NDP	PUN
AO	1	0.9869	-0.6205	-0.9543
NHP	0.9869	1	-0.5707	-0.9733
NDP	-0.6205	-0.5707	1	0.5536
PUN	-0.9543	-0.9733	0.5536	1

REGRESSION RESULTS

MODEL 1.1

Dependent Variable: EC
Method: Least Squares
Sample: 2008 2015
Included observations: 8

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-6935.364	2047.793	-3.386750	0.0276
EAYDP	0.451132	0.399685	1.128717	0.3221
PUN	6331.498	1523.812	4.155038	0.0142
RDPTNP	873.6058	435.4495	2.006216	0.1153

R-squared	0.994131	Mean dependent var	10156.30
Adjusted R-squared	0.989729	S.D. dependent var	4767.646
S.E. of regression	483.1713	Akaike info criterion	15.50547
Sum squared resid	933818.0	Schwarz criterion	15.54519
Log likelihood	-58.02189	Hannan-Quinn criter.	15.23757
F-statistic	225.8532	Durbin-Watson stat	2.177984
Prob(F-statistic)	0.000064		

MODEL 1.2

Dependent Variable: AO
Method: Least Squares
Sample: 2008 2015
Included observations: 8

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-8934.498	64719.34	-0.138050	0.8969
NHP	122.9281	36.83520	3.337246	0.0289
NDP	-103.6095	106.3858	-0.973904	0.3853
PUN	8254.439	22039.37	0.374532	0.7270

R-squared	0.979646	Mean dependent var	124399.3
Adjusted R-squared	0.964381	S.D. dependent var	22099.89
S.E. of regression	4170.892	Akaike info criterion	19.81650
Sum squared resid	69585357	Schwarz criterion	19.85622
Log likelihood	-75.26600	Hannan-Quinn criter.	19.54860
F-statistic	64.17540	Durbin-Watson stat	1.433619
Prob(F-statistic)	0.000771		

MODEL 2.1

Dependent Variable: LNEC
Method: Least Squares
Sample: 2008 2015
Included observations: 8

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.79E-11	9.33E-12	-1.921739	0.1270
LNEAYDP	1.000000	1.26E-12	7.96E+11	0.0000
LNPUN	1.000000	5.79E-13	1.73E+12	0.0000
LNRDPTNP	-1.95E-12	1.15E-12	-1.703542	0.1637

R-squared	1.000000	Mean dependent var	9.133142
Adjusted R-squared	1.000000	S.D. dependent var	0.459099
S.E. of regression	1.38E-13	Sum squared resid	7.66E-26
F-statistic	2.57E+25	Durbin-Watson stat	3.568379
Prob(F-statistic)	0.000000		

MODEL 2.2

Dependent Variable: LNAO
Method: Least Squares
Sample: 2008 2015
Included observations: 8

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	6.219111	1.466485	4.240827	0.0133
LNNHP	0.832743	0.195173	4.266687	0.0130
LNNDP	-0.069348	0.056382	-1.229980	0.2861
LNPUN	-0.060954	0.112388	-0.542352	0.6164

R-squared	0.986227	Mean dependent var	11.71735
Adjusted R-squared	0.975896	S.D. dependent var	0.178852
S.E. of regression	0.027767	Akaike info criterion	-4.023064
Sum squared resid	0.003084	Schwarz criterion	-3.983343
Log likelihood	20.09226	Hannan-Quinn criter.	-4.290965
F-statistic	95.47135	Durbin-Watson stat	2.231808
Prob(F-statistic)	0.000354		

REMEDIAL MODEL 1.1R: MULTICOLLINEARITY-REMEDIAL MODEL WITH VARIABLES FIRST DIFFERENCE FORM

Dependent Variable: DEC
Method: Least Squares
Sample: 2008 2015
Included observations: 8

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-501.0511	295.9103	-1.693253	0.1657
DEAYDP	0.070970	0.382094	0.185741	0.8617
DPUN	9489.654	1392.472	6.814968	0.0024
DRDPTNP	1271.252	452.4595	2.809649	0.0483

R-squared	0.989171	Mean dependent var	1792.688
Adjusted R-squared	0.981048	S.D. dependent var	3353.383
S.E. of regression	461.6420	Akaike info criterion	15.41431
Sum squared resid	852453.5	Schwarz criterion	15.45403
Log likelihood	-57.65724	Hannan-Quinn criter.	15.14641
F-statistic	121.7877	Durbin-Watson stat	2.205709
Prob(F-statistic)	0.000219		

REMEDIAL MODEL 1.2: MULTICOLLINEARITY-REMEDIAL MODEL WITH VARIABLES' FIRST DIFFERENCE FORM

Dependent Variable: DAO
Method: Least Squares
Sample: 2008 2015
Included observations: 8

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1298.736	4659.727	-0.278715	0.7943
DNHP	110.9480	67.09835	1.653512	0.1736
DNDP	-121.8040	106.4579	-1.144152	0.3164
DPUN	11706.82	14686.52	0.797113	0.4700

R-squared	0.630770	Mean dependent var	-8713.875
Adjusted R-squared	0.353847	S.D. dependent var	6115.863
S.E. of regression	4916.155	Akaike info criterion	20.14529
Sum squared resid	96674314	Schwarz criterion	20.18501
Log likelihood	-76.58118	Hannan-Quinn criter.	19.87739
F-statistic	2.277781	Durbin-Watson stat	1.698368
Prob(F-statistic)	0.221580		