Journal of Sustainable Development; Vol. 16, No. 3; 2023
ISSN 1913-9063 E-ISSN 1913-9071
Published by Canadian Center of Science and Education

Price Incentives and Supply Response in Cocoa -A Case of Border Regions of Ghana

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Received: February 2, 2023 Accepted: March 22, 2023 Online Published: March 24, 2023

doi:10.5539/jsd.v16n3p1 URL: https://doi.org/10.5539/jsd.v16n3p1

Abstract

Smuggling of cocoa between Ghana and its neighbouring producing countries such as Cote d'Ivoire and Togo is a frequent occurrence often to the advantage of the country posting higher producer price. Ghana is a net loser with regards to the smuggling of cocoa given relatively lower real producer price compared to its counterparts in production. Additionally, the close geographical location of key producing regions to the border lends support to such activities. This study investigates the supply response of cocoa in producing region such as Western North, Western South and Brong-Ahafo with proximity to Cote d'Ivoire and Volta which shares borders with Togo using data from 1981 to 2017. The study further estimates the volume of cocoa crop lost from these regions to the country's neighbours from 2000 to 2017. In the findings, relative price differences significantly impact the volumes of reported crop for the country with 1% higher price abroad driving down production volumes in Western North, South and Brong-Ahafo by 0.53%, 0.48%, and 0.11% respectively. In 2013/14 crop year the country lost averagely 25,494 MT and 21,883 MT due to smuggling out of Western North and South, moderating to 1,559 and 1,358 in 2016/17. The Volta region consistently records outflow in each crop year except for 1999/2000, with peak losses in 2010/11 of 2,160 MT moderating to 1,197 in 2016/17. Net gains into the country from cocoa smuggling spanning from 1999/2000 to 2016/17 is averagely 23,534 MT and 15,336MT into Western North and South. However cocoa smuggling for both Ghana and its neighbours is on the descent in recent years as price disparities reduce. Intensifying the collaboration between Ghana and its close counterparts to minimize real crop price differences will effectively curtail the menace and the negative fallout of this to each country.

Keywords: relative price, producer price, cocoa smuggling, illegal cross-border trade

1. Introduction

The agricultural sector offers enormous opportunities for improving Ghana's economic wellbeing despite the reducing weight of the sector in terms of its contribution to gross domestic product. Prioritizing agriculture offers significant opportunities for reducing poverty, ensuring food security and boosting growth (World Bank, 2017). The contribution of agriculture to Ghana's export revenues is largely dominated by cocoa and has remained pivotal to the countries strategies for development and poverty reduction (Vigneri & Kolavalli, 2018). Sustaining the cocoa industry is vital to livelihood enhancement in farming communities and economy wide growth. In this vein the industry is well regulated by Cocoa Board (COCOBOD) with yearly inputs and extensions, geared towards improving productivity. Despite such efforts production volumes remain low mostly below target due to agro-climatic and socio-economic factors. The price of the crop is a key socio-economic driver of production volumes, being a catalyst to effective farm management, input use and expansions in land cultivation. Pricing of cocoa domestically is set under the producer price review committee (PPRC) with the key objective of ensuring farmers receive stable and realistic price for their produce. Despite such interventions Amankwah-Amoah, Debrah & Nuertey (2018) points out cocoa producer prices in the country remain mostly lower than that of Cote d'Ivoire (CDV). This development incentivizes smuggling as it offers opportunities for higher rents for those close to the border especially if such differences are not accounted for by cost to trade but linked to tariffs and quantitative restrictions by governments (Metivier & Bouet, 2018; Ghoddusi, Rafizadeh & Rahmati, 2018; Golub, 2015).

Difference in crop price, more especially higher prices abroad affect realized volumes of cocoa domestically as growers close to the border divert some of their produce out of the country illegally (May, 1985). This fact though being established by studies such as Bulir (2002), fails to investigate the volume of crop losses from cocoa growing regions sharing border with CDV and Togo. The latest record of such an empirical investigation was undertaken by May in 1985 in which he tried to answer such a question for Brong-Ahafo and Volta region of Ghana. Why this research remains essential lie in the fact that current volume increase in cocoa comes from the Western region accounting for 55.5% of national output annually since 2000/2001 crop year to 2016/17. However, the region is not able to fully realize its full potential in terms of output. Which necessitate some research aimed at identifying the key factors that may be mitigating against the full realisation of the potential of this region. Also, even though May (1985) might have modeled smuggling in Volta region, the study was not able to provide estimates of smuggling which leaves room for providing such estimates to the industry. This is essential given the rate at which the region's cocoa production has been on the downhill in recent years. This research therefore extends on earlier attempt to first model cocoa supply response to relative price for four border regions, that is Western North (Note 1), Western South, Brong-Ahafo and Volta region and after which estimates volumes of crop lost through borders of these regions.

The study finds that investment decision related to cocoa farming are influenced by both local and foreign producer prices, more especially if such prices can be assessed at limited risk or cost to the trader. This is largely because same families stay across the border and farm lands cut across national boundaries. Increasing relative price negatively impacts cocoa supply in the long run for Western North, Western South and Brong-Ahafo regions of Ghana and Volta region in the short run. Rainfall and technological advancement to cocoa farming i.e., Cocoa Disease and Pest Control (CODAPEC) and hybrid seedlings are effective to increasing production in Western region and Brong-Ahafo region. Law enforcement curtails smuggling in Brong-Ahafo region, however, turning negative in the short run both for Brong-Ahafo and Volta regions. This implies law enforcers are not able to effectively handle smuggling in the short run, however in the long run, they are able to decipher the modulus operando of smugglers to effectively curb the menace.

2. Stylized Facts

2.1 Trends in Cocoa Production

Since the commercial takeoff of cocoa production in 1879, it has experienced varying phases of growth and stagnation largely driven by an interplay of internal and external conditions. Kolavalli & Vigneri (2011) demarcates these phases into the exponential growth of 1888-1937 when cocoa became a major commercial crop with Ghana becoming a leading world producer by 1911 up until mid-1970s (Brooks, Croppenstedt & Aggrey-Fynn, 2007). This was followed by stagnated growth between 1938 and 1975 caused mainly by political instability and the outbreak of pest and diseases, with more contraction in 1976 to 1983 spiked by the collapse of international cocoa prices, smuggling and severe droughts.

Structural reforms under phase two of the economic recovery programme (ERP) brought to fore the introduction of the cocoa rehabilitation programme which sort to enhance incentives in the industry, while providing innovative inputs to drive productivity. This contributed to production volumes reaching 404,452 metric tonnes in 1995/96 (International Cocoa Organisation (ICCO, 2018). The cocoa rehabilitation project also led to the liberalization of the internal marketing of the crop which shifted responsibility of domestic cocoa purchases to privately licensed buying companies. Further to this, internal restructuring of the regulatory institution was undertaken in 1992 for better supervision and monitoring of production which helped to sustain cocoa production above the 300,000 metric tonnes up until 2001/02 (Kolavalli & Vigneri, 2011). More buoyant national cocoa production above the 400,000 metric tonnes has persisted since 2002/2003 driven by a combination of policy initiatives and external developments one of which was the record high world prices that encouraged cocoa husbandry thus improving production see figure 1. Additionally, domestic supply-side interventions from COCOBOD in the form of fertilizer subsidies, disease control (CODAPEC) and improved extensions, encouraged the adoption of new technologies bolstering output. Kolavalli & Vigneri (2011) and Brooks et al. (2007) however, ascribes the output jump above 700,000 metric tonnes in 2003/04 to the influx of smuggled cocoa from Cote d'Ivoire amounting to between 120,000 to 150,000 metric tonnes. Largely because producer prices in Ghana at the time was $1,001 as compared to $672 for CDV (ICCO, 2018), in addition to the civil conflict in the country that restricted export of the crop. Since 2008/09 cocoa production has remained above the 700,000 metric tonnes except for 2010/2011 when a peak production above one million metric tonnes was achieved. Recent production increases can be attributed to renewed intensity of government interventions in the industry to boost production (Vigneri & Kolavalli, 2018). However, the sector has not been able to reach its desired productive capacity, with production indicated to be mostly short by 100,000 metric tonnes (Baah et al., 2011), due biological factors and weaker incentives. Producer prices in Ghana has mostly been lower than that of CDV aside early 1980s and some year in the 2000s see figure 2, affecting domestic purchases and thus national output.

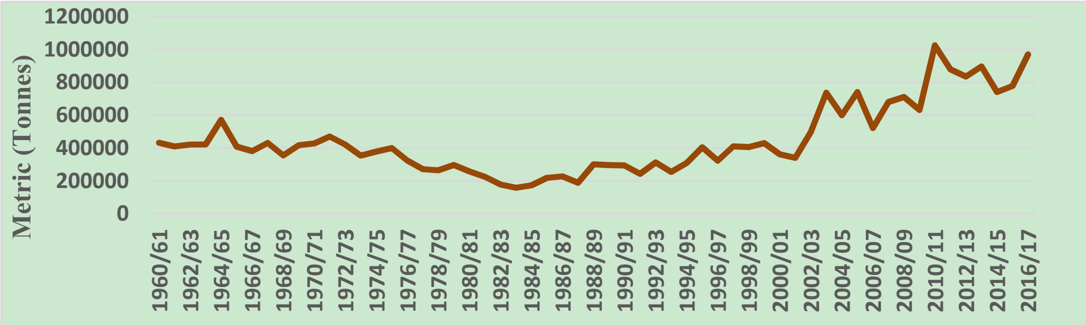


Figure 1. Cocoa Production (1961-2017)

Source: ICCO, 2018 and COCOBOD, 2018

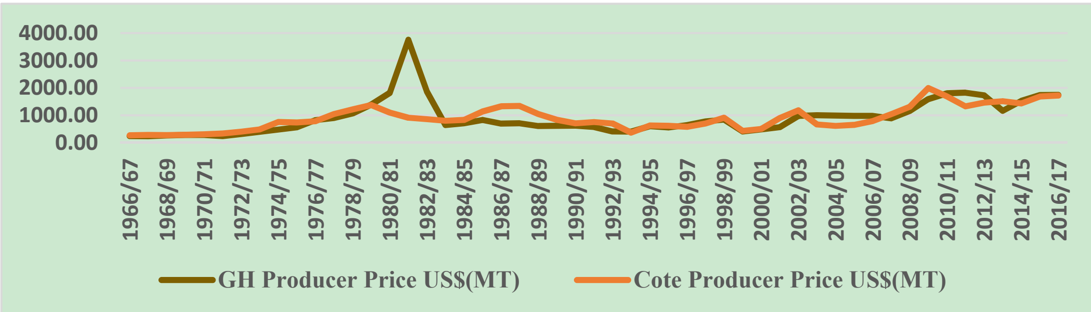


Figure 2. Producer Price Ghana and Cote d'Ivoire (1961-2017)

Source: computed from ICCO, 2018

2.2 Incentive to Cocoa Production

Price is the key indicator of economic profitability and productivity, the agricultural entrepreneur being exposed to substantial level of risk in investment, remains highly sensitive to market prices of goods produced as it moderates or exacerbates risk. Prices are not just important for the farmer but are of relevance to input providers and researchers for the advancement of the industry. Cocoa pricing in Ghana had been determined by competitive market forces prior to 1939 (Kolavalli, Vigneri, Maamah, & Poku, 2012). However, fluctuations in international prices evidenced by the collapse of the crop prices in 1935/1936, held some welfare challenges for farmers. To address the effect of price fluctuation on cocoa farmers' incomes, the colonial government set up the cocoa control board of West Africa to oversee the purchase and export of the crop. This institution metamorphosed into the gold coast cocoa marketing board (CMB), which later changed to COCOBOD in 1947 (Darkwah & Verter, 2014). One of the prime objectives of the board is to maintain guaranteed crop price for farmers in each crop season (Note 2).

This objective has often not been met driven by a multiplicity of factor notably the high dependence of government on cocoa revenue in the 60s, falling world prices and overvaluation of the currency that affected real producer prices (Kolavalli & Vigneri, 2011, Jebuni, Oduro, Asante, & Tsikata, 1992). The turbulence in the industry occasioned by both domestic and external factors greatly affected farm incomes and led to smuggling of the crop to Cote d'Ivoire (CDV) amounting to 20% of Ghana's cocoa harvest (Bulir, 2002). Declining real producer prices over the years driven by inflation and depreciated currency has affected input investment, expansion and effective maintenance of the crop impacting negatively on output. The positive pull of price incentives on cocoa production is evidenced by figure 3, which shows co-movement between real crop prices and production volumes except for some notable departures such as in 2004/05 and 2013/14.

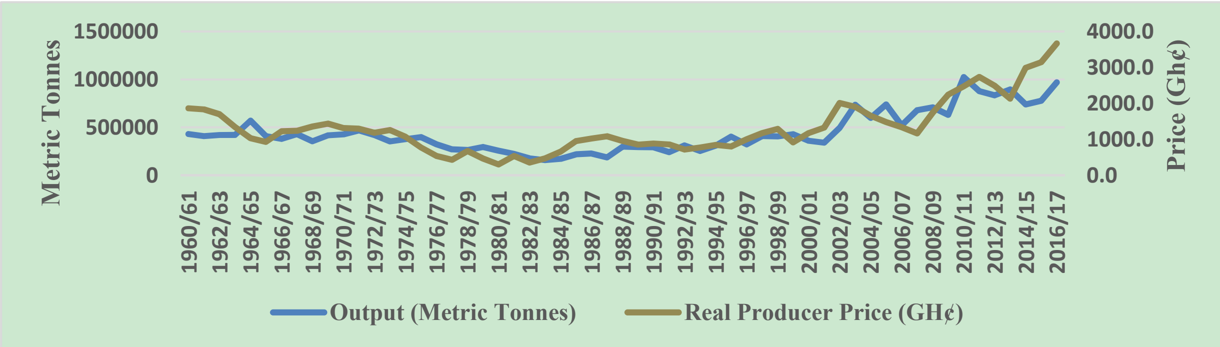


Figure 3. Output of Cocoa and Real Producer Prices (1961-2017)

Source: Computed from ICCO, 2018

3. Literature Review

3.1 Supply Response in Agriculture

Two main approaches have been adopted in literature to model agricultural supply response and classified by Stigler (2018) as either structural or empirical. The choice of method depends on the data, with structural models making use of farm level micro data that captures input prices and farm specific characteristic to supply using production or profit functions. General challenge with such models is the frequency of endogeneity amongst indicator variables which often necessitate the use of instrumental variables. Often used empirical models for agricultural supply are built on macro level farm data premised on the work of Nerlove (1956) in which he develops a supply response model for wheat, corn and cotton in USA. Agricultural supply is modeled taking cognizance of volatility in crop prices; where price volatility reduces sensitivity of farmers to price signals. Thus, price response is based on an expectation of price and not instantaneous changes to price. Formation of price expectation considers past prices, with weights diminishing over time. In each period, farmers revise expectations based on some proportion of the difference between price today and price in period $t-1$ given as:

$$p_t^{\wedge} - p_{t-1}^{\wedge} = \rho[p_{t-1} - p_{t-1}^{\wedge}] \qquad (1)\ 0<\rho\leq 1$$

$$p_t^{\wedge} = p_{t-1}^{\wedge} + \rho[p_{t-1} - p_{t-1}^{\wedge}] \qquad (2)$$

$$p_t^{\wedge} = \rho\, p_{t-1} + (1-\rho)\rho\, p_{t-2} + \ldots \qquad (3)$$

Where $p_t^{\wedge}$ is current price expectations, $p^{\wedge}_{t-1}$ past price expectations, p_{t-1} actual past prices and ρ the coefficient of expectations. Expected price becomes a weighted moving average of past price with the expectation coefficient lying between 0 and 1. Weight thereby decline towards zero which allow for the omission of price far into the future.

Further to this there is some partial adjustment in crop land allocation decisions. The partial adjustment theory assumes each year farmers have a desired expansion goal driven by long run profitability of own and competing crops. The actual cultivated land will deviate from the desired cultivation because of input restriction and some errors in measurement. The difference between desired land allocation and actual land allocated to farming is given by the adjustment factor as shown by equation 4.

$$Q_{c,t} - Q_{c,t-1} = \partial[Q^e_{c,t} - Q_{c,t-1}] \qquad (4)\ \ 0<\partial\leq 1$$

with, $Q_{c,t}$ being actual cocoa cultivated at time t, $Q_{c,t-1}$ actual cocoa cultivated at time $t-1$ and ∂ the adjustment factor

Several empirical studies have adopted adaptive expectation and partial adjustment models with the introduction of other productivity shifters as proposed by Brandow (1958) to estimate agricultural supply response. Recent applications despite some criticism against the expectation formation which is said to be ad hoc is given by (Triparthi & Prasad, 2009; Yu, Liu & You, 2011; Menezen & Piketty, 2012; Haile, Kalkuhl & von Braun, 2015;

Mustafa, Latif & Egwuma, 2016; Hendricks, Smith, & Villoria, 2018).

3.2 Cocoa Supply Response

The modeling of cocoa supply begins with the work of Stern (1964) who adopts Nerlove partial adjustment model and hypothesizes that the impact of price on cocoa production was transmitted through the farmers harvesting decision. However, the study could not find any empirical relationship between price and output. Bateman (1965) follows by modelling long run profitability in cocoa farming as a factor of prices expectations, bearing life of the crop and agroclimatic factors. The study control for climatic conditions picking March to May rainfall as the critical rainfall periods for the crop. The work finds rainfall can have a twofold effect on production. For instance, effective rainfall supports crop production, at the same time excessive rainfall can trigger the onset of the black pod disease.

Yeung, Pollak & Augusto (1979) also adopts the partial adjustment model to study cocoa supply response for Brazil, Cameroon, Ivory Coast, Ghana and Nigeria, with a three-year moving average of price, a dummy is introduced to capture sudden changes in cocoa output linked to disease and policy distortions, unexplained breaks in data or unforeseen disruption to production. Stryker (1990) and Frimpong-Ansah (1992) extends the foregoing formulation to capture the effect of competing crop using maize price to represent the price of food crop that compete with cocoa for fertilizer use and other maintenance expenditures. The finding from these studies indicates the responsiveness of cocoa to prices has been very low, with inelastic response of about 0.2 in the short run.

Abdulai & Rieder (1995) pioneers work on cocoa supply modelling that accounts for the time series properties of the data. They put forwards the argument that the trending nature of most time series can lead to superfluous results. Secondly Nerlove (1979) partial adjustment model though seeking to be dynamic was restrictive under conditions of optimizing behavior. Cointegration is then proposed as a method better suited for modeling the dynamic structure of agricultural production. This is because the transmission from inputs or policy initiatives to outputs travels beyond a single time period.

Following initial aggregate modeling of cocoa supply in Ghana, ensuing works argue earlier studies were not fully accounting for supply in cocoa because they do not account for the effect of relative price given that smuggling critically affects reported output for producing countries. Subsequently studies such as (e.g., Franco, 1981; May, 1985; Gyimah-Brempong & Apraku, 1987; Fosu, 1992; Bulir, 2002) have modelled cocoa supply response accounting for the effect of smuggling. Franco (1981) estimates the optimum cocoa producer prices in Ghana that generates optimum cocoa receipts to government. Using ordinary least square estimators the study finds in 1974/75 the optimal price needed to incentivize the industry producers was 1.3 times that of actual prevailing prices, indicating much higher increases in producer price was needed to re-establish incentive to the industry.

Bulir (2002) in the spirit of previous works expands on the modeling of cocoa smuggling. The study is justified on ground that previous studies did not make a distinction between the short and long run. The work puts forward arguments to the fact about one third of fluctuations of cocoa supply from trends can be accounted for by relative price difference. In the short run crop response to price is constrained by output response to fertilizer application efforts, weather variable and government policies. Relative prices on the other hand determine farmers' investment decision to plant, harvest and even where to sell their produce. Also, long run considerations of the relative profitability of cocoa vis-à-vis other economic activities will drive the decision whether to expand, uphold or contract land cultivation or even switch to another crop. The empirical estimates of supply elasticity to relative price between Ghana and Cote d'Ivoire was 0.6 in the long run. Short term elasticities were insignificant interpreted to reflect the medium-term character of farmer's choice process in relation to relative prices.

This current research will model supply response in cocoa while controlling for law enforcement a feature absent in studies on cocoa supply response. Also, the work will control for labour as production of cocoa is labour intensive. Further to this the research covers all border cocoa growing regions which remains peculiar to the current work. Also, an ARDL cointegration model will be used as it is shown to produce more robust estimate with smaller samples.

4. Methodology

4.1 Empirical Model

Cocoa supply is modelled on the assumption that tree stocks are given and production is influenced by price expectations as it drives the intensity of husbandry essential for optimal yields and output. Following specification like Franco (1981), May (1985) and Bulir (2002) however, with some modifications. Reported supply of cocoa as given by cocoa marketing company (CMC) is a fraction of unobserved total national production. The difference between total production and recorded production is that portion of cocoa sold in foreign markets unofficially.

$$Q_C^A = Q_C^T - C^S \tag{5}$$

Q_C^A, actual cocoa purchases Q_C^T, total cocoa production, C^S, cocoa smuggled

The fraction of cocoa smuggled is influenced by the difference between domestic producer prices and foreign producer prices (relative price)

$$C^S = f\left(\frac{P^F}{P^D}\right) \tag{6}$$

$\frac{P^F}{P^D}$ is the relative price (foreign producer price to domestic price) simple presented as P^R

Total production which is not observed, is a factor of producer price and other supply shifters

$$Q_C^T = f\left(P^D, Z_t^e\right) \tag{7}$$

P^D is domestic producer price and Z_t^e other exogenous factors

Substituting equations (6) and (7) into (5) cocoa supply is given as

$$Q_C^A = f\left(P^D, Z_t^e, P^R\right) \tag{8}$$

In the reduced form model, May (1985) captures the effect of agro climatic variables such as rainfall. Extensions to this formulation for this current study includes the effect of institutions or law enforcement on production. This is indicator is controlled for because the smuggler incurs cost to avoid detection, hence the higher the risk of detection, the higher the cost to smuggling trade. Also, productivity in agriculture is enhanced by the intensity of maintenance, therefore increasing labour cost will moderate husbandry and productivity. A key facilitator of crop productivity is the adoption of advancing technology to cocoa production. Key technologies available to the industry are 1) Hybrid cocoa seedlings that increases yields, 2) Cocoa disease and pest control (CODAPEC) programme designed to reduce disease and pests. These two were selected because of the disruptive effect of disease outbreak on cocoa, and because productivity levels in cocoa have largely been encouraged using hybrid seedlings. While earlier works just as Batman in 1965 uses coffee prices as an alternative to cocoa given price, later works just as Frimpong-Ansah (1992) and Stryker (1990) have used maize price to capture, competing crop prices. Maize price is found to follow closely general price of food crops and thus indicative of the relative profitability in other crop production. Increasing maize price will compete labour away from cocoa and reduce the intensity of maintenance and diversion of fertilizer and other input from cocoa farms.

Incorporating these extensions, cocoa output response for four cocoa growing regions i.e., Western North, Western South, Brong-Ahafo, and Volta region is presented in the equations 9. These regions have the unique characteristic of sharing borders with CDV for the first three regions and Togo for the last region.

$$Q_{C_{ti}}^A = f(P_d, p^r, R_{rain}, C_{custom}, Tec_{dum}) \tag{9}$$

$Q_{C_{ti}}^A$ is the reported output of cocoa at time t for the I^{th} region with $I = (1,...,4)$.

Leaving out subscript i and transforming into natural logarithms

$$\begin{aligned} \ln Q_{C_t}^A &= b_0 + b_1 \ln P_{dt} + b_2 \ln p_t^r + b_3 \ln P_{maizt} + b_4 \ln R_{ra\text{int}} \\ &+ b_5 Cust_t + b_6 Tec_{dum} + \upsilon_t \end{aligned} \tag{10}$$

where P_{dt} is domestic producer price, p_t^r is relative price, p_{maize} price of maize, R_{rain} annual rainfall, C_{custom} custom strength and Tec_{dum} dummy for technology (comprises of two technology variables as indicated).

Using an ARDL, bound cointegration, cocoa output response in each region is:

$$
\begin{aligned}
Q_{It}^{C} &= a_0 + \sum_{i=1}^{p} e_i \Delta Q_{It-1}^{C} + \sum_{i=0}^{q} f_i \Delta P_{It}^{D} + \sum_{i=0}^{q} g_i \Delta P_{It}^{r} + \sum_{i=0}^{q} h_i \Delta C_{It}^{u} \\
&+ \sum_{i=0}^{q} i_i \Delta R_{It}^{r} + \sum_{i=0}^{q} j_i \Delta Tec_t^{dum} + d_1 Q_{It-1}^{C} + d_2 P_{It-1}^{D} + d_3 P_{It-1}^{r} \\
&+ d_4 C_{It-1}^{u} + d_5 R_{It-1}^{r} + d_6 Tec_{t-1}^{dum} + \upsilon_t
\end{aligned} \tag{11}
$$

4.2 Data Summary

The summary of the data used as well as expected signs are given in table 1. Real producer price is constructed as yearly producer price deflated by consumer price index, and modelled as three-year moving average of price. Producer prices are taken from international cocoa organization (ICCO) for both Ghana and Cote d'Ivoire (CDV) whiles that for Togo is taken from Food and Agricultural Organisation (FAO). CPI data is sourced from the Federal Reserve Bank of ST. Louis with a base period of 2010. Relative producer price is given by two ratios, the ratio of CDV price to Ghana price and the ratio of Togo price to Ghana price. Producer price for the three countries is first converted from the local currency into a common currency US dollar using individual country exchange rate. The exchange rate data are taken from World Development Indicators (WDI). However, for Ghana the black-market exchange rate is used for the period 1961 to 1992 and for CDV up to 1983. CFA official rate for CDV was the same as black market rate for the period 1961 through to 1964. Ghana's black-market rates are taken from Pick World Currency Year book, while CDV black market rates are taken from May (1985). The price of maize is sourced from FAO and deflated by the consumer price index and converted into three year moving average. The effect of law enforcement is accounted for by an index of custom officials to total population in thousands of individuals, custom staff data taken from Ghana custom and preventive services while population figures are sourced from FAO. The data for customs was not a complete time series but came in sub-periods. Interpolation was done for the missing intervals of data. Rainfall measured in millimeters is aggregated for a year and taken from Ghana meteorological services. For this analysis, rainfall volumes for the 4 cocoa regions (i.e., Western North, Western South, Brong-Ahafo and Volta) are used. Dummies for technologies are computed taking the value 1 from initiation of policy and 0 prior to a given policy. The data was transformed into natural logs except for dummies for the estimations.

Table 1. Summary statistic

Variable	Mean	SD	Min	Max	Exp. Sign	Scale
Real Producer Price	1271.10	639.87	402.11	3270.31	+	Price/CPI
Relative Price (CDV/GH)	1.10	0.32	0.24	1.90	_	CDV/GH(USD)
Relative Price (Togo/GH)	1.72	0.66	0.75	3.83	_	Togo/GH (USD)
Real Maize price	486.95	129.40	267.8	749.68	+	Price/CPI
Annual Rainfall	92644.96	20404.71	61248	117700	+/_	Millimeter
Dummy CODAPEC	0.28	0.45	0	1	+	0, 1
Dummy Hybrids	0.14	0.35	0	1	+	0, 1
Custom	0.35	0.26	0.10	0.98	+	Custom/Pop. (1000)
Western North Output	131695.3	87286.63	19490.29	330951.1	Dep. Var	MT/Ha
Western South Output	112213	77916.19	15722.3	259419.7	Dep. Var	MT/Ha
Brong-Ahafo Output	52030.05	21260.57	28629	102474.6	Dep. Var	MT/Ha
Volta Output	1973.29	1231.31	594.82	6421.75	Dep. Var	MT/Ha

5. Presentation and Analysis of Results

5.1 Unit Roots Testing

ARDL modelling allows for the use of both I (0) and I (1) variables, however, the model is known to crush with I (2) variables. To avoid the use of any I (2) variable, unit root testing is undertaken to ascertain the order of integrations of each indicator variables using both ADF and KPSS unit root tests. The results reveal relative prices (CDV, Ghana) and relative price (Togo, Ghana) are stationary using the ADF test. Also, for the KPSS, the same variables and Western South were stationary at the 5 % level using critical values with trend and without trend of 0.463 and 0.146 respectively, see table for details. The rest of the variables selected for the estimation were I (1) being stationary after first differencing as shown in table 2 and 3. The mix of stationarity and non-stationary variables confirm the appropriateness of applying an ARDL model to the data since the technique allow the combination of both I (0) and I (1) variables in testing for cointegration.

Table 2. Unit roots testing using ADF

	LEVELS			DIFFERENCE		
Variables	Constant	Constant & Trend	Decision Rule	Constant	Constant & Trend	Lags
Real Producer Price	-0.178	-1.048	I (1)	-4.389	-5.160	1
Relative Price (CDV/GH)	-4.117	-4.111	I (0)	-4.894	-4.849	1
Relative Price (Togo/GH)	-3.320	-3.294	I (0)	-6.124	-6.131	1
Rainfall	-1.601	-0.125	I (1)	-2.993	-3.555	3
Maize Price	-0.640	-0.151	I (1)	-3.974	4.783	1
Dummy CODAPEC	-0.588	-1.897	I (1)	-5.196	-5.230	1
Dummy Hybrids	-0.351	-1.315	I (1)	-5.196	-5.403	1
Custom Ratio	-2.354	-2.242	I (1)	-5.129	-5.309	1
Output Western North	-0.038	-2.534	I (1)	-3.517	-3.474	2
Output Western South	-1.008	-3.117	I (1)	-3.948	-3.901	2
Output Brong-Ahafo	-0.123	-2.346	I (1)	-4.445	-4.568	2
Cocoa Output Volta	-1.562	-1.851	I (1)	-4.630	4.922	1

Note: Null is non stationarity

Table 3. KPSS Unit Roots Testing

	LEVELS			DIFFERENCE	
Variables	Constant	Constant & Trend	Decision Rule	Constant	Constant & Trend
Real Producer Price	1.22	0.583	I (1)	0.576	0.0354
Relative Price (CDV/GH)	0.132	0.0812	I (0)	0.03	0.0303
Relative Price (Togo/GH)	0.153	0.151	I (0)	0.0443	0.0272
Rainfall	1.04	0.3	I (1)	0.346	0.0997
Maize Price	0.257	0.259	I (1)	0.192	0.0749
Dummy CODAPEC	1.99	0.505	I (1)	0.138	0.0566
Dummy Hybrids	1.23	0.426	I (1)	0.225	0.0529
Custom Ratio	2.01	0.404	I (1)	0.217	0.0535
Output Western North	1.28	0.19	I (1)	0.113	0.0412
Output Western South	1.23	0.086	I (0)	0.0469	0.0466
Output Brong-Ahafo	1.03	0.262	I (1)	0.224	0.039
Output Volta	0.42	0.249	I (1)	0.175	0.0595

Note: Null for KPSS is stationarity, 5% critical value without trend is 0.463 and with trend 0.146

5.2 Bounds Testing for Long Run Relationship

Pesaran, Shin & Smith (2001) ARDL cointegration analysis models each of the variables of interest as a unique long run relationship which facilitates the identification of the cointegrating vectors. The identification of a single cointegration vector facilitates the reparameterization of the model into an equilibrium correction model giving both the short run dynamic and long run static model. Pesaran et al. (2001) provides critical values to the bound testing. however, Narayan (2005) highlights some limitation in using such critical values for small samples since their computations was based on a large sample of 500 to 1000 observations. Using a smaller sample of 30 to 80 observations, Narayan provides critical values for testing level relationship. The sample of this current study is 36, for this reason Narayan (2005) critical values is used to test for a long run relationship between cocoa and its explanatory variables.

The Akaike information criterion (AIC) is used to select the maximum lags to apply to each model with the bound test outcomes presented in table 4. The results confirm a long run relationship between cocoa output from each border region against the selected explanatory variables.

Table 错误!文档中没有指定样式的文字。. Bound Cointegration test of regional cocoa output response

Region	F-Statistic
Western North region	**12.556**
Western South region	7.805
Brong-Ahafo region	7.863
Volta region	6.901

Note: Critical values given by Narayan (2005) taken from Nkoro & Uto (2016)

5.3 Estimates of Regional Cocoa Supply Response

Having established a single cointegrating relationship, estimates of the long run and short run coefficients are derived and presented in table 5 and 6. The elasticities of response are computed from table 6. Pesaran et al. (2001) shows that the long run elasticities are computed as – (b_2/b_1) that is the independent coefficient deflated by the lagged dependent coefficient. However, the short run coefficients remain as elasticities, which are shown in table 7. Results are discussed concurrently. The findings point to some close similarities in outcome for Western North and South, which is expected since these two regions are homogenous, typically exhibiting similar topographical, climatic and farm characteristic. The effect of producer prices in the long run for Western North and South is negative and significant, however being positive for the short run. Cocoa production relies on effective maintenance of farms; one key routine is frequent harvesting of ripe cocoa fruits to prevent disease outbreak. Pod harvesting is often a costly process because cocoa trees fruit all year round requiring much labour especially for larger farms. Crop price is the incentive to effective maintenance. However, if the farmer is not convinced about the prospects of future price, since cocoa is perennial, they hedge in the current price and avoid further expenses on maintenance which is reflected in lower output by the next crop year. This submission is supported by Dana & Gilbert (2008) who points out that risk aversion will lead farmers to reduce inputs on farms to the extent that harvest prices are subject to uncertainty.

Farmers in Brong-Ahafo are not responsive to producer price changes perhaps because cocoa farming is usually on family land, managed with bequeath motive in mind, thus crop price may not always be the factor driving production for the tree crops. Dana & Gilbert (2008) again states tree crops production response to price is low because input application generally gives only a modest increase in yield. Also, prices are seldom too low as to make it worthwhile to cut down trees which still have a productive future, making production irresponsive to price. For the case of volta region producer price remains fundamental to improving on cocoa output in the long run, however, being negative in the short run.

Beginning with the three regions, the effect of relative price on cocoa supply is negative in the long term. As CDV producer price increases relative to that of Ghana, reported crop output in Western North, South and Brong-Ahafo regions decline with an elasticity of 0.53, 0.48, and 0.11 respectively. That is price differential cause producers to switch to the foreign market offering the higher price. In the short run relative price is not significant to explaining cocoa output from Brong-Ahafo, remaining however, significant, and positive to output from Western North and South. Western region outcome in the short run can be explained on the grounds that in the short run producers may not have the means to take advantage of the price difference abroad, however, given proximity they may increase maintenance to improve on production in anticipation of a future smuggling to the higher price area shoring up short run output locally. In the case of Volta region relative price drives cocoa supply positively in the long run, being negative in the short run. Related studies such as May (1985) obtains a negative relative price elasticity of output for Brong-Ahafo of 0.30. Estimates from Western North and South remain limited to this work.

Cocoa supply response to rainfall has dual effect on cocoa production. For the three regions outside Volta region, rainfall has a positive effect on production in the long run at 1% significance level, remaining negative at all lags in the short run. In the short run excess rainfall triggers the black pod disease which leads to pod loss reducing output, however, in the long run effective moisture is key to cocoa production. Rainfall is not significant to production for Volta region in long run being also negative in the short run. Other studies such as May (1985) also finds rainfall to be negative for Volta however, being insignificant.

The effect of competitive crops represented by maize price is modelled for all regions apart from Volta and is significant for Western North at 0.6% but not for Western South and Brong-Ahafo in the long run, however turning positive in the short run. Increasing price of maize leads to temporal diversion of inputs and labour to its production reducing cocoa maintenance and output for the given crop season.

Table 5. Long run elasticities of cocoa supply response

Variables: Dependent=Cocoa Output	Western North	Western South	Brong-Ahafo	Volta
Real Prices	-0.972	-0.796		3.677
Relative Prices	-0.531	-0.479	-0.108	2.112
Rainfall	16.430	15.939	0.423	
Maize Price	-0.604			
Dummy Hybrids	0.620	0.647		
Dummy CODAPEC	1.490	1.300	0.096	-3.829
Custom			0.589	

Note: Elasticities calculated from table 6, insignificant coefficient has been omitted

Table 6. Long run response of cocoa output supply

Variables	Western North	Western South	Brong-Ahafo	Volta
Real Prices	-0.795***	-0.602*	0.032	2.195**
	(0.267)	(0.284)	(0.071)	(0.919)
Relative Prices	-0.434**	-0.362*	-0.103*	1.263***
	(0.178)	(0.185)	(0.051)	(0.391)
Rainfall	13.44***	12.05***	0.405***	-0.436
	(1.782)	(1.974)	(0.086)	(0.827)
Maize Price	-0.494*	-0.277	-0.0425	
	(0.246)	(0.250)	(0.057)	
Dummy Hybrids	0.507***	0.489***		-0.656
	(0.114)	(0.125)		(1.035)
Dummy CODAPEC	1.219***	0.983***	0.092*	-2.286***
	(0.148)	(0.154)	(0.048)	(0.614)
Custom			0.564***	-2.647
			(0.182)	(1.722)
Intercept	-122.0***	-111.0***	5.617***	-11.03
	(17.30)	(19.11)	(1.598)	(10.58)
Adjusted R^2	0.845	0.762	0.599	0.733
F-statistic	37.8***	8.43***	5.60***	2.59*

Note: *** indicates significances at 1%, ** 5% and * 10%, figures in brackets are the standard errors

The effect of law enforcement for cocoa output in Ghana is modelled for Volta and Brong-Ahafo region as its inclusion for Western North and South renders the model parameters unstable. The presence of law enforcement is positive and significant to cocoa production from Brong-Ahafo region with an elasticity of 0.59, being insignificant however, for the case of Volta in the long run. For the short run, the presence of law enforcer reduces output from the two regions, however, they positively support output moving into the second lag in Volta region. Law enforcers may be overwhelmed by smugglers in the short run, thus failing to halt the trade but into the future they are able to effectively deal with the menace as they unravel smuggling route and strategies which contributes to the long run gains in output.

Technology shifters are supportive to cocoa productivity in the all regions except Volta. In this region CODAPEC even though significant is reducing production. This can be attributed to the possible administrative lags in spraying time and number of rounds, which can lead to pests and disease resistance causing greater pods loss. For instance, cocoa farms are supposed to be sprayed four times in the year; the government provides for two of such spraying rounds leaving the farmer to cater for the other two sprayings at the specified time. If the farmer is not resourced enough to buy chemicals, the remaining spraying will not take place implying disease eradication is not completed giving room or resistance and explosion of the diseases and pests. The effect of hybrid seedling was not significant at all for the Volta region, pointing to the fact that this region is lacking behind in the adoption of this technology, accounting for the lower output from this region.

The error correction term for all regions is significant at 1 percent showing a high level of adjustment of cocoa output to equilibrium from temporarily deviations in the short run. The speed of adjustment is 82%, 76%, 96% and 60% for Western North, Western South, and Brong-Ahafo and Volta region respectively.

Table 7. Short run dynamic response

Variables: Dependent=Cocoa Output	Western North	Western South	Brong-Ahafo	Volta
Error Correction Term	-0.818***	-0.756***	-0.958***	-0.597***
	(0.131)	(0.152)	(0.152)	(0.178)
Δ Output				-0.360**
				(0.164)
Δ Real producer Price	0.0282	-0.0510		-1.999**
	(0.238)	(0.246)		(0.937)
Lag1 Δ Real Producer Price	2.619***	2.102***		-1.315
	(0.379)	(0.394)		(1.090)
Δ Relative price	0.435***	0.450***		-0.603**
	(0.127)	(0.137)		(0.236)
Lag1 Δ Relative price	0.220*	0.183		
	(0.106)	(0.120)		
Δ Rainfall	-9.490***	-8.621***	-0.422***	1.620
	(1.143)	(1.261)	(0.133)	(1.320)
Lag1 Δ Rainfall	-3.267***	-2.549***	-0.674***	-1.194**
	(0.738)	(0.791)	(0.127)	(0.471)
Δ Maize Price	0.217	0.107		
	(0.215)	(0.221)		
Δ Custom			-4.923***	-30.82*
			(1.628)	(16.22)
Lag1Δ Custom				47.77**
				(18.25)
Lag1Δ Maize Price	0.306**	0.234*		
	(0.126)	(0.130)		

Δ Dummy Codapec	-0.994***	-0.821***		1.520***
	(0.139)	(0.145)		(0.489)
Lag1 Δ Dummy Codapec	-0.941***	-0.824***		0.996*
	(0.156)	(0.163)		(0.467)
Δ Dummy Hybrid	-0.734***	-0.596***		-2.426***
	(0.165)	(0.169)		(0.689)
Constant	-122.0***	-111.0***	5.617***	-11.03
	(17.30)	(19.11)	(1.598)	(10.58)

Note: *** indicates significances at 1%, ** 5% and * 10%, figures in brackets are the standard errors

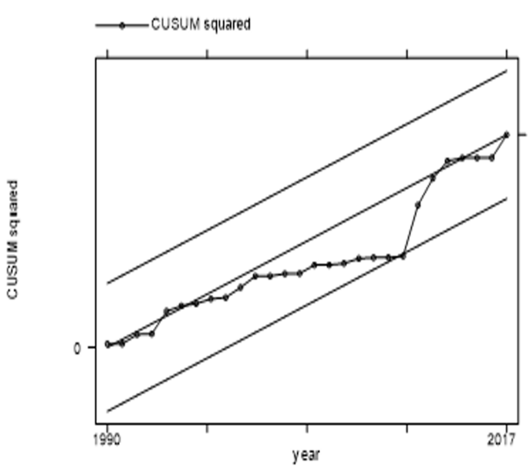
5.4 Model Diagnostics

Table 8 presents some post estimation diagnostic checks on the models estimated. The Ramsey Reset test shows there may be some omitted variables for Brong-Ahafo model, even though the errors of this model are normal and free from serial correlation. The coefficient estimates of parameters of the model are stable shown by the cumulative sum square estimate, however, there are some truncations of parameters effect on output at some point in the 1990s as shown by the cumulative sum squared (CUSUMQ) in figure 4, with some deviation from the 5% significance level. The three other models estimated are well specified and free from serial correlation and heteroscedasticity, with normal errors. Also, the model parameters are stable, confirming that the modelling of supply response of cocoa for those regions is appropriate.

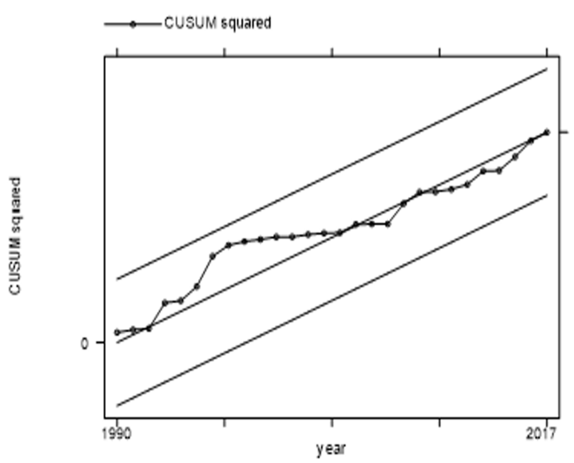
Table 8. Diagnostic and parameter stability test

Statistic	Western North	Western South	Brong-Ahafo	Volta
a) Serial correlation	0.105[0.746]	0.105[0.746]	0.021[0.886]	1.406[0.236]
b) Heteroscedasticity	0.23[0.632]	2.10[0.147]	9.57[0.002]	0.26[0.609]
c) Functional form	0.19[0.904]	1.66[0.228]	10.0[0.000]	0.59[0.635]
d) Normality	0.373[0.980]	0.763[0.713]	0.454[0.950]	1.183[0.363]
e) CUSUM	0.218[0.948]	0.106[0.948]	0.491[0.948]	0.547[0.948]
f) RMSE	0.097	0.101	0.061	0.274

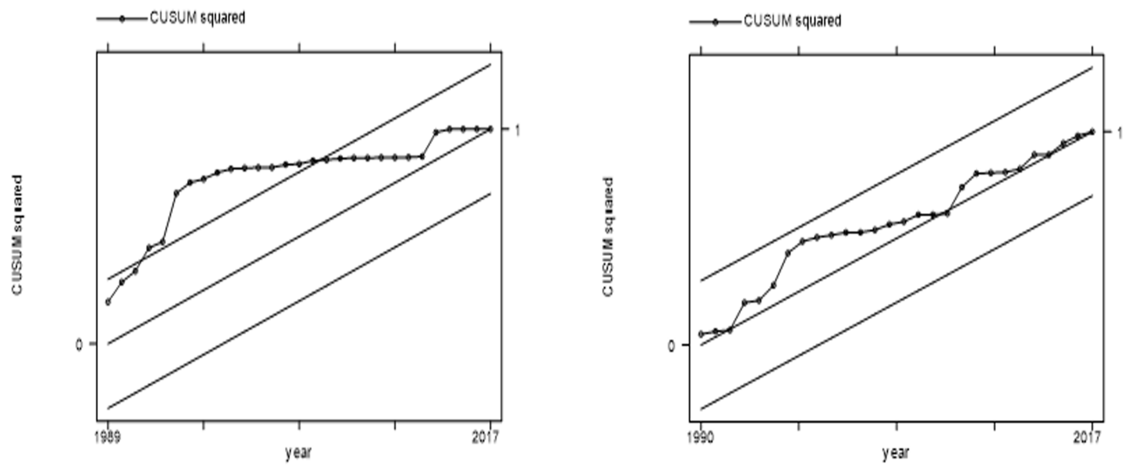
Note: */Nulls are (a) no serial correlation, (b)constant variance, (c) model does not have omitted variable, (d) errors are normal (e) no structural breaks, (f) root mean square error, probability values for all test in parenthesis.



Western North



Western South



Brong-Ahafo Volta

Figure 4. Stability test of cumulative sum squares for regions

5.5 Estimation of Cocoa Smuggling

Having examined the post estimation outcomes, models for Western North and South plus Volta regions are selected as the most acceptable for forecasting smuggling of the crop.

According to May (1985) recorded production in cocoa as indicated by sales to CMB is a fraction of unboserved national production. The farmer choses the fraction to sell domestically and internationally. This fraction is a function of relative prices as given in equation 12.

$$Q_A^C = C^s(P^r)Q_T^C \tag{12}$$

Where Q_A^C, is actual/reported production in cocoa C^s fraction sold to CMB, P^r relative price, Q_T^C total cocoa production

Recalling from equation 10 and restating it here, supply response in cocoa is given as:

$$\ln Q_{At}^c = b_0 + b_1 \ln P_{dt} + b_2 \ln p_t^r + b_3 \ln P_{maizt} + b_4 \ln R_{ra\,\mathrm{int}} \\ + b_5 Cust_t + b_6 Tec_{dum} + \upsilon_t$$

The estimated proportion $\hat{C}_t^s$ of cocoa sold to CMC at time t is given as:

$$\hat{C}_t^s = \left(P_t^r\right)^{\hat{b}_2} \tag{13}$$

Where $\hat{b}_2$ is the coefficient from equation 10, therefore the volume of cocoa smuggled at time t is as specified below

$$Q_{At}^{Sm} = \left(\frac{1-\hat{C}_t^s}{\hat{C}_t^s}\right) Q_{At}^c \tag{14}$$

Where Q_{At}^{sm}, is the volume of cocoa smuggled, other variables are as already defined.

The estimates of cocoa smuggling are presented in table 9. The data reveal that smuggling of cocoa from Ghana took place in the early 2000s to late 2000s while the middle of the decade was characterized with more inflows from the CDV into the country. The period after 2010 has witnessed only two significant outflows in 2014 with 25,494 MT and 21,883 MT being lost through the borders of Western North and South moderating to 1,559 MT and & 1, 358 MT in 2016/17. Net gains from cocoa smuggled into the country from CDV beginning from 2000 to 2017 is 23,534 MT and 15,336MT from Western North and South respectively.

May (1985) also estimates smuggling from Brong-Ahafo region at 33,277 MT in 1977, with an average smuggling of 27,600 MT after that period to 1982, whiles gains of cocoa from CDV through the region was 7,000 MT and 6,000 MT in 1963 and 1964.

The trend for Volta stands out slackly for attention, the region consistently records outflows from its borders in all crop seasons except for the year 1999/00. With peak losses taking place in 2010/11 of 2,160 MT and the lowest losses of 174 MT in 2013/14. Though the volumes from the region are marginally lower than all others it still calls for greater attention as it presents a ripe opportunity for investments tailored to improving production to directly benefit Togo rather than Ghana. Also, the presence of smuggling greatly underreports regional output which can be a disincentive to COCOBOD from investing resources in the region for productivity gains. Estimates of smuggling has moderated on both sides of the divide since 2014/15 crop year largely due to efforts at reducing price disparities between both countries, supporting the call for adequate price incentives for sustained production and growth of the industry.

Table 9. Regional smuggling of cocoa

Crop Year	2a.Cocoa Output Western North	2b. Fraction of Cocoa Sold to CMB	2c. Quantity Smuggled	3a.Cocoa Output Western South	3b. Fraction of Cocoa Sold to CMB	3c. Quantity Smuggled	4a.Cocoa Output Volta	4b. Fraction of Cocoa Sold to CMB	4c. Quantity Smuggled
1999/2000	133,416.5	1.02	(2,923)	107,623.6	1.02	(1,970)	2,351.0	0.80	588
2000/2001	101,105.2	1.01	(1,347)	86,066.9	1.01	(958)	1,494.3	1.76	(647)
2001/2002	98,137.0	1.22	(17,690)	83,728.0	1.18	(12,792)	1,021.0	3.84	(755)
2002/2003	160,418.0	1.09	(12,749)	116,169.0	1.07	(7,753)	913.0	1.94	(443)
2003/2004	253,609.0	0.84	47,826	166,041.0	0.87	25,736	1,909.0	1.65	(755)
2004/2005	194,113.0	0.81	44,188	150,133.0	0.84	28,011	1,336.0	1.16	(180)
2005/2006	237,244.2	0.84	45,702	184,978.8	0.86	29,279	1,000.6	1.26	(205)
2006/2007	193,500.4	0.91	18,534	166,346.4	0.93	13,188	760.6	1.58	(280)
2007/2008	197,372.0	1.07	(12,930)	172,086.0	1.06	(9,455)	838.0	2.15	(448)
2008/2009	222,421.0	1.06	(11,804)	190,771.0	1.05	(8,483)	951.0	3.64	(690)
2009/2010	183,616.0	1.10	(17,232)	173,706.5	1.09	(13,708)	594.8	4.46	(461)
2010/2011	330,951.1	0.97	9,380	259,419.7	0.98	6,118	3,240.5	3.00	(2,160)
2011/2012	282,662.8	0.87	41,905	242,574.4	0.89	29,646	3,833.0	1.89	(1,802)
2012/2013	243,075.5	0.93	18,381	215,030.8	0.94	13,480	4,495.4	1.71	(1,870)
2013/2014	238,992.9	1.12	(25,494)	243,697.9	1.10	(21,883)	3,480.9	1.05	(174)
2014/2015	192,978.1	0.97	5,130	187,490.1	0.98	4,148	2,650.2	1.22	(474)
2015/2016	202,261.3	0.99	2,730	213,041.4	0.99	2,396	2,679.6	2.08	(1,391)
2016/2017	243,799.1	0.99	1,559	254,771.8	0.99	1,358	6,421.8	1.23	(1,197)

5. Summary and Conclusions

This study examined the response of cocoa supply to relative price and subsequently provides estimates of cocoa smuggled between Ghana and its neighbouring producer countries with specific focus on four border regions i.e., Western North, Western South, Brong-Ahafo and Volta region. The study demonstrates that weak domestic price incentives is contributing to low records of cocoa in the country through cocoa smuggling. Reported production of cocoa is moderated by increasing foreign producer price relative to that of Ghana, with losses amounting to 25,494 MT and 21,883 MT in 2014 through the borders of Western region to Cote d'Ivoire, however moderating to 1,559 MT and & 1,358 MT in 2016/17. Thus, the findings indicate aside agro-climatic factors, reported output of cocoa in Western region is below potential because of smuggling occasioned by relative price differences. The Volta region losses cocoa to Togo on a consistent basis with losses reducing in 2016/17. Considering the findings, the study recommends more effort by the COCOBOD in partnership with Government to bridge the gap between domestic producer price and that of Cote d'Ivoire and Togo since this effort is yielding good dividends by reducing the incidence of smuggling. This can be achieved by reducing industry cost component in the computation of the producer price by the PPRC. Secondly there is an urgent need for an investigation into the consistent loss of crop between Volta region and Togo, perhaps there is weaker border control in the region which needs to be rectified. Further to this, the country needs to better equip customs and other security apparatus at the borders to handle both sporadic smuggling and long-term well-established activities of smugglers to effectively stem this menace.

Acknowledgements

Appreciation goes to COCOBOD and ICCO for the data support. I wish to also extend my appreciation to Professors: Bernardin Senadza, Festus Ebo-Turkson and Wisdom Akpalu for their review of my PhD dissertation which contained some aspects of this paper.

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Notes

Note 1. For administrative purposes, cocoa regions are demarcated into seven administrative regions to facilitate extension activities.

Note 2. See Kolavalli & Vigneri (2011) and Gyimah-Brempong & Apraku, (1987) for detailed history of price policy.