Journal of Economics and Sustainable Development
ISSN 2222-1700 (Paper) ISSN 2222-2855 (Online)
Vol.14, No.8, 2023

Relative Producer Price, Cross Border Smuggling and Productivity in Ghana's Cocoa Industry

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Abstract
Producer price differences between Ghana and its neighbours for an internationally traded commodity such as cocoa can be a recipe for smuggling. Against this background, price distortions can explain reported low productivity of cocoa in Ghana. This paper investigates the effect of price differences between Ghana on one hand and Cote d'Ivoire and Togo on the other hand on cocoa yields for Ghana using an autoregressive distributed lag (ARDL) cointegration model based on time series data spanning 1961 through 2017. We also estimates the volumes of cocoa smuggled from Ghana between 2000 and 2017. The study finds higher foreign producer price relative to Ghana reduces yields in cocoa in the short run, but improves on yields in the long run. Nationally an average of 40 kilograms per hectare of cocoa was lost to the country through smuggling between 1999/2000 and 2016/17. The study observes efforts has been made since 2001 to improve input support to the industry while enhancing price incentives to support productivity growth. Despite such interventions in the past two to three decades, illegal cross border trading appears to persists.
Keywords: Producer price, Relative price, Smuggling, Productivity, Cocoa
DOI: 10.7176/JESD/14-8-08
Publication date: April 30th 2023

1. Introduction

The importance of cocoa to the Ghanaian economy cannot be overemphasized. The contribution of agriculture to the country's export revenues is largely dominated by cocoa even amid current government efforts towards diversification within agriculture. Ghana's exports are largely accounted for by gold, oil and cocoa beans with 78.1% of export revenues in 2017 (Bank of Ghana, 2018). However, of the three, cocoa is the second largest foreign exchange earner after gold contributing over $2 billion to export revenues annually (Ghana Cocoa Board [COCOBOD], 2016; Bank of Ghana, 2019). The sector also accounts for 20-25% of total foreign exchange earnings (World Bank, 2018), being the largest non-resource export with 7% contribution to GDP. The cocoa industry presents job opportunities for skilled and unskilled labour in rural and urban Ghana with over one million Ghanaians projected to be employed in the sector (World Bank, 2018).

Sustainable production of cocoa relies on three key pillars of economic viability, productivity growth, and ecological sustainability (Wessel & Quist-Wessel, 2015). The economic viability of cocoa production derives its strength from its producer price. Price signals return to cocoa relative to other crops and nonfarm activity, which plays a crucial role in the adoption of new innovations to production, maintenance of cocoa farms and effective harvesting of the crop (Bulir, 2002). The price of cocoa locally is set by the Producer Price Review Committee (PPRC) of Ghana with a key objective of stabilizing farmer incomes while ensuring competitiveness (Kolavalli & Vigneri, 2011). PPRC aims to offer farmers 70% of net free on board (FOB) price of cocoa as producer price. The net FOB price is derived from the export price of cocoa less industry operating and marketing costs, which represents about 15% of the value of the crop (World Bank, 2018). This pricing scheme is indicated as being distortionary to the incentive process in cocoa farming given that producers often receive less than 70% of the real FOB price (World Bank, 2017). The divide between international price of the commodity and the price offered to producers can be a major disincentive to production. Further to this given that the Ghanaian cocoa farmer crop price is often lower than that of neighbouring cocoa producing countries such as Cote d'Ivoire (CDV) and Togo, an incentive to smuggle is created (Amankwah-Amoah, Debrah, & Nuertey, 2018). Ghanaian cocoa farmers close to the border with these two countries often divert some produce away from official buying agents of COCOBOD in response to price distortions (Bulir, 2002; Paglin, 1994; Deardorff & Stolper, 1990). This loss of crop across the border distorts estimates of crop output. Smuggling is reported as explaining the persistence of official output below or above its projected capacity with studies such as Bulir (2002), May (1985) and Franco (1981) presenting evidence to the fact that cocoa output response to relative price.

Productivity increases remain the bedrock to sustainable investment in cocoa production. The country's reported yields are amongst the lowest of growing countries at an average of 400-450 kg per hectare despite several efforts by COCOBOD to improve on yields (Wessel & Quist-Wessel, 2015; Nalley, Dixon & Popp, 2014). Research often ascribed productivity in the crop to agroclimatic and socio-economic factor (Dormon, Van Huis, Leeuwis, Obeng-Ofori, & Sakyi-Dawson, 2004). Economic factors encapsulated by the price of the crop, affects crop productivity through maintenance (Bulir, 2022). We extend on this by examining the effect of relative price on the crop productivity, premised on the assumption that COCOBOD's effort at addressing productivity concerns are not yielding the desired outcomes due to relatively lower price incentives which encourages smuggling. To model productivity response in cocoa we control for often missing indicator variables such as labour and law enforcement. Cocoa production in Ghana is labour intensive, thus accounting for labour cost is essential to modeling productivity response. Also, literature has established that price differential is a catalyst for smuggling, we seek to interrogate how law enforcement working through the smuggling channel contributes or otherwise to explain yields in cocoa. Further to this the study will estimate yield losses to the cocoa industry through smuggling, this remains unreported in related literature on the industry. Finally, we apply an ARDL cointegration technique which allows for different lags for the influencer variables. Cocoa is a perennial crop and as such has time lags in the transmission of inputs to output. For instance, hybrids seedling has an average time lag of three to four years to start fruiting. The flexibility of applying different lag structures better captures the dynamics of the crop productivity response.

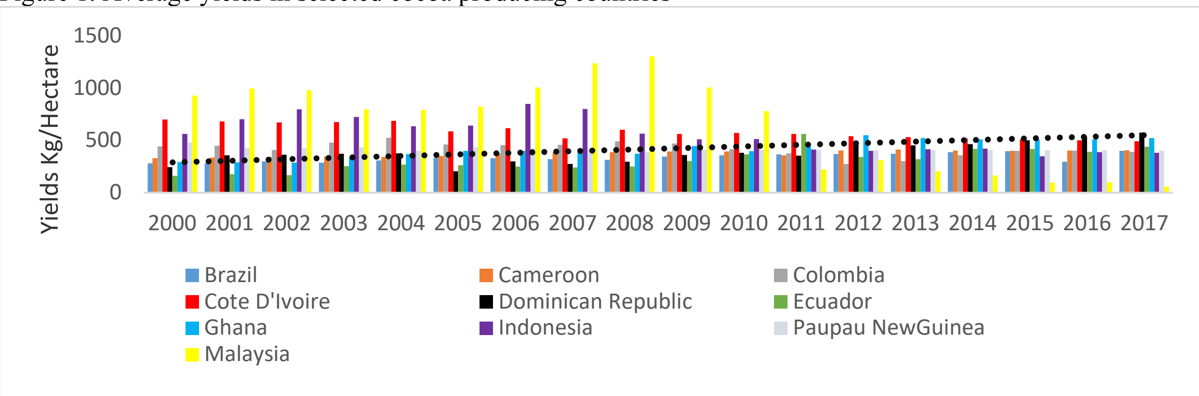
The rest of the paper is organized as follows. The next section reviews cocoa productivity and pricing. Section three conducts a theoretical and empirical literature review. Sections 4 and 5 present the methodology and results, respectively. Conclusions are offered in section 6.

2. Stylized Facts

2.1 Productivity in Cocoa

The production of cocoa in Ghana is largely accounted for by about 1.5 million small holder farmers cultivating an average of 1-3 hectares of land (COCOBOD, 2018). Two main cocoa varieties, the *Amazon and Amelonado*, were previously grown. The hybrid variety which is early bearing, high yielding and disease tolerant have been introduced to farmers since 1984, with progressively more farmers shifting to this new variety. Aneani & Ofori-Frimpong (2013) maintains that despite the adoption of high yielding cocoa variety by farmers, yields in Ghana remain relatively lower compared to other countries such as Indonesia, Malaysia and Cote d'Ivoire with Ghana overtaking the three however, from 2016 to 2017 (see figure 1). Average productivity per hectare of cocoa land is 400-450 kilograms (kg) about one tenth of yields achieved on experimental farms at Cocoa Research Institute Ghana (CRIG) stations. Production increases are therefore driven by expansion into virgin forest land of Western and Brong-Ahafo regions of the country (Baah, Anchirinah, & Amon-Armah, 2011).

Figure 1. Average yields in selected cocoa producing countries

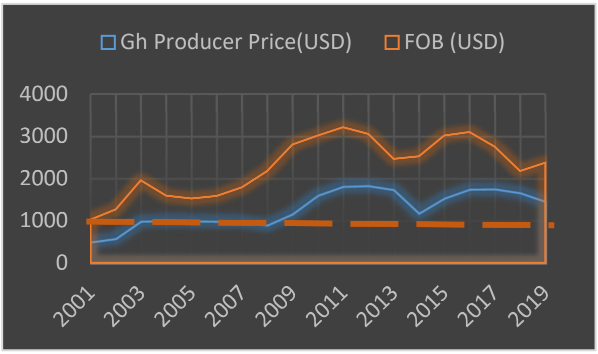


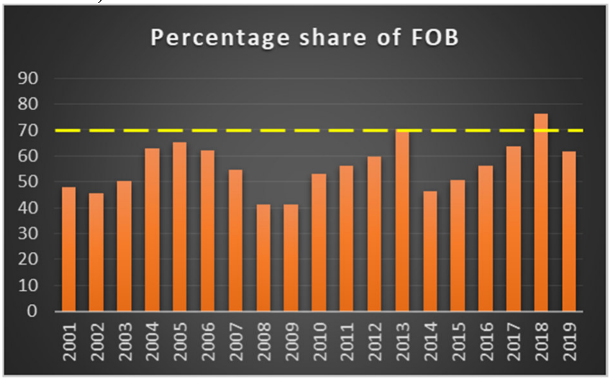
Source: Authors construction from FAO, 2019

2.2 Cocoa Producer Price

Price is the key indicator of economic profitability and productivity. Prior to 1939, the price of cocoa had been determined by market forces (Kolavalli, Vigneri, Maamah & Poku, 2012). Intense fluctuations in international prices with its associated financial stress on farmers in 1935/36 led to the setting up of the Cocoa Control Board of West Africa to ensure stable prices with predetermined producer price each crop season. Under the cocoa rehabilitation project of 1987 government renewed its commitment to give a larger share of the Free on Board (FOB) price to farmers with an initial target of 55% and later changed to 70% within the cocoa sector development strategy (Kolavalli et al., 2012). The Board in collaboration with government sets up the producer price review committee (PPRC) in 1983/84. This multi-stakeholder group is made up of COCOBOD, Government (represented by the Ministry of Finance), farmer representatives, transporters and buyers (Bymolt, Laven, & Tyzler, 2018; Darkwah, & Verter, 2014). The PPRC decides on the yearly producer price based on further consultation with a technical committee comprising of Institute of Social, Statistical and Economic Research (ISSER), University of Ghana and Bank of Ghana. The technical committee is responsible for the projection of FOB price, exchange rate and crop size. The Central Bank and Cocoa Marketing Company (CMC) forecast expected FOB price and exchange rates, while the crop size is forecasted by the COCOBOD based on pod count (Kolavalli et al., 2012). The key objective of this pricing system is to maintain stable farm incomes. However, stability in incomes is achieved on the back of high implicit taxation by the Board. This is because the producer price though above 70% of net FOB is largely below 70% of actual FOB price because of the deduction of industry cost in the computation (see figure 2). The World Bank in 2018 points out such pricing and taxation schemes deprives producers of a fair share of the export price of cocoa. Also, with fixed prices yearly, international price gains within the crop year are lost to the farmers. One may argue that the Board also bears downward pressures on crop price from the international market while still maintaining local producer prices. Even though this threat may exist, the crop is largely sold by forward contracts which provides some insulation against international price fluctuations.

Figure 2. Cocoa producer price and actual FOB price (2001-2019)





Source: Authors computation from ICCO and Bank of Ghana

3. Review of Literature

Smuggling is an informal/illegal trade that escapes the purview of regulatory controls and the national accounts (Aryeetey 2015; Loayza, 1997). The activity is considered a regular phenomenon in many countries around the word, though being more prevalent in African countries with considerable magnitude (Pace, Bouët, & Glauber, 2019). Smuggling in the African continent is a natural consequence of economic, cultural and ethnic relationships that transcend national boundaries (Little, 2010). It originates from long standing relationships and indigenous trade routes predating colonial boundaries, and often conducted amongst people of the same ethnic grouping who have a lot of commonalities socially and culturally. The phenomenon is also a consequence of the existence of different taxes for the same good between neighbouring countries. Schneider, Buehn, & Montenegro (2010) believes illegal activity is an outlet from the intensity of regulation and the complexity of regulation that make the cost of undertaking legal business costly. Formally traded goods might be subject to complex and non-transparent/harmonized regulatory and custom procedures, that are also time consuming, which incites business to avoid formal trade to escape such complexities (Hoffmann & Melly, 2018). In other instances, smuggling may be a response to industry specific institutional controls as in the existence and operations of marketing boards that cause price disparities across countries exemplified in Ghana and Cote d'Ivoire (Deardorff & Stolper, 1990; Lesser & Moise-Leeman, 2009).

The relative price of a good is its price in terms of another good and expressed as a ratio between the prices of any two goods. Relative price has predictive, systemic and appreciable effect on trade flow (Reinhart 1995), and can emanate out of differences in the taxation of the same good or service between neighbouring countries (Leal, Lopez-Laborda & Rodrigo, 2010). Cross-border trade is motivated by the systematic price differences across jurisdictions caused by differences import tariffs and taxations and exchange rate changes (Friberg, Steen & Ulsaker, 2019).

Typically, as in the case of cocoa marketing in Ghana, with regulated yearly price, relatively higher price in CDV leads Ghanaian cocoa farmers to sell their produce to the foreign country affecting national volumes. According to Heltberg & Tarp (2002) there is a two-step decision making process in response to relative price. In the first instance, farmers decide, whether to participate in the market when price are different and following which they decide how much to sell. In this regards Bulir (2002) states that cocoa farmers in Ghana investment decision in response to relative prices are twofold. When price increases, the farmer first decides if that increase in price is sufficient to meet maintenance while leaving some margin of profit. Sufficient price incentive will cause the farmer to increase maintenance which subsequently will improve output and generate more revenue. If the price increase cannot meet maintenance, then they will reduce farm maintenance more especially periodic harvesting which reduces yields. Following this initial decision to improve on maintenance or otherwise the farmer then considers price across the border to determine the relative profitability of their enterprise which determines the market to which they sell their produce.

Recent studies on smuggling of cocoa in Ghana is given by Amankwah-Amoah et al. (2018) who investigates the phenomenon using field studies with specific reference to the case of Western and Brong-Ahafo regions of Ghana. The focus of the research was to examine the effect of institutional weakness on the smuggling trade. They find deplorable road network as the key driver of coca smuggling from Western region to CDV. In addition, farmers received price for their crop in convertible currency (i.e., the CFA franc) which is an attraction.

Prior to Amankwah-Amoah et al. (2018), Kumar (1973) first presents an empirical study on cocoa smuggling in Ghana using non parametric methods. The study states about 57,000 metric tonnes of cocoa beans were smuggled out of the country in 1970/71 crop year under a well-organized trade involving large truck loads. According to Franco (1981) smuggling of cocoa can flow either from Ghana to her neighbours and from neighbouring CDV and Togo to Ghana. They estimate about 45,000 metric tonnes representing 17% of total production was smuggled out in 1977/78 crop year.

May (1985) finds as at 1982 there was not enough incentive for farmers to sell to CMC, hence only 70% of cocoa produced was sold officially. The low real producer price was a disincentive both for planting of new trees and proper maintenance of farms, given that Ghana's producer price was about 30% of CDV's in 1982 at the black-market. Fosu (1992) also finds 10% increase in the value of CDV producer price relative to Ghana leads to a 1.7 % decline in the Ghana's export volumes. Bulir (2002) updates previous work using cointegration techniques to model cocoa output response to relative price and obtains supply elasticity of 0.6 in the long run. Short term elasticities were insignificant interpreted to reflect the medium-term character of farmer's investment decisions in relation to relative prices. This study advances on the above literature by modeling yield response to relative price and further to this adopting an ARDL cointegration technique

4. Methodology

4.1 Theoretical Model

The agricultural investor makes planting decisions in one season, however, the total crop and prevailing price at harvest is observed in the next season. Investment decision are therefore formed based on expectation of price during harvest period. While expectations can be rational, adaptive or naïve, Tripathi (2009) indicates farmers in developing countries may not be able to effectively adopt rationality in expectation formation. This is largely because of their low educational level and the lack of all essential information on prices and other inputs of production to guide the rational choice (Muchapondwa, 2008).

This study assumes the cocoa farmer is not naïve about prices, their price forecast is based on a trend of past price allowing for the use of Nerlovian adaptive price expectations and a partial adjustment model. The partial adjustment model stipulates actual yields will differ from desired yields given lags in transmission of input into output defined by the perennial nature of cocoa production.

Similar to Utuk (2014), Ranjan Paltasingh & Goyari (2013) equilibrium yields in cocoa is expressed to be a function of expected prices and other exogenous supply shifters

$$Q^{e}_{c,t} = a + bP_t^{e} + cZ_t + v_t \tag{1}$$

$Q^{e}_{c,t}$, is expected/equilibrium cocoa yields, P_t^e is the expected price, Z_t set of other exogenous factors v_t the error term, a, b, c are the coefficient of the model

The relationship between current realized yields and long run equilibrium yields is given by a difference equation which assumes that actual yields given the transmission lags will deviate from the desired by some fraction (the adjustment factor). Thus, change in yields between two periods is proportionate to the difference between expected yields in the current period and the actual yields in the previous period:

$$Q_{c,t} - Q_{c,t-1} = \rho[Q^{e}_{c,t} - Q_{c,t-1}] \qquad 0 < \rho \leq 1 \tag{2}$$

Where, $Q_{c,t}$ is the actual cocoa yields at time t, $Q_{c,t-1}$ actual cocoa yields at time $t-1$ and ρ is the adjustment factor

Substituting equation 1 into 2 gives equation 3

$$Q_{c,t} - Q_{c,t-1} = \rho[a + bP_t^{e} + cZ_t + v_t - Q_{c,t-1}] \tag{3}$$

Expanding into equation 4

$$Q_{c,t} = \rho a + \rho b P_t^{e} + \rho c Z_t + (1-\rho)Q_{c,t-1} + \rho v_t \tag{4}$$

Domestic cocoa prices are set each year by COCOBOD based on projections of future and past international prices. The producer also expects price for the current crop year to be based on past producer price and prevailing international prices. Current period forecast is adjusted for error in forecast of price in previous period by some margin of the difference between actual and past forecast prices, indicated by Nerlove and Bessler (2001) as:

$$p^{e}_{c,t} - p^{e}_{c,t-1} = \delta[p_{c,t-1} - p^{e}_{c,t-1}] \tag{5}$$

Where $p^{e}_{c,t}$ is current cocoa price expectations, $p^{e}_{c,t-1}$ past cocoa price expectations and $p_{c,t-1}$ actual past cocoa prices, δ is the coefficient of expectation. To solve equation 5, it is transformed into a reduced form, using a distributed lag model with Koyck lags where the coefficients decline exponentially (Utuk, 2014). With Koyck distribution equation 5 is equivalent to 6, where expected price is a weighted moving average of an outturn of past price with weights declining towards zero. The parameter δ , is the rate of decay and $1-\delta$ is the speed of adjustment (expectation coefficient). The expectation coefficient lies between 0 and 1, for a value close to one, prices in the distance future have some impact on current yields, whereas for values close to zero, past price have little impact on current yields.

$$p^{e}_{c,t} = \delta p_{c,t-1} + (1-\delta)\delta p_{c,t-2} + (1-\delta)^2 \delta p_{c,t-3} + \dots \qquad (6)$$

Assuming $\delta = 1$ and substituting into equation 6. This assumption is made premised on the fact that it takes 3-5 years from initial investment based on price projection to harvesting first crop of cocoa using hybrid seedlings. Thus, price in the distant future has effect on current yields and output.
Substituting equation 6 into 4 gives equation 7

$$Q_{c,t} = \rho a + \rho b P_{ct-1} + \rho c Z_{c,t} + (1-\rho) Q_{c,t-1} + \rho v_t \qquad (7)$$

Simplifying into equation 8

$$Q_{c,t} = \beta_0 + \beta_1 P_{c,t-1} + \beta_2 Z_{c,t} + \beta_3 Q_{c,t-1} + u_t \qquad (8)$$

Where $\beta_0 = \rho a$, $\beta_1 = \rho b$, $\beta_2 = \rho c$, $\beta_3 = (1-\rho)$ and $u_t = \rho v_t$

The short run elasticities are given by the coefficients β_i except that of the lagged dependent variable, while the long run elasticities are obtained by dividing the short run coefficient by the coefficient of adjustment $(1-\beta_3)$ i.e., $\frac{\beta_i}{1-\beta_3}$

The long run coefficients are derived as follows
if

$$\begin{array}{llll} \beta_3 = (1-\rho), & \beta_0 = \rho a, & \beta_1 = \rho b, & \beta_2 = \rho c \\ \rho = 1-\beta_3 & \beta_0 = (1-\beta_3) a & \beta_1 = (1-\beta_3) b & \beta_2 = (1-\beta_3) c \\ & a = \frac{\beta_0}{(1-\beta_3)} & b = \frac{\beta_1}{(1-\beta_3)} & c = \frac{\beta_2}{(1-\beta_3)} \end{array} \qquad (9)$$

Where a, b and c represents the long run coefficients.

4.2 Empirical Model

Smuggling of cocoa in Ghana is modelled following May (1985). The model assumes recorded production in cocoa as given by cocoa sales to CMC is a fraction of unboserved national production.

$$Q^{C}_{A} = C^{s}(Q^{C}_{T}) \qquad (10)$$

Q^{C}_{A} is reported cocoa purchases by CMC, C^{s} is the fraction sold to CMC, Q^{C}_{T} is total unobserved cocoa production
Once cocoa is produced, the farmer makes the choice on which market to sell their goods. They can sell directly to CMC for the official produce price or sell outside the country for the foreign producer price. The fraction of cocoa sold is a function of relative prices in Ghana and neighbouring cocoa producing countries.

$$C^{s}(P^{r}) \qquad (11)$$

Equation 10 is rewritten as

$$Q^{C}_{A} = C^{s}(P^{r}) Q^{C}_{T} \qquad (12)$$

Smuggling involves cost which is accounted for by the risk of detection, therefore C^{s} is also a function of law enforcement. Q^{C}_{T} in the equation 12 is a factor of some covariate such as the domestic producer price and other supply shifters. Introducing the covariates of Q^{C}_{T} and transforming into natural logs actual yields in cocoa is given in equation 13

$$\ln Q^{yield}_{At} = a_0 + a_1 \ln P^{d}_{t-1} + a_2 \ln Q^{yield}_{At-1} + a_3 \ln P^{r}_{t} + a_4 \ln M^{p}_{t} + a_5 \ln R_t + a_6 L_t + a_6 \ln G_t + a_8 \ln C^{t}_{t} + a_9 O^{p}_{t} + a_{10} Tec_d + \upsilon_t \qquad (13)$$

Where Q^{yield}_{At} , is the reported yields for cocoa at time t , P^{d} is the lag of domestic producer price, Q^{yield}_{At-1} , lag of cocoa yields, p^{r}_{t} ,relative price, M^{p}_{t} , price of maize L_t labour cost, G_t GDP growth rate, C^{u}_{t} , law enforcement, R_t (annual rainfall alternated with temperatures), Tec_d dummy for technology (comprising of three technology variables such as hybrid seedlings, Cocoa Disease and Pest Control (CODAPEC or mass spraying) and High

Technology (Hi-Tech fertilizer programme) , O_t^p dummy for cocoa price reforms and υ_t the error term.

4.3 Estimation Methods

The ARDL/bounds cointegration technique of Pesaran et al. (2001) allows for an unrestricted inclusion of the lagged levels of the regressors presented in a single equation framework consisting of both long run and short run dynamic equation such as

$$\Delta y_t = \delta + \sum_{i=1}^{p} \theta_i \Delta y_{t-i} + \sum_{i=0}^{q} \phi_i \Delta x_{t-i} + \gamma_1 y_{t-1} + \gamma_2 x_{t-1} + v_t \qquad (14)$$

Where θ_i and ϕ_i are the short run coefficient and (γ_1, γ_2) are the long run coefficients. Expanding to include selected covariate, final model for estimation is presented in equation 15

$$\begin{aligned}\Delta Q_t^{yield} &= \varsigma_0 + \sum_{i=1}^{p} a_i \Delta Q_{t-1}^{yield} + \sum_{i=0}^{q} \alpha_i \Delta P_t^D + \sum_{i=0}^{q} \beta_i \Delta P_t^r + \sum_{i=0}^{q} \chi_i \Delta M_t^p + \sum_{i=0}^{q} \phi_i \Delta R_t \\ &+ \sum_{i=0}^{q} \delta_i \Delta C_t^u + \sum_{i=0}^{q} \gamma_i \Delta Tec_t + \sum_{i=0}^{q} o_i \Delta O_t^p + b_1 Q_{t-1}^{yield} + b_2 P_{t-1}^D + b_3 P_{t-1}^r + b_4 M_{t-1}^p \\ &+ b_5 R_{t-1}^n + b_6 C_{t-1}^u + b_7 Tec_{dt} + b_8 O_{dt}^p\end{aligned} \qquad (15)$$

p, q , are the lags of the dependent and independent variables, Δ is the changes, other variables are as already defined. Table 1 and 2 presents the summary of data, expected signs and sources.

Table 1. Data summary

Variables	Mean	Std. Dev.	Max	Exp. Sign	Scale
Yields	329.65	95.47	549.5		Kilogram/Ha
Real Producer Price	1,271.10	639.87	3,270.31	+	Price Gh¢/CPI
Relative Price (CDV/GH)	1.10	0.32	1.90	-	USD (CDV/GH)
Relative Price (Togo/GH)	1.72	0.66	3.83	-	USD (Togo/GH)
Real Maize price	486.95	129.40	749.68	-	Price/CPI
Annual rainfall	92,644.96	20,404.71	117,700	+-	Millimeter
Minimum wage	39.42	31.24	196	-	USD
Average temperature	27.37	0.48	28.19	-	Degree Celsius
Dummy CODAPEC	0.28	0.45	1	+	0, 1
Dummy Hi-Tech	0.26	0.44	1	+	0, 1
Dummy hybrids	0.14	0.35	1	+	0, 1
Custom	0.35	0.26	0.98	+	Custom/population (1000)
Dummy price reform	0.63	0.49	1	+	0, 1

Table 2. Data sources

Cocoa Yields	Food and Agriculture Organization (FAO)
Producer price	International Cocoa Organization (ICCO)
CPI	Federal Reserve Bank of St. Louis
Exchange rate	World Bank, World Development Indicators (WDI)
Rainfall	Ghana Metrological Assembly
Custom staff	Ghana Customs, Exercise and Preventive Services
Cocoa output	COCOBOD
Cultivated cocoa land	COCOBOD
Relative price	Generated by author
Price of Maize	FAO
Wages	Africapay.org
Temperature	World Bank
GDP Growth rate	WDI
Data Period	1961-2017

5. Results

5.1 Unit Roots Testing

ARDL cointegration allows for the testing of long run relationship with both I (0) and I (1) variables, however the model will crash with I (2) variables. Hence we test for the order of integration of the time series using first an augmented Dickey Fuller (ADF) and validating this with Kwiatkowski, Phillips Schmidt & Shin (KPSS) unit root test. For an ADF unit root test, the null hypothesis is non-stationarity while for KPSS the null is stationarity. Test results are similar for both the ADF and KPSS test. Four variables i.e., relative prices (CDV, Ghana), relative price

(Togo, Ghana), temperatures and growth rates were stationary. The rest of the indicator variables are stationary after first differencing. The mix of stationarity and non-stationary variables confirm the appropriateness of applying an ARDL model to the data.

5.2 Bounds Testing for Long Run Relationship

Pesaran et al. (2001) bound cointegration testing is based on a Wald test or F-statistic, in which they provide critical values to evaluate test results. However, Kripfganz & Schneider (2018) using surface regression produce finite sample and asymptotic critical values with their associated p-values which are considered superior. The paper adopts Kripfganz & Schneider (2018) critical values to evaluate test results.

Four different formulations for cocoa yield response in Ghana are tested. The first model controls for the major indicator variables discussed under the methodology. Subsequently other specifications are presented which control for specific variables of key interest. For instance, model 2 controls for temperature given the sensitivity of cocoa to high temperatures. Also model 3 accounts for policy reforms (price policy). Model 4 leaves out all agro-climatic factors to account for only price effect, growth and technology. In all the model's cocoa producer price and relative producer price are controlled for as they remain the key indicator variables of interest in the study. Post estimation analysis will later be undertaken to determine which of the model formulation better explain yield response in cocoa.

ARDL bound cointegration test models a unique long run relationship. We thereby model each of the indicator variables for each specification both as endogenous and exogenous variables to identify that unique long run relationship as shown in tables 3 through to 6. The selected maximum lags are 3, 4, 3 and 3 for each model respectively using Akaike information criteria (AIC). The ARDL bound results confirms a long run relationship between yields and selected explanatory variables. The null in each table is no level relationship.

Table 3. Model 1

Dependent variables	F-statistic
Yields	6.175
Producer prices	3.172
Relative Price	4.057
Maize price	2.367
Wages	3.297
Rainfall	2.649
Custom to Population ratio	0.787
Dummy price policy	1.493
Dummy Hi-Tech	1.072

Table 4. Model 2

Dependent variables	F-statistic
Yields	5.906
Producer price	2.155
Relative price	2.247
Rainfall	1.441
Wages	1.505
Temperatures	3.039
Technology	1.474

Table 5. Model 3

Dependent variables	F-statistic
Yields	6.006
Producer price	2.747
Relative price	3.963
Rainfall	2.261
Custom to Population	1.478
Dummy Hi-Tech	2.908
Dummy price policy	2.759

Table 6. Model 4

Dependent Variable	F-statistic
Yields	**6.536**
Producer price	1.766
Relative price	2.414
Maize price	2.237
Custom to population	1.057
GDP	3.593
Dummy hybrid	1.536
Dummy CODAPEC	1.253

5.3 Long and Short Run Estimates of Yield Response in Cocoa

The bound cointegration test has confirmed the existence of a long run relationship. We then present estimate of the long run and short run elasticities in table 7 through to 9. The computation of the long run elasticities is indicated in the methodology. Long run elasticities in table 7 are computed from table 8 with insignificant coefficients omitted while the short estimates are given in table 9. The outcomes for the four estimates are discussed concurrently. Beginning with yields response to price, the study finds that cocoa yields respond positively to increases in producer price for the long and short run. This is because price acts as a catalyst to enhancing farm maintenance for improved productivity. A percentage increase in price improves on productivity by 0.4% to 0.9% in the long run. Cocoa yields also responds to price in the short run at lag two with a percentage price increase improving productivity by 0.3%. These findings reflect the perennial nature of the crop, in that investment decisions crystalize over a longer time horizon.

The response of cocoa yields to relative price between Cote d'Ivoire (CDV) and Ghana was significant in model 2 through to 4, and significant between Togo and Ghana for model 1. The effect of relative price on productivity is explained premised on the submission by Bulir (2002) who points out relative price induces the farmer to make independent decisions on farm maintenance and sale of crop. In the first instance given domestic producer price, the farmer will improve on farm maintenance and harvesting if the price is attractive. Afterwards, the farmer considers neighbouring country producer price because of proximity to such markets to decide on which market to sell their produce. This is especially so because same families live across the borders with farm land often crossing both boundaries. The results for this study show increasing CDV price relative to Ghana improves on productivity by 0.31% to 0.89% in the long run given improved farm maintenance and the opportunity for short term diversion of the crop to the foreign market. The short run estimates thereby reveal decreasing cocoa productivity as producer price increases in CDV relative to that of Ghana with an elasticity of 0.11 to 0.40. Similar studies such as Fosu (1992) obtains an elasticity of cocoa exports response to relative prices between CDV and Ghana of 0.27.

Cross price effect is significant and negative for both the long run and the short run. In the long run productivity response to maize price is elastic in model1, and inelastic at 0.65 in model 4. Thus, cocoa productivity reduces as maize price increases, typically linked to diversion of inputs to maize production when its price is more attractive. In the short run, lag one maize price are positive to cocoa productivity largely because maize prices are indicative of general food crop prices. Increasing agricultural product prices acts as a signal of general economic activity and of future higher prices for agricultural goods encouraging cocoa maintenance towards that future expected price. Stryker (1990) and Hattink (1998) obtain cross price elasticity for cocoa of 0.14 and 0.05 respectively. These studies however, did not differentiate between the short and the long run.

Using rainfall data from cocoa growing districts, the results confirm a positive response of yields to rainfall in the long run and the short run with an elasticity is 0.79 for the long run, reducing to between 0.6 and 0.4 for the first and second lag in the short run estimates. The results confirm the dual effect of rainfall on productivity as indicated by Bateman (1965) who finds cocoa production in Ghana falls when humidity is very high due to disease outbreak. In this study, rainfall has a significant and negative effect on the crop in the long run for models 1 and 2 due to excessive rainfall, however being mostly positive to crop productivity in the short run.

Increasing labour wages improves on crop productivity in the long, however reducing productivity in the short run. These findings are supported by the submissions of Ninan (1984) who says labour availability for agricultural production is ensured by increasing wages especially during peak periods such as harvesting, Emanuel & Harrington (2021) also point out increasing pay for low wage earners improves on firm productivity by affecting the quality of labour selection and behaviour of existing labour. Cocoa production is highly labour intensive especially in terms of temporal labour for harvesting and processing of the beans for drying. Increasing wages improves on the quality and output of work by existing farm labourer enhancing productivity. At the same time those outside the labour force are enticed to join providing more labour for cocoa production. In the short run however, farmers may not immediately have the resource to employ the required labour for farm maintenance when labour cost rises, reducing maintenance and thereby productivity on farms.

Productivity in cocoa is responsive to law enforcement for the long and short run. In the long run increasing enforcement at the borders positively contributes to reported productivity with an elasticity of 0.27 and 0.17 in model 3 and 4. This is facilitated by halting crop losses through the national borders. In the short run the effect of law enforcement is negative and significant, largely because smuggling is not a long-term fixed activity, it is more of a sporadic activity that takes advantage of slight breaches to the intensity of supervision at the borders. Temporal relaxation of supervision at the borders allows for smuggling affecting the volumes of cocoa reported for Ghana. In the long run, law enforcers can predict the movement of smugglers and work to effectively control the flow of the trade by blocking their travel routes thus reducing crop losses.

All technology dummies such as hybrid seedling, CODAPEC and Hi-Tech were positive and significant for all models. This points to the fact that major productivity shift has taken place in the cocoa industry as opposed to Baah et al. (2011) submission that recent increases in production were driven by expansion in cultivated land rather than productivity gains. The response of cocoa yields to price reforms is positive and significant with an elasticity of 0.2 to 0.7. Related studies such Bulir (2002) did not find any significant effect of policy changes during the ERP on cocoa output.

Also, past yields in cocoa do not explain current yields. This finding is supported by the submission of Kozicka, Tacconi, Horna & Gotor (2018) who says enabling factor to productivity such as price and climatic conditions vary in each crop year, preventing the effective establishment of a trend that relates past yields to the current. The speed of adjustment of cocoa yields from short run deviations to the long run equilibrium levels given by the error correction term are instantaneous for the first and fourth model and above 60% in models two and three. Instantaneous speed of adjustment may indicate some level of serial correlation in those two models which will be investigated with some diagnostic test.

Table 7. Long run elasticities of yield response

Variables	Model 1	Model 2	Model 3	Model 4
Producer price	0.987		0.462	
Relative price (CDV/GH)		0.889	0.856	0.306
Relative price (Togo/GH)	0.093			
Rainfall	-0.585	-1.200	0.791	
Maize Price	-1.123			-0.658
Wages	0.295			
Custom			0.266	0.169
Dummy price reform	0.249		0.775	
Dummy Hi-tech			0.643	
Technology		0.754		
Dummy Hybrids				0.385
Dummy Codape				0.556

* Elasticities are calculated from table 4.7 with insignificant coefficient omitted

Table 8. Coefficient estimates of long run relationship

Variables/Dependent (Yields)	Model 1	Model 2	Model 3	Model 4
Producer price	1.03***	-0.228	0.341***	0.060
	(0.145)	(0.280)	(0.088)	(0.077)
Relative price (CDV/GH)	-0.023	0.720***	0.632***	0.320***
	(0.087)	(0.279)	(0.114)	(0.092)
Relative price (Togo/GH)	0.097*	0.135		-0.039
	(0.052)	(0.135)		(0.358)
Rainfall	-0.610**	-1.221*	0.584***	
	(0.247)	(0.715)	(0.138)	
Maize Price	-1.453***			-0.689***
	(0.198)			(0.075)
Wages	0.364***	-0.265		
	(0.074)	(0.173)		
Custom	0.035		0.196***	0.174***
	(0.064)		(0.061)	(0.044)
Dummy price reform	0.240***		0.572***	
	(0.093)		(0.145)	
Dummy Hi-tech	0.032		0.468***	
	(0.105)		(0.0103)	
Temperature		-0.137		
		(3.679)		
Technology		0.762*		
		(0.306)		
Growth rate				-0.003
				(0.005)
Dummy Hybrids				0.402***
				(0.077)
Dummy Codapec				0.581***
				(0.102)
Intercept	13.75**	7.402**	-2.358	10.031***
	(5.190)	(3.983)	(1.452)	(1.541)
Adjusted R^2	0.597	0.435	0.456	0.559
F-statistic	19.20***	18.67***	20.26***	27.26***

Note: Figures in brackets are the standard errors significance levels given by *** 1%, ** 5% * 10%

Table 9. Short run dynamic relationship

Variables/Dependent (Yields)	Model 1	Model 2	Model 3	Model 4
Error Correction Term	-1.043***	-0.638***	-0.738***	-1.032***
	(0.174)	(0.121)	(0.123)	(0.155)
Lag1 Δ Yields	0.0333			
	(0.139)			
Δ Producer price	-0.0433		0.204	0.193
	(0.175)		(0.204)	(0.184)
Lag1 Δ Producer price	-0.717***		-0.479**	-0.410*
	(0.233)		(0.219)	(0.212)
Lag2 Δ Producer price			0.350*	0.277
			(0.175)	(0.176)
Δ Relative price	-0.164*	-0.274***	-0.401***	-0.144**
	(0.0956)	(0.0870)	(0.107)	(0.0689)
Lag1 Δ Relative price (CDV/GH)	-0.141*	-0.248***	-0.254***	-0.0910
	(0.0787)	(0.0832)	(0.0797)	(0.0567)
Lag2 Δ Relative price (CDV/GH)	-0.116	-0.130*	-0.145*	
	(0.079)	(0.0662)	(0.0772)	
Lag1 Δ Relative price (Togo/GH)	-0.116*	-0.007		0.085
	(0.056)	(0.060)		(0.084)
Δ Rainfall	0.517		-0.260	
	(0.309)		(0.162)	
Lag1 Δ Rainfall	0.634**			
	(0.277)			
Lag2 Δ Rainfall	0.439**			
	(0.212)			
Δ Maize price	0.736**			0.535***
	(0.277)			(0.156)
Lag1 Δ Maize price	0.567***			0.465**
	(0.200)			(0.168)
Lag2 Δ Maize price	-0.0759***			0.516***
	(0.0206)			(0.171)
Δ Wages	-0.228***			
	(0.0679)			
Lag1 Δ Wages	-0.174***			
	(0.0462)			
Δ Custom	0.0181			-0.0629
	(0.0854)			(0.0755)
Lag1 Δ Custom				-0.145*
				(0.0776)

Note: Δ indicates first difference of variables

5.4 Diagnostic Test

Even though 4 models were estimated with varying control variables, the performance of each model is investigated to facilitate the selection of the most appropriate model of cocoa yields response. Key test carried out include a serial correlation using the Breusch Godfrey Lagrange multiplier test (LM), homoscedasticity (constancy of variance) using the Breusch Pagan test, normality using the Jarque Bera and a multicollinearity test using the variance inflation factor, Again, we test for the appropriateness of the specified model using Ramsey specification test. The results are given in table 10, with no serial correlation detected for models 2 through to 4. Model 1 however, suffers from serial correlation. All models however exhibit normality in errors with constant variance. There is no indication of omitted variable which shows the models were well specified. Also, Multicollinearity can be adequately rejected confirming parameters of the model are stable. Given the performance of explanatory variables, the root mean square error (RMSE) and the AIC, model 3 was selected as the appropriate model of cocoa yield response.

Table 10. Diagnostic test

Statistic	Model 1	Model 2	Model 3	Model 4
a) Serial correlation	8.42[0.01]	2.884[0.090]	0.120[0.729]	0.658[0.417]
b) Heteroscedasticity	0.00[0.9916]	0.05[0.8262[	0.02[0.8979]	1.12[0.289]
c) Functional form	1.24[0.3168]	0.16[0.9242]	0.22[0.8810]	0.97[0.423]
d)Parameter Stability	1.549[1.1430]	0.962[1.143]	0.625[0.9479]	0.550[0.947]
e) Normality	-1.224[0.880]	-0.429[0.667]	1.027[0.1521]	0.129[0.448]
f) VIF	11.23	4.21	4.75	5.6
g) RMSE	0.086	0.091	0.091	0.082
h) AIC	-49.07	-38.89	-42.43	-59.57

Note: Nulls hypothesis (a) no serial correlation, (b) constant variance, (c) model does not have omitted variable, (d) no structural breaks (e) errors are normal (f) a VIF below 10 indicate no multicollinearity between variables, (g) root mean square error (h) information criteria for model selection.

5.5 Estimation of Cocoa smuggling

Recalling from equation 13 and restating it here, yields response in cocoa is given as:

$$\ln Q_{At}^{yield} = a_0 + a_1 \ln P_{t-1}^{d} + a_2 \ln Q_{At-1}^{yield} + a_3 \ln P_t^{r} + a_4 \ln M_t^{p} + a_5 \ln R_t + a_6 L_t$$

$$+a_6 \ln G_t \frac{1}{2} + a_8 \ln C_t^{t} + a_9 O_t^{p} + a_{10} Tec_d + \upsilon_t$$

Recalling from equation 11 estimated fraction $\hat{C}_t^{s}$ of cocoa sold to CMC at time t is given as

$$\hat{C}_t^{s} = \left(P_t^{r}\right)^{\hat{a}_3} \quad (16)$$

the volume of cocoa smuggled at time t is computed with equation17

$$Q_t^{Smug} = \left(\frac{1-\hat{C}_t^{s}}{\hat{C}_t^{s}}\right) Q_{At}^{yield} \quad (17)$$

Where Q_t^{smug} , is the volume of cocoa smuggled, other variables are as already defined.

Adopting model 3, the computed volumes of cocoa smuggling from 1999/2000-2016/17 crop year is presented in table 11. The estimates reveal that the gainers and losers from cocoa smuggling keep changing. In the past 18 years, Ghana has lost an average of 61,022 metric tonnes (MT) of cocoa to Cote d'Ivoire, with the peak losses taking place in 2013/14 of 125,541 MT of cocoa valued at $384.5 million. The country has on the other hand gained on average 114,407 MT of cocoa smuggled from Cote d'Ivoire within the same period. However, loss of cocoa from both countries has moderated and been on a continuous decline since the high of 2013/14 crop season. Recent efforts by government to boost incentive of the sector while collaborating with CDV to limit smuggling is reflected in lowered outflows of cocoa across the border from both sides of the divide, with Ghana not registering any outflow since 2013/14 crop year. Inflows from CDV has also fallen by 90% since 2012/13.

Bulir (2002) estimates smuggling of cocoa from Ghana to CDV in the 1970s between 40,000 MT and 60,000 MT. Franco (1981) on the other hand using non-parametric methods also estimates national cocoa smuggling from Ghana at 50,000 MT in 1978/79, while Brooks, Croppenstedt & Aggrey-Fynn (2007) without empirical estimates points out smuggling inflows from CDV to Ghana in 2003/04 was between 120,000 MT to 150,000 MT. This study estimates average smuggling inflows from CDV into Ghana in 2003/04 at 158,115 MT moderated to 9,016 MT in 2016/17.

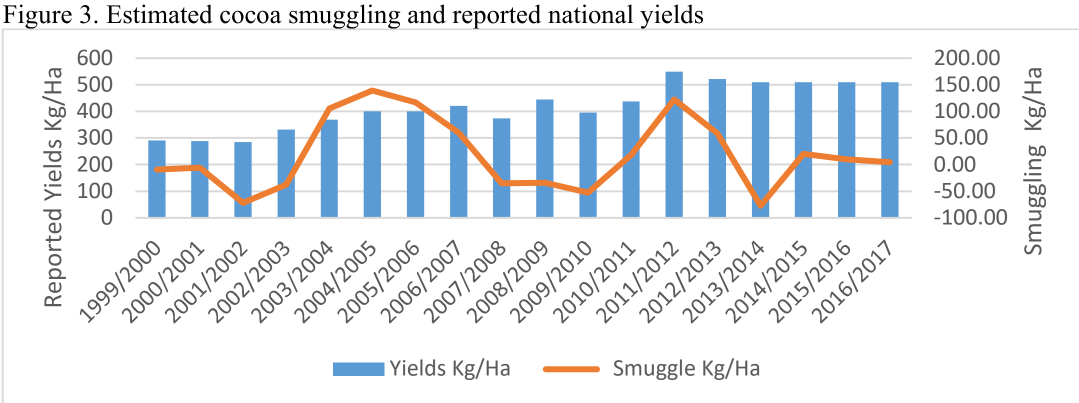
The findings from this study confirms that on average 40 kg/ha of cocoa is lost annually to Ghana from 1999/2000 to 2016/17 crop year. Figure 3 plots officially reported cocoa yields and estimated smuggled volumes of cocoa. The diagram shows from 1999/2000 to 2002/03 productivity was on a steady decline, at the same time there was smuggling of cocoa away from Ghana. Productivity gains were made from 2003/04 to 2007/08 which coincides with the period Ghana gained most from smuggling inflows into the country, buttressing the research prognosis that national productivity is affected by smuggling volumes. Further evidence of productivity following smuggling patterns is showcased in 2011/12 when Ghana's cocoa yields unprecedentedly jumped to 550 kg/ha, the highest recorded productive levels within the 18-year period which also coincided with one of the highest periods of inflow of cocoa from CDV of 122.5 kg/ha of cocoa. Steady decline in inflows from CDV has been met with steady decline in registered productivity rates since then to a stable level of 510 kg/ha.

Table 12. Volumes of cocoa smuggled (1999/2000- 2016/2017)

1.Year	2.Cocoa Yields (Kg/Ha)	3.Cultivated land (Ha)	4. Relative price	5. Fraction of cocoa sold	6. Smuggled cocoa (kg/Ha)	7. Total Smuggled cocoa (Ton/Ha)	8. Value USD per Ton
1999/2000	291	1300000	1.052372	1.032787423	-9.24142	(12,013.84)	(10,859,387.74)
2000/2001	289	1500000	1.031398	1.019730351	-5.584	(8,376.01)	(9,116,243.75)
2001/2002	285	1350000	1.580898	1.335694726	-71.6279	(96,697.65)	(172,029,117.59)
2002/2003	331	1195000	1.210231	1.128165184	-37.6373	(44,976.61)	(78,821,664.74)
2003/2004	369	1500000	0.671618	0.777573445	105.41	158,115.33	245,237,146.87
2004/2005	400	2000000	0.623397	0.74180762	139.223	278,446.73	428,288,926.32
2005/2006	400	1850000	0.666367	0.773725668	116.979	216,411.34	344,210,417.90
2006/2007	420	1835000	0.809969	0.875290199	59.8409	109,807.97	214,607,704.01
2007/2008	374	1463000	1.168958	1.103694301	-35.0911	(51,338.25)	(132,298,357.44)
2008/2009	444	1822500	1.133885	1.082649038	-33.9024	(61,787.19)	(178,619,423.85)
2009/2010	395	1656000	1.25492	1.154317704	-52.8065	(87,447.59)	(273,763,312.50)
2010/2011	437	1625000	0.937636	0.960120131	18.168	29,522.99	87,934,020.27
2011/2012	550	1625000	0.727223	0.817662385	122.538	199,123.86	476,590,829.38
2012/2013	522	1625000	0.845387	0.899288823	58.4699	95,013.55	231,746,930.88
2013/2014	510	1625000	1.296815	1.178525475	-77.2559	(125,540.76)	(384,502,244.39)
2014/2015	510	1625000	0.941338	0.962514239	19.8623	32,276.22	101,191,326.22
2015/2016	510	1625000	0.969583	0.980667291	10.0541	16,337.84	47,236,880.37
2016/2017	510	1896289	0.985425	0.990763525	4.75452	9,015.94	18,296,391.33

Note: Column 5 is computed with equation 16, column 6 with equation 17, column 7 is column 6 by column 3 converted to tonnes per hectare, cocoa prices per tonnes is taken from FRED times column 7 to get column 8. Figures in brackets indicates smuggling out of Ghana

Figure 3. Estimated cocoa smuggling and reported national yields



Note: Figures below zero are losses to the country figures above the zero line are gains to the country

6. Conclusions and Recommendations

Addressing productivity concerns remains key to sustainability of the cocoa industry. Sustainable production is driven by both agroclimatic conditions and socio-economic factor. Industry regulators are making continuing effort to improve on price incentives with inputs support to enhance productivity of the sector. Gains from such efforts are being derailed by smuggling due the proximity of neighbouring producer countries offering higher producer price to their farmers. This research establishes productivity losses of 40kg/ha each crop year from 1999/2000 through to 2016/17. Despite some gains to productivity through smuggling inflow, on the average Ghana is a net loser to cocoa smuggling. The phenomenon is on the decline due to better coordination between neighbouring countries to reduce price disparities. Nonetheless give the greater loss to Ghana from such incidence, the weight of responsibility lies on the country to continue to maintenance competitive incentives in the industry to curtail the menace.

In light of the above the study recommends for COCOBOD to take steps to reduce the industry cost component in the computation of yearly producer price to ensure farmers receive a fair share of the free on-board price of cocoa. To achieve a reduction in industry cost, there is the need for COCOBOD to operate in a more efficient manner to deliver value to farmers. This can be achieved by improving on data access and availability. For instance, the Board does not have a comprehensive dataset on the actual number of farmers and active cocoa farm lands under cultivation. It is therefore necessary to improve on data collection, mapping and registration of farmers to promote farm and farmer identification. This will not only help target project implementation but also support in the effective planning, procurement, costing of operational activities to reduce any budget overages. Effective budgeting and application of the budget based on concise data would go a long way to reduce the industry cost and increase the percentage of FOB price that is made available to farmers.

Acknowledgments
Appreciations goes to COCOBOD and ICCO for the data support.

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