Is Hedging Ghana's Cocoa Export Revenue Risk Beneficial?

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Abstract

This paper assesses the usefulness of risk hedging on futures markets for a cocoa exporter subject to concurrent price and output (revenue) risks. The analysis is conducted for Ghana, the world's second largest exporter of cocoa beans. Using recent cash and futures price data, the cocoa exporter's utility maximization problem (UMP) is solved using a Constant Relative Risk Aversion (CRRA) utility function which displays risk vulnerability. Simulation results indicate that production risk drives the optimal hedge ratio well below unity for all values of the risk parameter. When transaction costs are incorporated, into the hedger's UMP, optimal hedge ratios decline further for reasonable values of the risk parameter although hedge ratios remain positive. The findings indicate that only limited use of the futures market is beneficial for Ghana as a cocoa exporter. Such results caution policy makers who advocate for market-based cocoa export revenue risk management schemes without properly accounting for transaction costs.

Key words: Transaction costs, risk management, cocoa, hedge ratio, risk vulnerability.

JEL Classification: MO; N27; Q13; Q14; and Q17

Introduction

Cocoa exporting Sub-Saharan African (SSA) governments typically depend heavily on cocoa export revenue to finance development projects, exposing them to export revenue risk (Borenstein, Jeane and Sandri, 2009; Lence, 2009; Razzaque, Osafo-Kwaako and Grynberg, 2007).[i] Export revenue variability emanating from either export price or production uncertainty can lead to undesirable consequences for sovereign exporters overly dependent on export revenue (Newbery and Stiglitz, 1981; Razzaque, Osafo-Kwaako and Grynberg, 2007). For instance, export revenue risk can increase the likelihood of default on sovereign debt and also lead to macroeconomic instability in export revenue-dependent SSA countries (Malone, 2005).[ii]

This paper focuses on the export revenue risk problem facing Ghana, the second largest cocoa exporter in the world where revenue risk is understood to represent the sum of price and output risks. Ghana is chosen for analysis because it is somewhat typical of the cocoa exporting SSA countries and relies heavily on cocoa export revenue: cocoa provides nearly thirty percent of Ghana's export revenue (Pinnamang Tutu and Armah, 2011).

Export revenue risk has assumed great importance recently because non-market strategies including buffer stocks, buffer funds and commodity agreements designed to minimize commodity revenue risk have failed (Borenstein, Jeane and Sandri, 2009; Larson, Anderson and Verangis, 2004). Further, because of the recent efforts by the World Trade Organization (WTO) to liberalize markets and foster competition in world markets, risk management methods such as the cocoa agreements and buffer stocks are not likely to be encouraged in the future (Lence, 2009; Borenstein, Jeane and Sandri, 2009). As an alternative, market-based risk management strategies including hedging have been proposed to manage export revenue risk (Lence, 2009).

Should marketing boards of cocoa revenue-dependent SSA countries such as Ghana use the futures markets to mitigate price and output (revenue) risks? Will futures hedging of revenue risk increase exporter's welfare relative to the unhedged position? How large should optimal hedge ratios be especially after accounting for transaction costs which have been shown in prior research to affect their attractiveness? Answers to these questions are of value to policy makers as they provide information on the effectiveness of futures markets in hedging revenue risk.

In a well-known paper, Rolfo (1980) analyzed the Utility Maximization Problem (UMP) facing a cocoa exporting country exposed to simultaneous price and production (revenue) risk. The cocoa industry was selected for analysis because it is plagued with production uncertainty and risk (Rolfo, 1980). Rolfo focused on SSA's major cocoa exporters: Ghana, La Cote d'Ivoire (CIV), and Nigeria that together account for nearly seventy percent of world production and depend to varying degrees on cocoa export revenues to fund development (Gibson, 2007). Rolfo's formulation described a sovereign cocoa exporter exposed to concurrent price and production risk taking a pre-harvest (September) position in the futures market to establish a price at harvest (March). In the absence of production risk, a traditional recommendation of protecting a long position in a physical market involves taking a short position of equal size in the futures market (Hieronymus, 1971; Rolfo, 1980). Given production risk, Rolfo (1980) finds limited or no use of the futures markets is superior to a full hedge.[iii]

While Rolfo's analysis is highly informative, his findings may be limited in several dimensions. For example, since his data ran from 1956 to 1976, the results are dated and may no longer be relevant for current hedging decisions. In particular, fundamental changes have occurred in cocoa markets since Rolfo's work. Consider Figures 1 and 2 which respectively provide plots of futures and subsequent spot prices (cash price), and variance of futures prices for cocoa from 1960 to 2008. Clear evidence emerges of a structural break in futures and spot prices, and in the variance of futures prices. The earlier period was characterized by lower and less variable prices, and by a closer relationship between futures and spot prices.[iv] Statistical evidence of a structural break in the variance of futures prices is presented in Table 1 which displays results of the Miller Jackknife test, a non-parametric test of structural change in the variance that does not assume equal medians. From Table 1 the null hypothesis that the ratio of the variances of futures price before and after 1978 is unity is strongly rejected at 5 % significance level. Since optimal hedge ratios are respectively influenced either by changes in the correlation between cash and futures prices or by changes in the variance of the futures price (over time), the structural change in 1978 indicates a need to reassess the cocoa exporter's hedging decisions. More importantly, Rolfo's analysis ignores transaction costs. Mattos, Garcia and Nelson (2008) demonstrate that when transaction costs are considered when solving the utility maximization problem of an agent, optimal hedge ratios may change considerably.

Here we investigate the revenue risk problem facing Ghana, the cocoa exporter, incorporating transaction costs and using more recent data. We first compute optimal hedge ratios using quadratic utility with zero transactions costs for different values of the Coefficient of Absolute Risk Aversion (CARA). Transaction costs are then incorporated into the cocoa exporter's utility maximization problem and the optimal hedge ratios are recalculated. We then repeat the analysis with a more realistic Constant Relative Risk Aversion (CRRA) utility function (Nelson and Escalante, 2004). The Nelson and Escalante (2004) utility function allows for the more reasonable Decreasing Absolute Risk Aversion (DARA) and Decreasing Absolute Risk Prudence (DAP) assumptions, and also displays risk vulnerability which is the most natural restriction on preferences (Mattos, Garcia and Nelson, 2008). A search program in Visual Basic was developed to compute optimal hedge ratios by solving the UMP of the cocoa exporter with Nelson and Escalante (2004) type preferences exposed to revenue risk and transaction costs. We find that optimal hedge ratios are small but positive even when transactions costs and production risks are incorporated into the UMP of the cocoa producer. Limited use of the futures markets will therefore improve cocoa exporter utility relative to the unhedged position validating Rolfo.

Literature Review

The question of whether cocoa revenue-dependent sovereigns should hedge export revenue risk was first addressed by Rolfo (1980). Rolfo derived joint optimal price and output (revenue) risk hedge ratios for the major SSA cocoa producers: Ghana, CIV and Nigeria and found that limited or no use of futures markets may be superior to a full hedge. The optimal hedge ratio was computed assuming utility maximization of the exporters' final wealth.

Rolfo maximized logarithmic utility and quadratic utility functions to develop optimal hedge ratios from the UMP. The log utility function displays Constant Relative Risk Aversion (CRRA), a realistic preference representation, but does not allow the risk parameter to vary as it is fixed at unity. The log utility assumption is thus restrictive and unlikely to be very useful because it does not allow analysis of how the hedge ratios change as the risk parameter changes.

In comparison, quadratic utility exhibits Constant Absolute Risk Aversion (CARA) and has been criticized in the literature as an unrealistic representation of preferences (Mattos, Nelson and Garcia, 2008). In particular, the quadratic utility function implies increasing absolute risk aversion (which means that risky assets are inferior goods) and satiation (which means that the utility starts decreasing after a satiation point). Both are not consistent with observed behavior (Mattos, Nelson and Garcia, 2008; Nelson and Escalante, 2004). However, given quadratic utility, preferences can be represented by the mean and variance of the underlying wealth distribution, greatly simplifying the utility maximization problem (Rolfo, 1980).

The simplicity of the computation of the mean-variance hedge (MVH) derived by assuming quadratic utility explains its popularity of use in the literature despite inconsistency with the actual behavior of economic agents (Outtara, Schroeder and Sorenson, 1990; Lence, 1996). Although more recent literature no longer assumes preferences with quadratic utility due to its unrealistic properties, the mean-variance model (that is typically implied by quadratic utility) is still used if the underlying utility displays CARA and returns are normally distributed.

Here, instead of a CARA utility function with normal returns, we employ a CRRA utility function first defined by Nelson and Escalante (2004) which is consistent with observed behavior because it displays Constant Relative Risk Aversion (CRRA), Decreasing Absolute Risk Aversion (DARA), Decreasing Absolute Risk Prudence (DAP) as well as risk vulnerability. CRRA, DARA, DAP and risk vulnerability are desirable characteristics of utility functions (Gollier and Pratt, 1996; Nelson and Escalante, 2004; Mattos, Garcia and Nelson, 2008). Since Gollier and Pratt (1996) demonstrate convincingly that risk vulnerability is the most natural restriction of utility functions, the Nelson and Escalante (2004) CRRA utility function, which is risk vulnerable, is best suited for modeling risk preferences of agents and is employed in this research.[v]

Apart from unrealistic preferences (which can undermine the acuracy of optimal hedge rations), Collins (1997) argues that changes in the assumptions used to develop optimal hedge ratios can influence their magnitude and usefulness. In particular, Collins emphasizes that when any of the assumptions underlying the derivation of the mean-variance hedges (MVH) which can be derived from CARA utility changes, MV hedges change dramatically.[vi] Although Rolfo relaxes the production risk assumption he does not take into account how transaction costs, such as brokerage fees, can affect the optimal hedge ratios. We relax both assumptions and investigate how production risks and transaction costs simultaneously affect the optimal hedge assuming the cocoa exporter has realistic preferences.

Following **Rolfo (1990), Sy (1990)** and **Outtara, Schroeder** and **Sorenson (1990)** also examined the costs and benefits of hedging commodity export revenue risk in a utility framework. **Sy (1990)** compared the relative costs and benefits from hedging the revenue risks of a basket of goods (cocoa, coffee and cotton) for La Cote d'Ivoire (CIV). **Sy (1990)** focused primarily on the change in utility from hedging price risk when production risk is introduced into the standard hedging problem. He then compared the gains from minimizing risk using futures markets with gains in utility from mitigating risk using stabilization programs. In contrast to **Rolfo (1980), Sy (1990)** does not define a pre-harvest to harvest hedge horizon for his analysis. Instead, he defines an annual export price index as the ratio of annual total export revenue to the total export volume. He uses this annual price index (the cash) and annual average New York Stock Exchange futures price data from 1973 to 1984 to compute MVH ratios by Ordinary Least Squares.

Consistent with Rolfo's findings, **Sy (1990)** concludes the hedge ratios for mitigating cocoa price risk alone are positive and smaller than unity.[vii] In contrast to **Rolfo's** conclusions, **Sy (1990)** finds that when production risk is introduced, hedge ratios are not always negative. They can be positive depending on the joint distribution of futures prices, cash prices and production. However the benefits from market risk management exceed the benefits from stabilization policies so CIV will benefit greatly from hedging cocoa market risks. Similar to Rolfo, **Sy's** findings may be dated and not necessarily relevant to the contemporary risk management problem that SSA cocoa exporters face. Further, Sy also fails to include and analyze effects of transaction costs on the optimal hedge ratios.

Although they analyzed coffee not cocoa revenue risk, the research by Outtara, Schroeder and Sorenson (1990) is relevant here because it uses a similar method to Rolfo (1980) to analyze a similar problem. Outtara, Schroeder and Sorenson (1990) investigated the possibility of reducing the CIV coffee marketing board's export revenue risk by using futures markets. Following Rolfo, they develop optimal hedge ratios by maximizing a quadratic utility function for a coffee exporter exposed to export revenue risk. Futures prices from 1973/74 to 1986/87 were collected to generate forecast errors using the coffee contract on the New York Sugar, Coffee and Cocoa Exchange (SCCE).[viii] Cash prices and output forecasts were obtained from the USDA. The futures forecast price is the May closing futures reported on the last day of October, while the futures price at expiration is the May futures reported on the first day of May. They concluded that the CIV could reduce revenue risk by 29 percent if they hedged 125 percent of production over the 1973/74 to 1986/87 period. Since Outtara, Schroeder and Sorenson (1990) suggest that CIV should hedge more than total output, CIV may derive speculative profits from declining prices over the period. However, speculation will increase CIV's risk making it an undesirable strategy given their risk minimizing objective.

Similar to Rolfo (1980) and Sy (1990), Outtara, Schroeder and Sorenson (1990) use a CARA utility function that exhibits increasing absolute risk aversion (IARA). IARA is an extremely undesirable property of risk preferences (Mattos, Nelson and Garcia, 2008). Like Sy, Outtara, Schroeder and Sorenson (1990) also neglect the effect of transaction costs on the optimal hedge ratio. We contribute to the literature by re-analyzing the cocoa exporter's revenue risk problem originally defined by Rolfo in the post structural break cocoa market. In particular, we use a more realistic utility function that exhibits the desirable decreasing absolute risk aversion (DARA), constant relative risk aversion (CRRA), risk vulnerability and decreasing absolute risk prudence (DAP) properties. We then consider the effect of transactions cost on the optimal hedge ratio.

Problem Formulation, Model and Methods

Despite export and domestic market liberalization in the 1990's, a substantial amount of the cocoa exported from Sub-Saharan Africa (SSA) is controlled by governmental agencies and not by private agents (**Dand, 1999**). In Ghana, in spite of domestic market liberalization in 1994, the government-run Cocoa Marketing Board (COCOBOD) remains a monopoly exporter of Ghana cocoa (**Bulir, 2002**).[ix] Hence, COCOBOD is Ghana's principal decision maker on cocoa production, marketing and exportation.[x] Funds generated by COCOBOD through its various activities are used for consumption smoothing, economic development and growth.

Substantial production variation exists in the amount of cocoa harvested and exported due to unexpected rainfall patterns, diseases and pest attacks (**Rolfo, 1980**). COCOBOD is therefore concerned about how production risk can alter the effects of export revenue risk on sovereign exporter utility. Further COCOBOD is also concerned about the effects of price variability on export revenue risk because it directly faces the world cocoa prices which exhibit considerable price variability influenced respectively by elastic demand and inelastic supply (**Razzaque, Osafo-Kwaako** and **Grynberg, 2007**).[xi]

Elevated price and production risk result in considerable revenue risk with associated and undesirable consequences.[xii] Here, we assume the COCOBOD takes a pre-harvest position in the futures market in order to guard against unexpected variation in cocoa export revenues emanating from price or output risk at harvest time.[xiii] The main Ghanaian cocoa harvest season commences in October and ends in January. The hedge uses New York Board of Trade (NBYOT) futures contracts and is assumed to be placed on the first trading day of July (pre-harvest) and closed on the last trading day of December (harvest).[xiv] This six-month hedge horizon was selected for analysis of the revenue risk minimization problem using futures markets because it is most representative of the marketing situation faced by COCOBOD. At the decision date (pre-harvest, t = 0), the COCOBOD can sell h commodity contracts on the exchange each of which reflects a specific production quantity in the futures market at price f. At harvest (t = 1), COCOBOD can deliver the quantity of cocoa specified by the contracts to an identified delivery point which is unusual or can simply repurchase cocoa at the random futures price P_f on the exchange. Cash sales are made at the end of the hedging period, and COCOBOD will receive that price. Conceptually, losses in the cash market can be recouped in the futures market and vice versa. We acknowledge here that hedging production risk with futures has been criticized by **Just, Just** and **Khantachavana (2010)** and others but in the absence of viable alternative methods of production risk management choices hedging offers the best odds to effectively minimize risk out of the best existing methods so we use it here.[xv]

Here we perform the analysis using historical rather than expectational measures of production uncertainty. However, production forecasts which were available when Rolfo performed his analysis have been discontinued (**Gil** and **Duffus**), and the limited number of observations and the presence of a structural break in production makes the usefulness of other forecast methods (e.g., ARIMA) limited.

Following **Rolfo (1980),** the formulation distinguishes between the random actual cash prices (P) when the hedge is lifted, and prices recorded on the futures exchange, f and P_f. P is the stochastic cash price received by COCOBOD and is used to reflect actual world cocoa cash prices. Both futures contract settlement price and the cash prices are used to compute optimal joint price-output hedge ratios. The revenue function of the cocoa exporter exposed to simultaneous price and output risks in the absence of transaction costs is defined in (1),

(1) $R = PQ + h(f - P_f)$,

Where Q is the random quantity, h is the futures position, f is the futures price on the day the hedge is placed and P_f is the futures settlement price recorded on the last trading day. The returns or cocoa export revenue, R, are the sum of the returns in the cash market, and the returns the exporter realizes from transactions in the futures markets. When transaction costs are incorporated, the revenue function in (1) can be re-written as in (2),

(2) $R = PQ + h(f - P_f - b)$,

b in (2) is transaction costs in the form of brokerage fees in US dollars per ton.[xvi] The utility maximization problem (UMP) of the Ghana cocoa marketing board is modeled first with quadratic utility then with a constant relative risk aversion (CRRA) utility function U (.) where U (.)’ > 0, U’’ < 0, and the utility function is concave. Utility is defined as a function of export revenue (R).

The Cocoa Exporter with Quadratic (Mean-Variance) Utility Function

The UMP with quadratic utility function is given in (3) where h, the futures position, is the choice variable in COCOBOD's Utility Maximization Problem.

$$(3)\ \text{Max: } EU(\mu_R(R(h)), \sigma_R^{\ 2}(R(h))) = \mu_R(R(h)) - \gamma\sigma_R^{\ 2}(R(h)) =$$

$$\text{E}[\ E[PQ + h(f - P_f - b)] - \gamma E\{[PQ + h(f - P_f - b) - E[PQ + h(f - P_f - b)]\}^2\ ], \text{ and}$$

$\mu_R(R(h))$ and $\sigma_R^{\ 2}(R(h))$ are respectively the mean and variance of export revenue and γ is the risk parameter (the coefficient of relative risk aversion or CRRA).[xvii] The optimal futures position obtained by solving (3) is given in (4)

$$(4)\ \ h = \text{cov}\,ariance[PQ, P_f\,]/\,\sigma_{Pf}^{\ 2} + E[(f - P_f - b)/\,2\sigma_{Pf}^{\ 2}\gamma],$$

where $\sigma_{Pf}^{\ 2}$ is the variance of P_f. Note that in equations (3) and (4), E is the mathematical expectation operator so the expected value of stochastic cocoa exporter revenue is, E(R) $= \mu_R(R(h)) = E[PQ + h(f - P_f - b)]$ and the variance of stochastic revenue is $\sigma_R^{\ 2}(R(h)))$ = $E\{[PQ + h(f - P_f - b) - E[PQ + h(f - P_f - b)]\}^2$. The first component of h in (4) is the pure revenue hedge, the coefficient of P_f in a linear regression where PQ is the dependent variable and P_f is the independent variable (**Rolfo, 1980**). The second term is the bias in futures price (**Rolfo, 1980**) less transaction costs. When transaction costs are zero, (4) is identical to Rolfo (1980)'s derivations.

Cocoa Exporter with Nelson Escalante (2004) Utility Function

Nelson and **Escalante (2004)** demonstrated that when the joint distribution of cash and futures returns are elliptically symmetric and final wealth satisfies the location-scale condition, expected utility can be written as a function of the first two moments of the return distribution

(**Chamberlain, 1983**; and **Meyer, 1987**). We verified that final wealth satisfied the location-scale condition in the objective function developed using **Nelson** and **Escalante's (2004)** utility function.[xviii] We used the Jacque-Bera test to ensure normality of returns as normality is an accepted form of elliptical symmetry. We thus maximize the expected utility of the **Nelson** and **Escalante** CRRA location-scale utility function as in (5)

$$\text{(5) Max: } EU(\mu_R(R(h)), \sigma_R{}^2(R(h))) = -1/(\mu_R(R(h))^2 - \gamma(\sigma_R{}^2(R(h))) .$$

To maximizing (5), we simply maximize its denominator since both operations give the same answer. To identify h as the explicit choice variable, we re-write (5) as an explicit function of h and then maximize the denominator of the resulting function where h is the choice variable (6).

$$\text{(6) Max: } (\mu_R(R(h))^2 - \gamma\sigma_R{}^2(R(h))) =$$

$$(E[(R(h))^2 - \gamma E[(R(h) - E[R(h)]]^2) =$$

$$E[PQ + h(f - P_f - b)]^2 - \gamma E\{[PQ + h(f - P_f - b) - E[PQ + h(f - P_f - b)]\}^2 .$$

Let $\sigma_R{}^2(R(h))$ be defined as in (7)

$$\text{(7) } \sigma_R{}^2(R(h)) = \text{E[R (h)-E(R (h))]}^2 =$$

$$E[PQ - h(P_f - f - b)] - E[PQ - hb]]^2 ,$$

We can then solve the utility function in (8) for h, the optimal hedge position.

$$\text{(8) Max } E[PQ + h(P_f - f - b)]^2 - \gamma E\{[PQ + h(P_f - f - b) - E[PQ + h(P_f - f - b)]\}^2 .$$

A closed form solution to (8) can be obtained as long as we assume a zero basis (i.e., assuming P_f = P) and is included in the appendix. When we allow for non-zero basis, a more realistic case, a closed form solution is difficult to obtain but a search procedure similar to that employed by Rolfo (1980) can be developed to determine h, the optimal futures position and H, the optimal hedge ratio.

The Optimal Hedge Ratio When Basis Risk Is Present

In the presence of basis risk ($P_f \neq P$), a search program was written in Visual Basic to solve for optimal hedge ratios. The search program uses the following algorithm: First set transaction costs, b = 0. For each pre-determined level of the hedge ratio ($H = h / \mu_Q$) between 0 and 1 in steps of 0.01, obtain the value of the utility function for the twenty-eight observations from t = 1 (1980) to t = 28 (2008). Next sum the twenty-eight values and divide by twenty-eight to get the expected value of the utility function over the period for that value of H. Repeat the calculations for each value of H from 0.01…1.0. The value of H between 0 and 1 (0.01, 0.02…1.0) that corresponds to the highest expected value of the utility function over the period is the optimal hedge ratio. By repeating the search over the range of H values the optimal hedge can be found for different risk parameter values.

To identify the effects of transaction costs, b is included and changed and the process is repeated. The optimal hedge ratio corresponding to each level of transactions costs can then be compared to the optimal hedge ratios when b = 0 and those obtained from the MVH to determine how robust optimal joint hedge ratios are to changes in transaction costs and to preference type. For each pair of values of H and b, the expected utility can be computed and compared respectively to the expected utility where H = 0 and when both H and b have zero values. This enables a comparison of the utilities of a hedged and unhedged exporter given the presence or absence of transaction costs.

DATA

Transaction costs

Transactions cost is modeled as brokerage fees because the brokerage fee is the most important component of transaction costs. Six levels of brokerage fees in $/ton: 0, 10, 50, 100, 200, and 500 were selected. Note that each futures contract contains 10 tons of cocoa beans (the standard contract). Transaction costs can include a number of factors including information costs, monitoring costs, and actual monetary costs of trading related to brokerage fees. Here we examine fees from 0 to 500 $/ton. The likely range of brokerage fees that COCOBOD will face is between $0 and $100. However transactions costs incorporate huge start up fixed costs and other financial requirements which when spread over the total number of contracts purchased will increase the transactions cost per contract significantly. For example, there are costs associated with training the risk managers at the marketing board to use the futures market. Alternatively a foreign risk management firm could be contracted but either option is expensive. We therefore use $500 per contract as the cut off point for transactions costs.

Brokerage fees have been declining over the years and can normally be negotiated downward for large volume futures participants such as the COCOBOD. Brokerage fees vary depending on whether the hedge is large or small or whether the hedger wants full service or a per round term transaction. A very large prospective hedger such as the COCOBOD can obtain between 25 and 60 dollars per ton. Smaller hedgers will pay substantially more in brokerage fees per ton so the levels of brokerage fees we chose make sense.

The data used in the analysis were limited to the 1980-2008 periods to avoid a structural break in 1978 in world cocoa prices caused mainly by the policies of the Ghanaian government. Hedge horizons were chosen so that December is the harvest month which coincides with October-January, the main cocoa harvest season in Ghana (**COCOBOD, 2000**). Cocoa futures and output data from 1980-2008 were obtained respectively from the New York Board of Trade

(NYBOT) and the Ghana cocoa marketing board (COCOBOD). The NYBOT was used because it is liquid and because the cocoa contract traded has specifications that are compatible with the cocoa SSA countries export. To eliminate trend effects the cocoa revenue data is de-trended by applying a linear trend.[xix]

Table 2 contains summary statistics for cocoa production and revenue for Ghana as well as for the futures and spot prices used in the research. Based on standard deviations of prices, revenue and production (assumed to reflect exports since in-country storage is minimal) it is evident that there is substantial price, production and revenue risk. Further, the mean of spot prices (1775.4) is bigger than that of the futures price (1514.2) which might be indicative of a bias in futures forecasts. The mean of the futures price at expiration (1553.2) is also greater than the futures price implying that the optimal hedge is an increasing function of the risk parameter (**Outtara, Schroeder** and **Sorenson, 1990**).[xx] More importantly, the standard deviation of futures prices is smaller than that for spot prices, a favorable occurrence for very risk-averse agents and very volatile markets such as the cocoa market. This is because when the futures are less risky than the cash price, risk management using futures contracts is typically more effective. Table 3 contains results of correlation and covariance between the futures price, the futures price at expiration and the random spot price. It is clear that the futures at expiration is almost perfectly correlated with the spot price so it can be used a substitute for the cash price at contract expiration. Correlation between all prices is high ranging from 0.9 to 1.

Results

The pure price hedge (minimum variance hedge), computed at infinite risk aversion, zero production risk and zero transaction costs or from the regression of cash on futures is 0.82 as shown in Table 4. This means, faced with just price risk, a typical cocoa exporter like Ghana should hedge 82 % of output in order to enjoy a level utility from export revenue greater than the unhedged position (zero hedge). Table 4 also displays optimal "revenue hedge ratios" for Ghana using quadratic utility for values of the risk parameter γ between 0.000000001 and ∞ which represents the range from a risk loving to an extremely risk averse cocoa exporter. An identical range was used by **Rolfo (1980)** so results using this range of γ make for an interesting comparison with his work. Note that to obtain equivalent values of ψ, the Constant Absolute Risk Aversion (CARA) for the quadratic utility, γ (the coefficient of relative risk aversion) must be divided by the mean of export revenue.

When $\gamma = \infty$, the second term drops out in equation (4) and we get the pure revenue hedge (**Rolfo, 1980; Outtara, Schroeder** and **Sorenson, 1990**). The pure revenue hedge (with infinite risk aversion), for quadratic utility, which can equivalently be computed using the regression of revenue on futures price for Ghana, assuming zero transactions costs is 0.44 as shown in Table 4. Further, for all levels of γ larger than 0.001, the revenue hedge is also 0.44. In comparison, **Rolfo (1980)** finds using quadratic utility that the optimal revenue hedge ratios for Ghana, is 0.6 for γ larger than 0.001 so our results are only slightly different from Rolfo's.

Since we are using data after the 1980 structural break, the market we analyze is in theory, fundamentally different from what **Rolfo (1980)** analyzed. Therefore we expect to find similar but not identical results as **Rolfo (1980)** when we use the quadratic utility function. From Table 4, the optimal hedge ratios do not vary much with γ but similar to the results of **Rolfo** and Outtara, Schroeder and **Sorenson (1990),** they drop precipitously after a cut of value or γ. Here the threshold value of γ is 0.0001. The conclusion from the analysis using quadratic utility and zero transactions costs is that Ghana would benefit from hedging cocoa export revenue. The Ghana Cocoa Marketing Board should only hedge a part of output. A similar conclusion was drawn by **Rolfo (1980).**

When transactions costs are incorporated into the UMP for a typical SSA cocoa exporter such as Ghana facing price and production risks, optimal hedge ratios decline. Transactions costs alter optimal hedge ratios at a γ or CRRA of 4 corresponding to a CARA of 0.000005 using quadratic utility. From Table 5, between $0 and $10 dollars per contract, the optimal hedge ratio shrinks from 0.44 to 0.38. This represents a 6 % decline in the hedge ratio. At any value of the transactions cost greater than $10, the optimal hedge ratio is negative meaning a long hedge is superior to a short hedge. A negative (long) hedge ratio means that the cocoa marketing board should go long both the commodity and the futures contract. That is, COCOBOD should execute a reverse hedge **(Rolfo, 1980)**. However, reverse hedging is impractical here since it increases risk.[xxi]

If we compute optimal hedge ratios with the more realistic CRRA utility function (**Nelson** and **Escalante, 2004**), the results are different from the quadratic utility case but comparable to results using log utility.[xxii] From Table 6, the pure revenue hedge ratio (infinite risk aversion) for Ghana, computed at zero transactions costs using the more representative **Nelson** and **Escalante (2004)** utility function is 0.31. This is comparable to the finding of Rolfo for log utility (which is also a CRRA utility function but has a fixed CRRA γ value of 1). Rolfo finds that Ghana should hedge 0.15 of its export volume. The fact that the CRRA utility functions (**Nelson** and **Escalante**) display smaller hedge ratios than the quadratic utility is to be expected because the former also displays decreasing absolute risk prudence which means it is less sensitive to risk (**Chen, X., H. H. Wang** and **R. C. Mittelhammer, 2006**). Insensitivity to risk implies that as revenues increase COCOBOD is unlikely to seek more protection from risk because its preferences are not sensitive to risk. An agent whose utility is quadratic more sensitive to risk as revenues increase and will seek more protection from risk leading him to choose a higher optimal hedge ratio.

The optimal hedge ratios using CRRA utility are fairly constant at different values of the risk parameter (γ). From Table 6, the optimal hedge ratio for Ghana remains constant at 0.31 at CRRA risk parameter value (γ) greater than 0.0000001, then turns negative. The constant optimal hedge ratio for values for the range of γ between infinity and 0.0000001 indicates that the speculative component of the hedge is inconsequential. For the range of γ greater than 0.0000001 or for risk lovers, the speculative part of the hedge dominates so the hedger is net long (**Outarra, Schroeder** and **Sorenson, 1990**). A long hedge here implies speculation which is not desirable here given the risk minimization objective outlined in COCOBOD's UMP.

Similar to the results of the quadratic utility analysis, the optimal hedge declines monotonically at risk parameter value (γ) of 4 for fairly reasonable values of transactions cost ($0 to $100 per ton). Rolfo also used a similar range of γ for Ghana in his work therefore we assume the same range of γ (1-5) for the Ghana cocoa marketing board.[xxiii] For Ghana, transactions costs appear to exert considerable influence on optimal hedge ratios at a constant relative risk parameter γ of 4 using the **Nelson** and **Escalante (2004)** utility function although the transaction cost effect is less dramatic than in the quadratic utility case.

From Table 7, between $0 and $100 dollars per contract, which represents the feasible range of transactions costs for a large hedger such as Ghana, the hedge ratio declines from a value of 0.31 (the pure revenue hedge) to 0.2. This represents an 11% decline in the hedge ratio.

Figure 3 graphically illustrates the point that Table 7 makes. From Fig 3, any value of the transaction cost above $350 per contract results in a negative hedge ratio or a long hedge. A long hedge indicates a speculative position which does not make sense for COCOBOD whose primary focus is to minimize not increase risk.

Transaction costs have many components not all of which has been accounted for by brokerage fees. In particular for a SSA country such as Ghana, there is large hidden costs such as the cost of educating the will-be risk managers at the Ghana Cocoa Marketing Board about futures markets and contracts as well as other financial requirements for using future contracts all of which will increase the relevant feasible range of transactions contracts. In other words, there will be a fixed cost which will decline as the number of contracts purchased decreases in addition to the variable cost per contract. Still it is unlikely that the transactions costs paid per contract will be as high as $350. The results using **Nelson** and **Escalante's (2004)** utility suggest optimal hedge ratios for the Ghana Cocoa Marketing Board remain positive even after transactions costs are considered. Therefore, from the results of the **Nelson** and **Escalante (2004)** utility, limited use of the futures market appears to be optimal for Ghana even when we take transaction costs into account given reasonable values of the risk parameter.

The result obtained from using the **Nelson** and **Escalante (2004)** utility function, that revenue hedging with futures markets is utility improving for the cocoa exporter, is in contrast to the conclusions from the quadratic utility analysis but is consistent with the result obtained by **Borenstein, Jeane** and **Sandri (2009)**, who compare the benefits of precautionary savings to the benefits from hedging for export-revenue dependent countries.[xxiv] Our results using the **Nelson** and **Escalante (2004)** utility is also consistent with the results of **Sy (1990),** who assesses the possibility of hedging cocoa revenue risk for CIV.

Note that **Lence (2009)** finds the opposite result to what this paper concludes most probably because he endogenizes the production decision. He investigates whether atomistic producers in developing countries should hedge revenue risk using a dynamic model that allows for price to influence expected production. He concludes that hedging reduces risk, increases production and lowers price because of a downward sloping demand function. Hedgers "win" when their production is small but lose when their production is large. For large potential hedgers like the SSA cocoa exporters, he finds hedging is sub-optimal because it reduces their welfare.[xxv] Note that what fundamentally drives Lence's findings, which is in contrast to this paper's conclusions, is the fact that he builds a model where hedging activity in the futures market (selling of the contract) puts a downward pressure on price. In this case, just like any other technology that causes a parallel shift in supply, the introduction of futures through its risk reducing effects will cause prices to decline as output rises. Thus producers will lose welfare.

Further, **Lence (2009)** makes some assumptions that are very different from those made here. In particular, he assumes a zero basis and employs a CARA type not a CRRA type utility function so the fact that his results agree with the conclusions from the analysis here using quadratic utility but is disagreement with the more realistic CRRA analysis is hardly surprising. Further his measure of welfare is narrow and is unlikely to be informative at least for SSA cocoa exporters. **Malone (2005)** has explained that the benefit from hedging for large sovereign exporters dependent on export revenue has many dimensions including reducing variability of export revenue, reducing the probability of default on loans, and enhancing credit worthiness.

However, **Lence (2009)** measure of hedging benefit to hedgers does not include the enhanced reputation from a constant stream of export revenue that enables commodity sovereign exporters to enjoy low interest rates on loans. **Borenstein, Jeane** and **Sandri (2009)** find substantial exporter utility gains due to hedging because of the enhanced credit reputation typically associated with sovereign exporters who hedge their revenues. By contrast, because the interest rates on the international market are prohibitive, countries that are dependent on export revenue but do not manage revenue risk often have little alternatives other than to settle for International Monetary Fund (IMF) loans with low interest rates but imposed stringent conditions that are detrimental to borrower welfare. For example, the Ghanaian government settled for an IMF loan in 2009 because internationally available loans had very high interest rates. The IMF condition for the loan was a freeze in government hiring. When armed robbery in Ghana escalated, the government was bound by a contract with IMF not to increase the police force to meet the challenge of rising crimes and murders. This chain of events could have been prevented if Ghana managed its export risk, reduced probability of default on loans and acquired a healthy credit to be able to enjoy low interest rates from international lenders.

From the result of the more representative **Nelson** and **Escalante (2004)** utility function used in this research, the major cocoa exporters Ghana and CIV should hedge less than full output when facing pure price risk. When faced with revenue risk, they should hedge considerably less than they hedged when facing pure price risk for values of the CRRA risk parameter between 1 and 5. When transactions costs are considered, the typical SSA cocoa exporter will choose to hedge a very small portion of his output. This result partly validates **Rolfo's (1980)'s** conclusions that a minimum use of the futures market or none at all is superior to a full hedge. The data used in this research spans 1980-2008 and Rolfo used 1956-1976 data and we have evidence of a structural break in 1978 so we did not expect Rolfo's result to be necessarily relevant to the UMP facing an SSA cocoa exporter today. However, the evidence suggests that Rolfo's conclusions remain relevant, at least in part, today.

Limitations of the Research

The research suffered from a lack of access to data. In particular, the Gil and Duffus cocoa output forecasts which were originally used by **Rolfo (1980)** in his analysis were unavailable because they had been discontinued over two decades ago. Consequently, it was impossible to extend Rolfo's work using his own methods to the relevant date range of this research using data from an identical source. The result from such an analysis (if it had been done) could immediately tell us how drastic an effect the changes in the cocoa sector have had on the UMP of Ghana as a cocoa producer and on corresponding optimal hedge ratios that minimize export revenue risk. Given the difference in utility functions used by Rolfo and the current authors the result of such an analysis will also make for useful comparisons to our research results in order to demonstrate the importance of getting the utility function right. Further, it is also not clear whether the values of the risk parameter employed in the simulation exercises are correct. The literature is lacking in providing that information. The results of the research are obviously limited by the accuracy of the second best solution of predicating our measure of CRRA on literature values instead of directly estimating it. Lastly the definition of utility as used here is narrow and should be generalized to reflect risk reduction from a smoothened income stream when export revenues are hedged.

Suggestions for Further Research

In terms of further research, following **Malone (2005),** it will be interesting to simulate the reduction in the probability of sovereign default risk that a smoothened cocoa export revenue risk from hedging entails. The reduction in cost of sovereign borrowing from different degrees of income smoothing due to hedging should also provide valuable information to policy-makers.

More detailed analysis of the effect of transportation costs on the optimal hedge ratios and on the utility from hedging revenue risk will provide pertinent information for Ghanaian policy makers. Incorporation of the utility derived from reduced borrowing rates and decreased probability of sovereign default on loans (that hedging entails) into the utility maximization problem of the cocoa-exporting SSA sovereign are also useful candidates for further research.

Further research must also investigate if the structure of domestic cocoa marketing in Ghana is likely to change in response to a smoothened income and whether that change will reduce risks for COCOBOD making risk management less of an issue and hedging of little value. In particular, as **Prebisch** **a**nd **Singer (1954**) have argued, terms of trade decline over time for primary products like cocoa so it might be a good idea for the producers of primary products to move up the chain into processing. It could plausibly be argued that since comparative advantage is dynamic not static, by investing into technology, Ghana might actually secure a comparative advantage in processing cocoa over time which can help it process more cocoa beans. If Ghana substantially increases the proportion of cocoa beans processed domestically then hedging against variation in the process of cocoa beans becomes less relevant because cocoa input acquisition will be assured and the price will be pre-determined by forward contracts.

The move into processing critically depends on whether the value added per tonne of processing more than compensates for the lost premiums per tonne selling raw cocoa beans. Ghana enjoys quality premiums from selling the beans because Ghana cocoa is the most quality cocoa. It is the industry standard in terms of quality. Cocoa from all other countries is discounted to Ghana cocoa. Preliminary research by **Pinnamang Tutu (2010),** suggests that the value added from processing seems to be increasing over time and in turn, the tonnage processed by Ghana is inching up. However at the moment almost all the main crop cocoa (80% of total production) is still wholly exported. Research that identifies what combination of total beans produced should be exported and what percentage should also be processed in Ghana will be valuable information for Ghanaian cocoa policy makers.

Conclusion

SSA cocoa producers such as Ghana are typically exposed to both production and price risk which results in revenue risk. Revenue risk can be managed using futures contracts. However, the use of futures markets incorporates costs that may take away from the benefits. This analysis which investigated the effect of transaction costs and risk tolerance on the optimal hedge was carried out using cocoa revenue data from Ghana, a major SSA cocoa producer and respectively, quadratic utility and **Nelson** and **Escalante (2004)'s** CRRA utility functions. We confirm Rolfo's result that the optimal hedge is increasing in the risk parameter for both utility functions for the range of data used. However, using quadratic utility, we find that for reasonable values of the risk parameter, and positive transaction costs we obtain very small positive hedge ratios or negative hedge ratios which imply that the cocoa exporter should hedge a miniscule portion of total export or not at all.

By contrast using the **Nelson** and **Escalante (2004)** utility function which is a more believable representation of preferences, optimal hedge ratios remain positive even after transactions costs are considered. Since the optimal hedge ratio is the solution of a utility maximization problem, the exporter can only do as well or better than not hedging.[xxvi] This means that for Ghana, limited use of the futures market is utility improving. This partly confirms Rolfo results. The conclusion from this study is that from a utility perspective, limited use of the futures market for hedging revenue risk will benefit Ghana and more generally, SSA's cocoa exporters. The significant negative influence of transactions costs on the optimal hedge ratios cautions policy makers who advocate risk management strategies for SSA's commodity exporters without careful empirical evidence to back up their recommendation.

Figure 1. Cash and Futures Cocoa Prices, 1960-2008

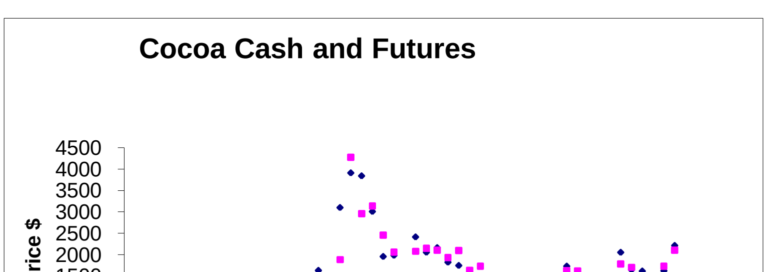

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Figure 2. Futures Price Variances, 1960-2008

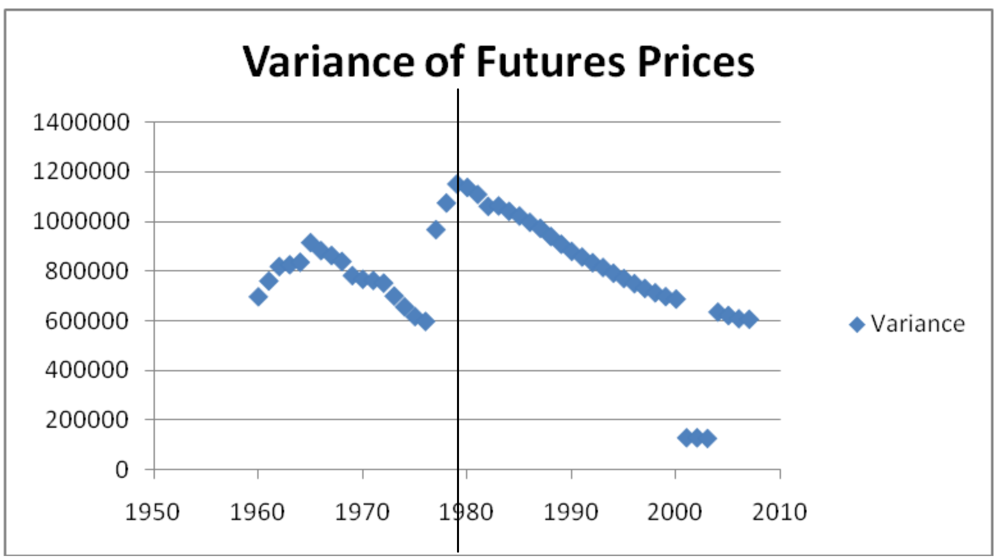
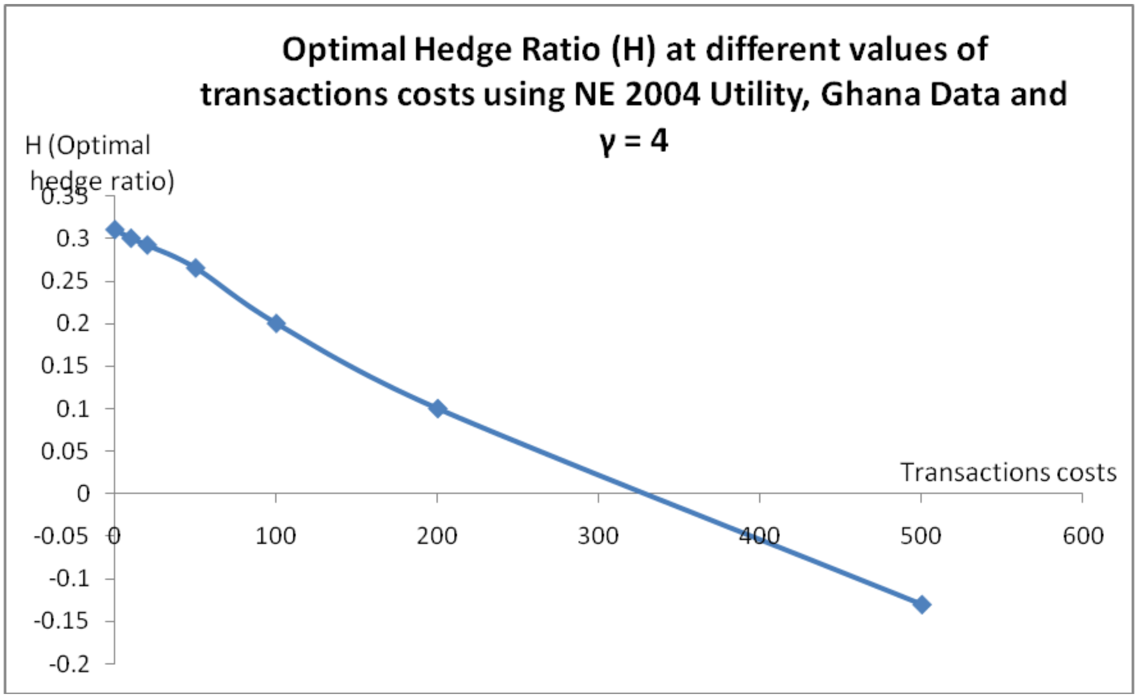


Figure 3. OHR at different Transaction Costs, $\gamma = 4$ and using NE 2004 Utility



Data Source: Export Revenue data was obtained from the Ghana Cocoa Marketing Board

Table 1. Structural Break Test for the Variance of Cocoa Futures Price

	Structural Break	m	n	Q-Stat	MI P-value
Standard Deviation of the Futures Price	July 1978	18	30	-5.0	<0.001

Ho: The Ratio of the variances from the two periods is unity
Ha: Ratio of the variances from the two periods is not unity
m = # of observations before the break.
n = # of observations after the break.
MI: Miller jackknife test for differences in variance between two periods.
For large m and n, Q converges to a standard normal distribution. High Q-Stat is strong evidence of a structural break

Table 2. Summary Statistics for Annual Prices, Production and Revenues, Ghana, 1980-2008

Production (* 1000 tonnes)	Mean	Std. Dev.	Min	Max
Ghana	493.37	69.79	360.05	653.32
Random Revenue (*$1000)				
Ghana	885640.8	281240.4	353567.6	1301458
Prices ($)	Mean	Std. Dev.	Min	Max
Cash	1775.37	453.72	890	2690
Futures at Expiration	1553.22	441	877	2469
Futures Forecast	1514.22	440.36	692	2513

Table 3. Correlations and Covariances between Cash and Futures Prices, 1980-2008

	Futures price	Cash price	Futures at expiration
Futures price	1		
	(194477)		
Cash price	0.86	1	
	(171581)	(205861)	
Futures at exp	0.9	0.96	1
	(174761)	(205861)	(195679)

Variance and Covariances are in parentheses.

Table 4. Optimal Hedge Ratios at Different Values of the Risk Parameter for Quadratic utility for Ghana as a Cocoa Exporter

Risk Aversion Parameter (γ)	b=0 Ghana
∞	0.44
1000	0.44
100	0.44
10	0.44
4	0.44
3	0.44
2	0.44
1	0.44
0.1	0.44
0.01	0.44
0.001	0.43
0.0001	0.41
0.00001	0.12
0.0000001	-1.00
0.00000001	-1.01
Cash hedge	0.82
Pure Revenue Hedge	0.44

Table 5. Comparisons of Optimal Hedge Ratios (MVH) for Ghana at a value of the Risk parameter (γ) of 4 and at Different Transactions Costs Using Quadratic Utility

Transaction costs ($ b) given γ=4	Ghana
0	0.44
10	0.38
20	-1
50	-1
100	-1
200	-1

Table 6. Optimal Hedge Ratios at Different Values of CRRA for Nelson and Escalante utlity Function for Different Values of the CRRA risk Parameter for Ghana

Risk Aversion Parameter (γ)	b=0 Ghana
∞	0.31
1000	0.31
100	0.31
10	0.31
4	0.31
3	0.31
2	0.31
1	0.31
0.1	0.31
0.01	0.31
0.001	0.31
0.0001	0.31
0.00001	0.1
0.0000001	-0.96
0.00000001	-19.96
Cash hedge	0.819
Pure Revenue Hedge	0.31

Table 7. Comparisons of Optimal Hedge Ratios for the Ghana Cocoa Marketing Board at a CRRA risk parameter value (γ) of4 and at Different Transactions Costs (B)

Ghana Data, NE 2004 Utlity and CRRA Transactions cost($ b per contract)	Risk Parameter (γ=4)
0	0.31
10	0.3
20	0.292
50	0.265
100	0.2
200	0.1
250	-0.13

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Appendix 1. The Closed-form Optimal Solution for the Optimal hedge When Basis Risk is Absent

Here P= P*f so we can use that information to* solve the utility function in (A.1) for h, the optimal hedge position.

A.1 Max $E[PQ+h(P_f - f - b)]^2 - \gamma E\{[PQ+h(P_f - f - b) - E[PQ+h(P_f - f - b)]\}^2$.

A closed form solution to (8) can be obtained if we assume no basis risk (i.e., assuming P_f = P) and is included in the appendix. When we allow for basis risk a closed form solution is difficult to obtain but a search procedure similar to that employed by Rolfo (1980) can be developed to determine h and by implication the optimal hedge ratio. The search procedure is discussed in more detail in the text and is the procedure used to generate our results because it is more practical to assume non-zero basis risk. Assuming no basis risk so that P_f = P, we can expand the last term in (A.1) to get (A.2)

(A.12) $E[PQ - h(P_f - f - b) - E[PQ - hb]]^2 = \sigma_R{}^2(R(h))$

$= E(P^2Q^2) - [PQ]^2 - 2hE(PQ(P-f) + h^2E(P-f)^2$.

Let $h^2E(P-f)^2 = \sigma_{P\,f}{}^2$ so we have (A.3),

A.3 $\sigma_R{}^2(R(h))) = E(P^2Q^2) - [PQ]^2 - 2hE(PQ(P-f) + h^2\ \sigma_{P\,f}{}^2$.

To solve for h we need only consider terms that contain h in (A.3). Expanding the last two terms in (A.3) by adding and subtracting f and μ_Q, we obtain A.4

A.4 $\sigma_R{}^2(R(h)) = h^2\sigma_{Pf}{}^2 - 2hE(\{P - f + f\}\{Q - \mu_Q + \mu_Q\}(P - f))$,

where μ_Q is the mean of output. Simplifying this expression, we arrive ate (A.5)

A.5 $\sigma_R{}^2(R(h)) = h^2\sigma_{Pf}{}^2$ -2hE ({P-f} ^{2} {Q-μ_Q}) + 2hC $\sigma_{P\,f}{}^2$ + 2hf E ({P-f}{Q-μ_Q}).

Let E({P-f}{Q-μ_Q}) = covariance (P,Q) = $\rho\ \sigma_{pf}\ \sigma_Q$ where ρ is the correlation coefficient between P and Q, and σ_{pf} and σ_Q are respectively the standard deviation of P (= P_f) and Q. So now we have A.6

A.6 $\sigma_R{}^2(R(h))$ = $h^2\ \sigma_{Pf}{}^2$ -2hE ({P-f} ^{2}{Q-μ_Q}) - 2h$\mu_Q\ \sigma_{Pf}{}^2$ - 2hf $\rho\sigma_{pf}\ \sigma_Q$.

The maximization problem now becomes

A.7 Max $E[PQ+h(P_f - f - b)]^2 - \gamma(E\{[h^2\sigma_{Pf}{}^2 - 2hE[(P-f)^2\{Q-\mu_Q\}$ - 2h$\mu_Q\ \sigma_{Pf}{}^2$ - 2hf $\rho\sigma_{pf}\ \sigma_Q$).

The futures position, h, is the solution of the optimization problem in (A.7) and is given by (A.8):

A.8 h = [2 γ E({P-f}^{2}{Q-μ_Q})] / [2 $\gamma\ \sigma_{pf}{}^2$- 2b^2] + [2 γ f $\rho\ \sigma_{Pf}\ \sigma_Q + \mu_Q\ \sigma_{Pf}{}^2$] / [2 $\gamma\ \sigma_{Pf}{}^2$-2b] –[2bE(PQ)] / [2 $\gamma\ \sigma_{Pf}{}^2$-2b].

Assuming normality, the third and fourth moments of the distribution of price, revenue and quantity are all zero so h is given by

A.9 h = [2 γ f $\rho\ \sigma_{pf}\ \sigma_Q + \mu_Q\ \sigma_{Pf}{}^2$] / [2 $\gamma\ \sigma_{Pf}{}^2$-2b] – [2b E (PQ)] / [2 $\gamma\ \sigma_{Pf}{}^2$-2b].

Given normality, and in the absence of transactions costs, b = 0 and we get

A.10 h = [f $\rho\ \sigma_Q / \sigma_{Pf}$] + μ_Q .

The hedge ratio H = h / μ_Q so from (A.10), we get (A.11)

A.11 H = ρ (f / σ_{Pf}) (σ_Q / μ_Q) + 1.

Therefore if ρ is negative, both the correlation between Q and P and transactions costs (b) will tend to reduce the optimal hedge ratio. Note that equation (A.11) has a very intuitive interpretation because (f / σ_{Pf}) is the inverse of the coefficient of variation of futures price at expiration and (σ_Q / μ_Q) is the coefficient of variation of stochastic output (Mackinnon, 1967).

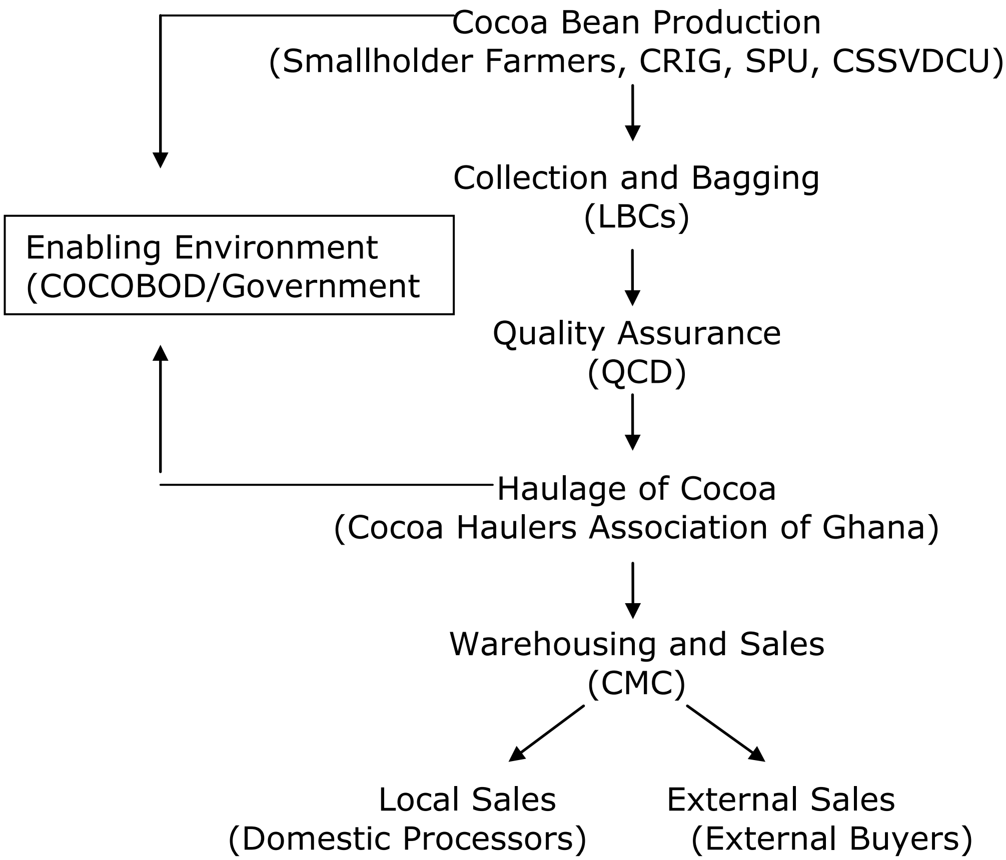
Clearly if $\rho < 0$ so that price and production are negatively related, then the optimal hedge ratio is less than unity. This result is similar to the conclusions drawn by Mackinnon (1967) and Rolfo (1980): in the presence of production risk and no transactions costs the optimal hedge ratio is less than unity. The more negatively correlated are price and output, the smaller the optimal hedge ratio. If in addition, price and production are not correlated then we get

(A.12) $\rho = 0$ and H = 1 in an unbiased futures market.

The cocoa exporter should fully hedge output. The result H = 1 is the usual case described by Hieronymus (1971) for a merchant faced only with price risk and has support in the literature (see Ederington, 1971; Rolfo, 1980 and McKinnon, 1967). If transactions costs are not zero then we get (A.13)

(A.13) $H = [2 \gamma f \rho \sigma_{pf} \sigma_Q + \mu_Q \sigma_{Pf}] / [2 \gamma \sigma_{Pf}^2 - 2b] \mu_Q - [2bE(PQ)] / \mu_Q [2 \gamma \sigma_{Pf}^2 - 2b].$

Appendix 2. Ghana's Unique Domestic Cocoa Supply Chain



LBC: Licensed Buying Agent
SPU: Seed Production Unit
CRIG: Cocoa Research Institute of Ghana
CCVDCU: Cocoa Swollen Shoot Virus Disease Control Unit
CMC: Cocoa Marketing Company
Source: Pinnamang-Tutu (2010).

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[i] The world cocoa market is made of a few oligopolistic producers (such as Ghana, La Cote d'Ivoire or CIV, Nigeria and Cameroun) mainly in SSA and a few large oligopsonistic buyers or processors (such as Barry Callebaut, Nestle, ADM and Cargill) mainly located in Europe and the USA. Cocoa has a small elasticity of supply and a relatively larger elasticity of demand because suppliers of cocoa are dependent on cocoa revenue and have no option but to sell what they produce (Bulir, 2002).

[ii] A recent related problem pertinent to export price risk emanates out of the uncertainty associated with variations in import price since most developing countries now import majority of the food they consume. See Sarris, Conforti and Prakesh (2011) for an excellent theoretical and empirical treatment of import price risk.

[iii] We acknowledge that some changes have occurred in the global cocoa cash market since Rolfo's (1980) work which may question both the relevance of a marketing board and the continued need for SSA cocoa producers to construct a futures hedge to minimize cocoa revenue risk. In particular the World Cocoa foundation reports that in some cocoa producing countries, multinational processors of cocoa are (forward) contracting directly with farmers

eliminating the need for price risk management through futures hedging. However this situation does not apply to Ghana (the cocoa market being studied here) because in Ghana, all cocoa is eventually bought up by the state-owned Cocoa Marketing Board (COCOBOD). COCOBOD directly exports cocoa to the international cocoa cash market so the revenue risk problem persists since it directly faces the risky world price of cocoa. Ghana produces two types of cocoa crop; the main crop and the mid crop. COCOBOD wholly exports the main crop but sells the mid-crop at a discounted price to multinational companies like Cargill and ADM who process cocoa in Ghana. Even though it is theoretically feasible to envisage that Cargill and ADM can contract with local farmers directly so that a cash forward contract may suffice to minimize risk, COCOBOD does not allow direct purchasing of even the mid-crop by multinational processors. COCOBOD chooses to be the domestic monopsony buyer of all cocoa because it wants to ensure all cocoa originating from Ghana meets the necessary quality requirement (Pinnamang Tutu, 2010). In the world where majority of the cocoa is sold directly from the farmer to the processor by means of forward contracts, there is little need for marketing boards so COCOBOD should have been eliminated long ago and if it has not been eliminated it will soon lose pertinence and be eliminated just as the marketing boards in La Cote d'Ivoire (CIV) and other producing countries have been eliminated. There is no large-scale direct contracting between multinational cocoa processors and Ghanaian cocoa farmers. Ghanaian farmers only sell to licensed cocoa buying agents but COCOBOD eventually buys back all the cocoa (main crop and mid-crop) from Licensed Buying Agents (LBAs) before selling the mid-crop cocoa to processing companies and exporting the main crop. COCOBOD provides essential quality control services to the domestic Ghanaian cocoa supply chain.

In Ghana COCOBOD is vital to the cocoa marketing chain both to guarantee a stable producer price and because of the other services it provides which help to sustain Ghana's unique supply chain. COCOBOD enjoys significant premiums as a monopsony buyer of cocoa in Ghana and an oligopolistic exporter of cocoa internationally selling a "differentiated product" because Ghana cocoa is the most quality cocoa in the world. Ghana cocoa is the industry standard. All cocoa is discounted to Ghana cocoa. It will be strange for COCOBOD to give up its premiums by liberalizing the export of cocoa thus diluting the quality of Ghana cocoa and compromising its own existence. Liberalizing the marketing of cocoa means COCOBOD will cease all the quality control measures it currently undertakes. All the marketing and research experience it has acquired will be useless. From a development point of view, the Ghana government is unlikely to approve of that especially given the high quality premiums that Ghana cocoa enjoys.

According to officials of COCOBOD, there are strong indications that La Cote d'Ivoire (CIV), the largest cocoa exporter which currently operates a liberalized cocoa exporting system, will revert to the marketing board system in order to regulate the production and branding of its cocoa, improve the quality of the beans and to increase efficiency in its cocoa supply chain. This has become necessary because transportation and marketing problems emanating from poor roads and lack of large storage facilities are undermining the market activities of Licensed Buying Agents (LBCs) in CIV's liberalized cocoa market. What is more, the quality of the beans keeps falling. A liberalized market works well if the government is willing to provide public goods such as roads, health facilities for farmers and quality control services despite losing control of the market. It seems CIV's government cannot sustainably provide these public goods in a liberalized environment. Given the outcome in CIV little incentive remains for COCOBOD to undermine its own existence.

In Ghana, COCOBOD closely works with government to ensure that roads to cocoa growing areas receive urgent attention. COCOBOD maintains cocoa research divisions that ensure farmers get access to fertilizer, and disease resistant seeds. The government occasionally organizes mass spraying of cocoa trees to eliminate the dreaded Capsid and Swollen Shoot diseases. As a monopsony buyer of all main-crop cocoa, COCOBOD also closely monitors the quality and weight of cocoa beans before export or sales to Ghana-based MNCs. With time it is becoming clear that the activities of COCOBOD are helping the Ghana cocoa industry while the choice of market liberalization is hurting the CIV cocoa industry. It is possible the organization of the entire world cocoa industry will morph towards the Ghana model.

[iv] The structural break was most likely the result of Ghanaian cocoa policy between 1973 and 1977 (COCOBOD, 2000). The government pursued a "feed yourself" policy based on boosting domestic foodstuff production and limiting imports and exports. The domestic cocoa producer price was slashed and subsidies were introduced for production of inputs for foodstuff such as cassava, yam, cocoyam and maize. Farmers responded by burning their cocoa farms; world cocoa supply dipped and prices spiked.

[v] Prudence is defined by a positive third derivative of a utility function. Risk vulnerability means an addition of background risk to initial wealth causes risk-averse agents to become more risk averse towards any other independent risk (Mattos, Nelson and Garcia, 2008).

[vi] The relevant assumptions of the MVH model include: (a) production is deterministic, (b) agent's total wealth is invested in the cash position, (c) no transaction costs, and (d) the futures market is efficient. See Collins (1997) and Benninga, Eldor and Zilcha (1983) for a full discussion.

A positive hedge ratio as used in this paper involves selling futures in some proportion to the underlying quantity to manage risk. Conversely, a negative hedge ratio involves buying futures contracts and is commonly identified as speculation or perversely "reverse" hedging.

[vii] A positive hedge ratio as used in this paper involves selling futures in some proportion to the underlying quantity to manage risk. Conversely, a negative hedge ratio involves buying futures contracts and is commonly identified as speculation or perversely "reverse" hedging.

[viii] In April 1998, New York's Coffee, Sugar and Cocoa Exchange (CSCE) merged with the Cotton Exchange to form the NYBOT (Dand, 1999).

[ix] See Appendix 2 at the end of this paper and Pinnamang-Tutu (2010) for more details on the institutional organization of the cocoa industry in Ghana.

[x] The domestic Ghana cocoa market is partly liberalized in that there are Licensed Buying Agents (LBAs) who can buy cocoa directly from farmers but have to sell back to COCOBOD. COCOBOD exports the main crop and sells the mid-crop to processors in Ghana. While policy makers in Ghana have hailed the contribution of COCOBOD in optimizing the marketing of cocoa in Ghana, economists have argued that direct contracting by Ghana-based multinational such as Arthur Daniels and Michel (ADM) and Cargill will eventually lead to the elimination of COCOBOD. In fact cocoa marketing boards in other countries have been eliminated after crumbling from pressure by the WTO, the IMF and other bodies to liberalize the domestic cocoa trade (Bulir, 2002). However the situation in Ghana is different because COCOBOD has a unique relationship with farmers which cannot be easily abrogated. COCOBOD has several divisions engaged in cocoa research to improve the quality of Ghana cocoa through close monitoring of cocoa harvesting, drying and packaging. COCOBOD also provides access to fertilizer, insecticides and herbicides. COCOBOD has been instructive in ensuring that Ghana cocoa has remained the most quality cocoa in the world for the last 50 years. Ghana cocoa therefore enjoys quality premiums since all other cocoa is discounted to Ghana cocoa. This is one reason that the COCOBOD is so vital and is unlikely to be eliminated in the immediate future.

[xi] The combination of elastic demand and inelastic supply, buyer and seller power and informational inefficiencies means cocoa prices are highly variable. Since COCOBOD faces the variable world cocoa price, there is the need to manage the revenue risk. Hedging is a market-based risk management strategy that can be used to manage risk. At the moment the only risk strategy being employed by COCOBOD is forward contracting for the mid-crop that it sells to processors operating in Ghana. COCOBOD still faces significant risk in the export market for its main crop which it exports to the world market so managing export risk remains an important problem for COCOBOD. Further, although not yet mentioned, there are several significant advantages of hedging over forward-contracting apart from the benefits of a market risk management scheme for the wholly exported main crop that hedging promises. Some are:
1] The futures price received at expiration is typically higher than the forward cash price.
2] The producer has greater marketing flexibility with futures than with forward contracts. Because the producer can fulfill his commitment to the futures by simply buying an equal and offsetting contract, the futures market allows the producer to easily adjust to changing conditions.
3] Futures contracts can be traded from a few days to nearly a year in advance, allowing the producer a longer period of time to choose a price. This allows more flexibility in managing market risk. A hedge can also be more easily rolled forward in response to changing market conditions/risk.
4] Market access is better with a futures contract compared to a cash contract. Sometimes with a forward cash contract difficulty arises in locating a nearby buyer who wishes to enter into a contract.

[xii] Risk is measured by the variance which is a two-sided measure.

[xiii] Production decisions are not modeled because COCOBOD has no direct control over how much is planted.

[xiv] This hedge horizon is convenient because the cocoa futures market (NYBOT) has five contract months in a year: March, May, July, September and December.

[xv] Just, Just and Kabvachadana (2010) assert that the current literature on production risk describes methods of dealing with production risk that can neither discern production risk preferences nor discern the factors that relate to production risk preferences. There is also evidence that prior estimation of production risk has severe problems,. Finally there is a general failure of current models to address the important policy or behavioral issues related to production risk.

[xvi] The analysis here does not consider the effect of the variability of transportation costs on the optimal hedge ratio and consequently on the usefulness of hedging. Suppose the transportation costs is labeled t, then it can enter the revenue function R as $R = PQ + h\,(f - P_f - b - t)$ where all variables retain their previous definitions. Here we do not focus too much on the volatility of transportation and other costs because the transportation costs and the brokerage costs are pretty much fixed over time. Further transportation costs usually increases in a systematic way with volume so there is little variation to talk about in transportation costs. Transportation costs will most likely have the same qualitative effect (direction) as brokerage fees because it reduces the utility from hedging just as any cost will do: it will tend to reduce hedge ratios. We do acknowledge, however, that transportation cost has been found in the literature to sometimes significantly change the hedge ratio. For example Haigh and Holt (2000) indicate that transportation costs do vary appreciably and can influence the optimal hedge especially if the random prices are Free on Board (FOB) prices. However we remain comfortable with our decision not to focus on transportation costs because such a focus will unduly complicate the analysis and is better suited for further research.

[xvii] For clarity of presentation, in solving for h from the maximization of expected utility, we will leave out the overall expectation sign (E) because the utility itself is a function of mean and variances which are also defined using the expectation (E) sign. However the computations are done with the correct expression of expected utility.

[xviii] Following the analytical proof by NE (2004) that the NE (2004) utility function satisfies the location scale condition, we verified analytically that the identical NE (2004) that we employ also satisfied the location scale condition. There is nothing new here. Since we are using an identical utility function to that used by NE (2004) we just followed their derivations and made sure it applied to our case. For more details of why this utility function satisfies the location-scale condition and for an example of its application see Nelson and Escalante (2004).

[xix] A note of caution is, justified here because de-trending the random revenue data but not the futures data might complicate interpretation of the hedge ratios. However, to the extent that we use simulation techniques and not regression analysis to estimate the optimal hedge ratios, the differential transformation of the data does not pose a big problem. We recognize that the price and output variables in the revenue expression are in levels before being de-trended but that futures at expiration and futures data in the revenue expression are also in levels but are never detrended so this may complicate the interpretation of the findings had regression been used to compute optimal hedge ratios. However, since the analytical expression in levels for computing hedge ratios used in the simulations analysis is essentially identical to expression of the hedge ratio in differences we do not expect de-trending to cause problems.

[xx] The basis at contract expiration is large; it is 12.5 percent of the spot price. Typically such a basis should be eliminated by arbitrage activities. However since the revenue data used in the simulation data was obtained from COCOBOD while the futures data is from the NYBOT the cash and futures data have a spatial difference so it will be difficult for traders to go long the futures, stand for delivery, and then turnaround and sell it on the spot market. Further, the large basis at expiration might be due to quality differentials that cannot be arbitraged away. Ghana cocoa is the world's most quality cocoa and enjoys a significant premium. However most of the cocoa sold in the NYBOT comes from South America. Some of the difference in basis may be explained by quality differentials because the cash price (P) in the revenue stream is based on actual cash prices received by COCOBOD but the futures at expiration that is defined in the export revenue stream are prices recorded by the NYBOT in New York. These later prices may be more heavily influenced by the average price of less quality non-Ghanaian cocoa e.g. (CIV) cocoa since CIV dominates the NYBOT market. The failure of successful arbitrage to reduce the basis may also be due to insufficient liquidity in the market to support this speculation. Since traders may include large cocoa

buyers like processors who need the cocoa as an input in production there may be a convenience yield in possessing the cocoa. Therefore, once the contract is purchased the trader who might be an affiliate of a cocoa buyer cocoa may have no incentives to re-sell cocoa in the cash market (because of risk of failure to acquire cocoa input when needed) although he can make money if he were to speculate on cocoa prices. Further, short-run uncertainty about supply due to informational inefficiencies in the short run may result in this bias. In a revenue or utility context, the appreciation of the futures push towards "speculating" on futures by going long rather than short in the more traditional hedging framework but speculating is not the objective of COCOBOD as it will expose COCOBOD to even more risk contradicting COCOBOD's risk minimizing objective.

[xxi] Technically, a long hedge is a hedge used by buyers of a product where they buy the futures in anticipation of subsequent cash purchases. In this way, they protect themselves against price increases in the cash market because as long as futures and cash move up together they can resell the futures at a higher price and offset the loss in the cash market with a gain in the futures market. COCOBOD is a seller not a buyer of cocoa so it is seeking protection from price declines not price increases so the long hedge is not favored here. In fact price appreciation is favorable to COCOBOD since it increases COCOBOD's utility.

[xxii] In Rolfo's case optimal hedges from the four countries he considered CIV, Ghana Nigeria and Cameroun all declined by considerable amounts when production risk is also considered in addition to price risk when using log utility which displays CRRA but not increasing absolute risk aversion. The CRRA function by contrast provides low OHRs because they exhibit DARA while quadratic utility exhibits CARA. Their risk aversion decreases as they revenue increases so they need less protection from risk and hedge less leading to small hedge ratios.

[xxiii] For US farmers values of the CRRA risk parameter γ between 1 and 5 are the most reasonable representation of risk preferences (Nelson and Escalante, 2004).

[xxiv] Borenstein et al (2009) use a dynamic optimization model to estimate the welfare gains of hedging against commodity price risk for commodity-exporting countries. They consider a small open economy that is exposed to shocks in the price of the commodity that it exports. They then compare welfare from two scenarios: a baseline no hedging case to the hedging case where hedging is done using futures contracts. They find that hedging has two dimensions of benefits because although it reduces income volatility and smoothens consumption, it also reduces the propensity for the sovereign to hold foreign assets as precautionary saving. This paper focuses of the first dimension of welfare that hedging with futures entails although the benefit from minimizing the precautionary motive could also be substantial because it implies reduced interest on sovereign debt.

[xxv] Note that Lence (1996) models the atomistic farmer's production decision in trying to determine whether or not SSA countries should hedge cocoa revenue risk so he is also concerned with the production decision. This researcher does not take production decisions into account in formulating the Utility Maximization Problem (UMP) of COCOBOD. COCOBOD's actions are taken as representative of the actions of the Ghanaian government so that the total volume of cocoa produced is pre-determined. What Lence (1996) is identifying in his conclusion that SSA countries should not hedge because of the supposed utility eroding effect of hedging is the "technology effect of hedging" where prices plummet after production increases because of reduced risk. This drop in prices reduces farmer welfare from a utility perspective especially since the supply of cocoa is inelastic. Since the production decision is exogenous in this research the model does not capture the reduction in utility due to the technology effect so that in contrast to Lence (1996) this paper is less likely to conclude that the COCOBOD should not hedge cocoa revenue risk. It can be argued that the modeling approach adopted here following Rolfo (1980) is more relevant to the COCOBOD decisions because COCOBOD is unconcerned with the production decision. Lence makes other unreasonable assumptions such as assuming that the utility function is CARA instead of displaying DARA, CRRA, decreasing risk prudence and risk vulnerability all of which raises questions about the validity of his conclusions.

[xxvi] In solving for the optimal hedge ratio (h) from the UMP, the search program looks for that hedge ratio that yields the maximum utility by sequentially testing all possible values of h in the relevant 0 -1 range for a short hedge. Consequently if a positive value of h is chosen as the optimal hedge ratio that value gives a utility value greater than the no hedge position (h = 0).