

Essays on Commodity Risk Management

By

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Abstract

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Using a sample consisted of fifteen African commodity - dependent countries, this paper outlines commodity price risk that low income countries were exposed to and discusses the significance of such exposure to the low income countries' fiscal stability. Considering the political issues that are related to implement these commodity risk management strategies, we illustrate how a county exposed to market shocks can hedge against fluctuation in the price of its major export commodities, using futures and options markets at a very low cost.

The discussion suggests that by using modern financial hedging instruments, such as options, we can not only mitigate

the commodity price risk, but further foster the initiation of modern financial market in low income countries.

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Session 1: Introduction

Today as many as 38 developing countries are estimated to be dependent on a single commodity for majority of their exports income, while 48 countries depend on two. These countries depend on commodities as a source of livelihood, employment, foreign exchange, government revenue and the commodity exports provides the principal stimulus for economics. For these commodity dependent countries, macroeconomic stability, debt suitability and growth of the economic are highly related with the external shocks such natural disasters, regional crisis or war, and most importantly the international market (or terms -of -trade) shocks.

A low income country usually depends on export income, foreign transfer and foreign reserves to service their foreign debt .The price volatility of a small number of commodities, therefore, presents a major risk that could seriously damage the already tenuous economies and fiscal balances of commodity dependent countries, possibly leading to sovereign defaults. To make the problem worse, it is precisely such countries which often also lack the resources to hold large stocks of foreign reserves as a buffer against shocks.

In this paper we will investigate financial instruments and strategies that may mitigate this risk with the political issues that associated with hedging in mind.

The paper is organized as following. We begin by reviewing the recent research on macroeconomics volatility and commodity price risk as well as the hedging of such risks.

In the next section we discuss the link between macroeconomic volatility and sovereign default the point of view of low income countries. We concerned with macroeconomic indicator such as exports, imports and gross domestic product of the fifteen low income countries. After review the relevant data, we show that there are several low income countries whose economies are significantly exposed to one or two commodity price and volatility risks. We also show, in particular, that the price faced by the low income country on it major export commodities (e.g sugar) and the volatility of these commodity prices. We claim that hedging these risks with inexpensive instruments may bring considerable fiscal and macroeconomic stability to these economies. We support these arguments with data and simple econometric evidence.

In the next section we consider the financial engineering of instruments that can be used to *hedge* such risks. We will discuss the simple instrument and then proceed with more complicated exotic options. We prove that, as a result of implementing these hedge strategies, it is possible to help to stabilize the economy of these commodity dependent countries at a relative low cost.

The following section deals with examples of *pricing* such instruments and gives the demonstration the cost of these instruments.

In the next section we provide the *cost* of more elaborate structures that may reduce the effects of commodity price volatility, while at the same time help to initiate a market for LIC bonds.

Then, the following section provides a *back-testing* argument on the advantages of such hedging strategies in a case study, namely the case of Ghana and gold price volatility. We show that the utilization of even the simplest method - vanilla options would have added significant stability to exports of Ghana during the years 1988-2000.

The last section is conclusion.

Session2: Literature Review

Commodity-dependence of many Latin America and Africa countries combining with the unstable commodity price in international market posts a challenge: How to help to manage the commodity risk for this low income and commodity – dependent countries?

Modern market-based financial instruments, such as futures options, swaps and various forms of collateralized finance might not be the best solution to the question but no better alternatives are currently available (Rutten, 1998). *Luis Catao and Sndeeep kapu*, in their paper *Missing Link : Volatility and the Debt Intolerance Paradox* (Kapu, 2004) shed light on the “Debt intolerance”¹ phenomenon and examined the extent to which volatility explains sovereign risk. Their study further advanced the paper by Reinhart, Rogoff and Savastano (Reinhardt, 2003) , which combined macroeconomic data for the post 1970 period with information about sovereigns’ credit histories since the early nineteenth century. Reinhart’s paper studied the concept of “debt intolerance”, meaning in emerging markets’ sovereign riskiness appears to be out of proportion to the size of the

1 Developing countries typically face a upward sloping supply schedule for international debt ,and may be altogether excluded or international capital market during A BAD STATES OF THE WORLD (Diaz -Alejandro,1984;and sachs 1989; Eichengreen and Lindert,1989)

respective debt burdens. While these studies all argued that external term of trade is a key factor in the sovereign risk of many developing countries and “this greater volatility is associated with higher default probability” (Kapu, 2004). This paper, using the empirical data from fifteen Africa commodity dependent countries, particularly focuses on the commodity price volatility issues in these countries.

Knowing the effect of commodity volatility on the fragile economy of commodity dependent countries, it is important to know the effective and practical measure that can be used to manage the commodity risks and stabilize these countries income stream from commodity export.

Several strategies have been suggested by literatures. Commodity – Linked or commodity – indexed bond, in which the principal and perhaps the interest payments are a function of the price of the underlying commodity on which the bond is written. Atta-Mensah (2004), Miur and Yamauchi (1998) O’hara (1984) has proposed to use such structure to help the low income countries to manage risks. In this paper, we will look at the possibility of using a more cost efficient and flexible instruments - derivative to hedge the commodity price risk.

Session 3: the significance of Commodity risk management for low income countries

The importance of hedging commodity price volatility specially for commodity dependent countries should be set clearly, since there is not one, but at least two dimensions to it. The Low income countries exhibit extreme dependence on commodity price volatility through external accounts and government revenues. An adverse shock to commodity prices will affect the trade account negatively and dramatically, but, due to government ownership of natural resources, it will also have quite negative effects on government's fiscal balance. The point of this paper is that, new financial instruments, and cleverly chosen strategies can mitigate such risks significantly.

However, there is a second dimension to the problem. Financial solutions to such problems encountered by low income countries will become more lasting and “efficient” if they create environments that contribute to actual trading of the newly introduced instruments. This is especially true in case of low income countries. These economies do not, in general, have significant bond and equity markets where debt instruments or stocks trade. To the extent commodity price hedging can help to introduce indirectly, any rudimentary

trading of debt instruments, the hedging activity may be more successful while at the same time the costs of this hedging may decrease. It may also have more lasting effects, at least for some of the low income countries under consideration.

In order to illustrate this general point consider the following two strategies.

Case 1

In the first case World Bank issues a bond valued at 100% on behalf of the low income countries and at the same time sells an option valued at \$P to the . The option has the purpose of hedging commodity price volatility and may have any desired structure. The proceeds of \$100 are then extended as a loan to the low income countries. World Bank is exposed to the default risk. The World Bank will put \$50 aside as margin from its capital.

Case 2

In the second case, then low income countries issues a bond valued at $100-P$. The World Bank provides a (commodity price triggered) Credit Default Swap (CDS) at cost to the buyers of the bond.² The World Bank will put \$50 of its capital aside as a guarantee for payments during a potential default.

The initial cash flows generated by these two strategies are going to be similar. Also, the credit risks associated with them are the same. In each case, the bond holder is exposed to World Bank default risk and the World Bank is exposed to low income country default risk. The associated commodity price-linked option would also be the same.

Yet, the second case has one major advantage. The structure introduces credit default swap for the relevant low income countries in the market place. Some of these CDSs may be traded, albeit thinly and this may kick-start a market for such low income countries -based CDSs. A thin CDS market in such credits eventually may lead international investors allocate a small portion of their portfolios to low income

² Of course, the price need not be zero in reality. We make this assumption because it facilitates comparison with the first strategy, where the zero price of a CDS is already implicit

countries' credits through Collateralized Debt Obligations (CDOs). Even a minuscule allocation from such portfolios would have a major effect in kick-starting a debt market for some of these low income countries.³

Hence, in this paper we intend to discuss instruments that mitigate commodity price volatility through indirect use of CDSs. However, the instruments that we discuss below are designed that, if desired, the dependence on CDSs may be eliminated in a fairly straightforward way.

Consider an issuer who is exposed to cash flows depending on a commodity price $x(t)$.⁴The issuer sells bonds with maturity T . These bonds have to be rolled over at maturity.⁵ The market for these bonds is very thin. If $x(t)$'s volatility increases significantly near the maturity date, the market may refuse to roll these bonds over, or simply, the sovereign defaults. This creates a major credit risk linked to commodity price volatility. The risk increases the cost of borrowing and makes it harder, or even impossible to issue

³ In fact trading and hedging of CDS positions will, in principle, lead to secondary trading of the low income country bonds.

⁴ The X_t can be a vector.

⁵ One can also look at these bonds as World Bank loans to

bonds for such issuers. Can this problem be addressed using new financial market instruments? In this paper, we will address this problem from a Low income country's point of view.

Contingent credit line that may be triggered by commodity price volatility is one way to address the problem. However, they have not been used by sovereign issuers. In the remaining of this we will discuss some alternative structures and provide some initial estimates of how much they would cost.

There could be many approaches to mitigating low income country's commodity price risk. We study four cases. The first possibility is to use future or forward to hedge the commodity price risk. Secondly, a low income country can also buy *vanilla* Put or Call options on the relevant commodities to eliminate the associated commodity price risk. We will argue that the first two methods could be quite expensive. The third possibility is to *buy structured option* products, thus the high cost of the vanilla options is lowered by *selling* other options simultaneously. Such structures become cost effective but introduce other risks in terms of possible losses and mark-to-market adjustments. They may not even be politically feasible.

The fourth approach, which we emphasize in this paper, is to mitigate commodity price risk using *exotic options i.e. barrier options*

One possible structure that we study in the paper is the following. An option is attached to a typical bond. The option has a knock-in /knock-out feature. If $x(t)$ exceeds a certain knock-in barrier, then, either the bond maturity is extended n years, or the bond holder receives a Credit Default Swap(CDS)⁶

In fact, we argue in this paper that an efficient way of mitigating commodity price risks is to use CDSs. One can envision a wide variety of these kinds of structures, so they can become an extremely valuable tool in dealing with low income countries' commodity price risk.

⁶ A long CDS contract protects the bond holder against defaults. If the issuer defaults, the principal and the accrued interest will be paid by the CDS writer. As a compensation for this insurance service the CDS writer receives a periodic fee, called the CDS rate.

Session 4: commodity dependent countries and Commodity Price Volatility

In this section, we discuss relevant data from fifteen low-income countries to illustrate the extent to which commodity price volatility may affect such economies. Our sample consists of Burundi, Central African Republic, Ivory Coast Eritrea, Ghana, Malawi, Tanzania, Zambia, Sao Tome and Principe, Togo, Guyana, Honduras, Nicaragua, Bangladesh and Cambodia, all of which are commodity dependent countries.

In the first part of this section, we study the correlation of commodity price volatility with macroeconomic indicators. We chose Government Revenues, Government Budget Deficit, Exports, Imports, and Gross Domestic Product as the main indicators to look at.⁷ We see that the vast majority of the countries under investigation export primary commodities. Leading import-commodities, on the other hand, are petroleum, petroleum products, and machinery.

In the sections below we investigate the correlation between these commodity prices and the macroeconomics indicators.

⁷ See Appendices 1 and 2

4.1 Fiscal balance

An unfavorable movement in a commodity's price may have severe adverse effects on a low income country's macroeconomic performance. We first consider the effect of commodity price volatility on the *fiscal balances* of the low income countries in our sample. Using the commodity prices that are most relevant for these countries, we calculate the statistical correlation between the country's government deficit, government revenues and the respective commodity prices.⁸

The dependence of government revenue, and hence the deficit, of a few commodity prices is overwhelming. In Appendix 1 we indicate the correlations above 27% in red. A look at these estimates suggest that for all countries under consideration, except Bangladesh, there is at least one, and often two major commodity prices where the correlation between fiscal balance and the price exceeds 25%. For about

⁸ In calculating the estimates shown in the Appendix, the relevant time series have been converted into USD, using period average exchange rates (Source, IFS). Commodity prices are levels, some commodities have more price quotations than others.

two thirds of the low income countries this correlation is in fact above 40%.

Thus it appears that commodity price movements affect low income countries government revenues very significantly, and this causes significant movements in governments' deficit. To the extent government debt is directly linked to government deficits, these results indicate quite clearly that commodity price volatility may have significant impact on debt sustainability and low income countries sovereign default. The results discussed below support this conclusion.

4.2 Exports

An LIC that exports large amounts of a commodity whose price had moved unfavorably, and whose share of exports on GDP is high, will most likely not perform very well during that period. A remarkably high percentage of low income countries have exports consisting of one or two leading commodities. In four cases, there is just one leading export commodity whose share on total exports exceeds 50%. Such commodities often have a significant effect on the countries' GDP. A case in point is Zambia, where the main export commodity (copper) represents 80.33% of exports. The effect of copper exports on Zambia's GDP is very significant, and

stands at 22.25%. Burundi's exports of coffee have a share of 68.8 % in all exports; Malawi's economy depends on tobacco, which represents 66.7% of the total exports.

The number of countries that have two leading primary commodities representing more than 50% of exports on total exports is larger. Eleven countries have three export commodities representing more than 50% of the total exports. In Tanzania and Nicaragua, three leading export commodities have a share of 46%. The last two economies are Bangladesh and Cambodia, whose leading export commodities are not primary commodities but textiles.

Next, we investigate the relationship between the leading export commodities and each country's GDP. We look at the share of each particular commodity exports on GDP, as well as the share of the total exports on GDP for each country in the sample. Taking our sample countries, we see that the share of total exports on GDP varies with each country. There is no visible relationship between the countries that have a higher share of exports on GDP and the countries that don't. We notice that seven countries have significant economic dependency on exports.

4.3 Imports

Our findings indicate, as expected, that imports are also significantly correlated with commodity prices. The interesting point is the level of significance that petroleum and machinery imports represent for these countries. The conclusion is similar to the one reached for exports. The low income countries' economies are, to a considerable degree, exposed to market risks of the leading import commodities' price fluctuations. To see this, consider the shares of commodities in total imports and GDP. Usually, the leading import commodities in the sample countries are either petroleum products or machinery, or both. The percentage share of single imported commodities on total imports is significantly lower than that of exports. In fact, finding a single commodity that corresponds to more than 8% of the total imports is a significant result.

In our sample, we have ten out of fifteen countries that have such commodity shares in their import portfolios. The commodity in eight out of ten cases is petroleum (crude or petroleum products). The two exceptions are Cambodia and Sao Tome and Principe. In Cambodia, the leading import

commodity is tobacco, which represents 16.22% of total Cambodian imports. For Sao Tome and Principe, the leading import commodity is machinery (aircrafts).

When we consider the percentage share of total imports on GDP, we immediately see that this case is different from what is found for exports. We have thirteen countries, whose percentage share of total imports on GDP is higher than 20%. In our sample the average share of total imports on GDP is decisively higher than the average share of total exports on GDP. The total imports/GDP ratios are especially high for the following countries: Guyana (89.57%), Eritrea (72.63%), Nicaragua (61.18%), and Sao Tome and Principe (46.95%).

4.4 Commodity Prices and Volatility

In the preceding section we identified low income countries whose external trade depends on certain commodities. Commodity prices are highly volatile, and hence expose the primarily commodity trading Low income countries to strong volatility. This in turn affects their macroeconomic balances and the economy's performance. In this section, we discuss the following issues: (1) Commodity price volatility;

(2) correlation between commodity prices;

(3) Co-movement of commodity prices and macroeconomic indicators of low income countries, and

(4) The difference between implied and realized volatility of selected commodity price futures.

That the volatility of commodity prices is very high can be seen in the plots of monthly percentage changes⁹. The peaks and troughs vary considerably, with price jumps of 20% and more, are not an exception, but the norm. On the other hand, some commodity prices seem to exhibit low volatility over the course of roughly the last two decades.¹⁰

We also see that commodity price risks are largely independent of each other ¹¹ the results show generally low covariance between the commodity prices in our sample. The correlation coefficients are rarely above 0.1. Correlation coefficients higher than 10% occur, between Sugar, Maize and Soybean -- where this type of effect might be expected, as all of these products represent agricultural inputs for food processing, and therefore are interrelated. Similarly, Tea and Coffee move partly together.

⁹ See Appendix 3

¹⁰ See, Figure 7: Soybean and Figure 8: Sugar in the appendix.

¹¹ See Appendix 4, Table 3, Table 4

As mentioned above, the low income countries data show that the share of primary commodity trade in total trade and GDP is quite significant. At the same time, high volatility in world commodity prices implies considerable adverse risk exposure, even when the domestic fundamentals for macroeconomic performance are sound. We calculate simple Bravais-Pearson correlation coefficients between selected commodity prices and growth rates in macroeconomic indicators such as exports, imports and GDP.¹² The results indicate a significant relationship between commodity prices and imports, exports, or GDP's growth rates. Consider Burundi as an example. We see that Burundi's exports and GDP growth rates correlate remarkably with coffee prices growth rates. The correlation coefficients are high at 0.55 and .35, respectively.

Consider now commodity price volatilities, more precisely the price volatilities of futures contracts written on different commodities. This is relevant because, as we discuss in the next section, there are two types of volatilities concerning commodities futures. The first is the actual realized volatility while the second type is the implied volatility. The implied volatility is obtained to a large extent, independent of

¹² See Appendix 5

market movements, by the Black-Scholes pricing formula. The data show that the two volatilities are not the same.¹³ Even though the series are highly correlated, the difference between the implied and the historical (i.e. realized) is significant and mostly positive.

¹³ See Appendix 5

Session 5: The concept of commodity price volatility

Markets distinguish several different types of volatilities. Some of these notions can be very delicate and may hide subtleties that may not be immediately clear to audiences accustomed to econometric analysis. The notion of traded volatility in financial markets may incorporate a risk premium and need to be carefully spelled out.

More specifically, we will consider three different types of volatilities in this paper. The historical volatility is easiest to understand for economists. This is the statistical estimate of the standard deviation at time t using a proper one-sided moving average filter. We let this be denoted by S_t . Then the estimate will be as following:

$$S_t = \sqrt{\frac{1}{n} \sum_{i=0}^{n-1} w_i (X_{t-i} - \bar{X}_t)^2}$$

where the weights are positive and satisfy,

$$\sum_{i=0}^{n-1} w_i = 1$$

\bar{x}_t is the moving average mean.

The *implied volatility* is a more complex notion. It represents the average volatility that will make a European option with expiration date T generate enough trading gains, so that the market maker breaks even on the trade. In case this implied volatility is backed-out from the Black-Scholes formula, it is called the Black-Scholes implied volatility. We let this volatility be denoted by σ_t . It is given by solving the non-linear equation:

$$f(x_t, K, r, \sigma_t, T - t) = \text{Observed option premium}$$

where $f(\cdot)$ is the Black-Scholes formula. The $x_t, K, r, \sigma_t, T - t$ are respectively the commodity price, strike price, risk-free interest rate and the remaining life of the option.

As shown in the appendices, the time series data on σ_t and the historical volatility S_t may be quite different for the same risk factor because of at least two reasons. First of all, the Black-Scholes formula does not conform to conditions prevailing in most markets yet it is used as a convention in invoicing option trades. The trader then “adjusts” the implied volatility so that the formula gives the correct dollar value of

the option. The more important adjustment for our purposes in this paper will be made for the following reason.

An option has a well-defined life. During this period, volatility and correlation need to be considered as stochastic processes rather than constants. Several events may occur during this period and the underlying volatilities and correlations may change in a *predictable* fashion.¹⁴

The trader has to factor in any option price these potentially higher volatilities and correlations. This is done by raising the average volatility plugged in the Black-Scholes formula, or by raising the average correlations. As a result, the implied volatilities may diverge significantly from the historical volatility. We must point out that this is a critical factor in devising hedging approaches for low income countries exposures. It is plausible that market makers would introduce significant “adjustments” to historical volatilities and correlations when they price low income countries risks.

The final reason why implied and historical volatilities may differ has to do with risk premium. One can claim that volatility is a risky asset, containing a separate risk than the ones involved in the underlying price. Under these conditions

¹⁴ The so called “*smile effects*”.

its trading will command a risk premium. Again, low income countries-linked options may end up having significant volatility risk premiums.

According to this discussion, *an economics-related* analysis of the commodity price volatility risk should *not* use the notion of implied volatility. For such discussions the historical volatility is the correct notion to use. On the other hand, the implied volatility has to be used when considering the *cost* of hedging strategies.

The third notion of volatility is *local volatility*. It is essentially a technical concept. Local volatility is used in pricing options and/or obtaining Greeks via the Monte Carlo or Lattice methods. It is a volatility surface obtained from live and arbitrage-free option prices that the trader uses as benchmark. This volatility surface is a function of time t and of the underlying price x_t . It is calibrated in a way that the model replicates the benchmark prices as closely as possible. Local volatility will be denoted as σ_t^{local}

This concept is relevant in case further work is done on low income countries -linked options. We do not use local volatility in this paper, since we would like to obtain upper

bounds on instrument prices rather than precise estimates of the related costs. In further work, these instruments should be priced with local volatility or similar tools.

Session 6: From data to prices

We now look at some numbers of commodity price volatility. Our main point is to show that volatility *itself* is a very volatile stochastic process. To see this, consider Table 1 that displays the *implied volatilities* of selected commodities. In this table we report the observed implied volatilities for major commodities for two points in time, namely the end of July 2004 and the end of November 2004. The last column is more important. It gives the range of implied volatilities during the last 6 years.

The importance of this table is in the following. In the table we see a great deal of volatility variation for coffee, sugar, crude oil, natural gas. Hence, commodity prices are not only volatile, but this volatility can suddenly and significantly spike upwards. In the same Table we report volatilities of some equity indices and of exchange rates for comparison purposes. The same phenomenon is visible in these financial variables as well. Implied volatility can change from over 60% to 10% over a relatively "short" period of 6 years. Such spikes of volatility are essentially what make sovereign defaults more likely.

Table 1

This table shows the implied volatilities (in percentage) of some selected commodities. Note the significant volatility in the volatility numbers.

Commodity	November ,2004	July,2004	6-year Range
S&P500	13.2	14.5	11.8-39.5
Eurodollar	22	27.3	8.4-63.1
Euro	11.3	9.7	7.2-16.7
Yen	10.3	9.5	7.6-32.2
Corn	20.1	24	15.6-39.6
Wheat	23.1	23.1	19.2-35.0
Coffee	31.2	30.7	29.9-90.9
Sugar	27.9	30.3	25.4-56.2
Cotton	31.6	38.8	15.8-43.4
Crude Oil	42.2	36.6	28.4-63.3
Natural Gas	58.2	36.8	30.0-113.9
Copper	29.7	29.7	28.4-63.3
Gold	33.6	34.4	14.6-38.4
Live Cattle	18.3	23	9.6-35.7

Tables 2 and 3 give the details of implied volatility movements for two important “commodities” namely, Gold and Crude Oil. The tables show how statistical volatility differed from implied volatility, at a point in time, and over two daily

ranges. The numbers are striking. They indicate that implied volatility has been much more stable over these periods when compared with statistical volatility. Tables 2 and 3 provide some evidence for the fact that markets' view of volatility changes much less than the statistical volatility measures do. In this sense, option prices may seem "too high" during days of low observed commodity price volatility.

Table 2

This table showed the implied Volatility for gold and statistical volatility movements for GOLD. The data indicated that implied volatility has been much more stable over these periods compared with statistical volatility.

Gold	Current ¹⁵	200 Day			150 Day		
		High	Low	Percentile	High	Low	Percentile
1 Day Implied Vol.	17.65	17.71	15.97	96.47	17.71	15.97	96.47
5 Day stat. Vol.	9.95	28.93	4.2	21	27.17	4.2	25.33
10 Day stat. Vol.	9.64	23.97	6.48	9.5	22.73	6.48	12.67
20 Day stat. Vol.	11.92	233.19	9.69	13	21.44	9.69	17.33
40 Day stat. Vol.	12.16	20.22	10.72	10.5	19.27	10.72	14
50 Day stat. Vol.	11.64	19.64	11.19	4.5	19.64	11.19	6

¹⁵ In the Tables" current "means the end of November,2004

These tables show that the instruments written to mitigate commodity price risk should consider the price *as well as* the volatility of the price as the underlying risk. In the present version of the paper we consider only the instruments that are written on the price. The volatility of the price is assumed to be constant. However, it is not clear at the outset whether this is the right approach.

Table 3

This table shows the implied volatility movements for crude oil. The data again indicate that implied volatility has been much more stable over these periods compared with statistical volatility

Gold	Current ¹⁶	200 Day			150 Day		
		High	Low			High	Low
1 Day Implied Vol.	29.07	33.78	21.56	71.93	33.78	21.56	71.93
5 Day stat. Vol.	26.66	59.1	4.78	71	59.1	4.78	64
10 Day stat. Vol.	28.1	44.71	9.78	78	44.71	9.78	70.67
20 Day stat. Vol.	31.44	34.82	13.25	88.5	34.82	13.25	84.64
40 Day stat. Vol.	27.57	29.21	15.64	90	29.21	16.57	86.67
50 Day stat. Vol.	25.32	27.58	15.66	73	27.58	16.58	64

¹⁶ In the Tables" current "means the end of November,2004

Session 7: Hedging Commodity Price Volatility

We consider three different ways one can hedge low income countries commodity price risk. In the first case the World Bank may want to issue a bond on behalf of the low income countries while at the same time selling insurance to the government to eliminate the risks of a unfavorable price movement.

This can be done by using *vanilla* Put or Call options on the relevant commodities to eliminate the associated price risk. We will see that this approach may be too expensive.

The second possibility is to buy structured option products, where the high cost of the vanilla options is lowered by *selling* other options simultaneously. We will discuss a Risk Reversal as an example. Such structures are cost effective but introduce other risks in terms of possible losses and mark-to-market adjustments.

The third approach, which we emphasize in this paper, is to mitigate commodity price risk using barrier options. We will study them in more detail.

7.1 Use of Vanilla options

The first tool that comes to mind for hedging commodity price volatility is a *vanilla option*. The way vanilla options can be used is quite straightforward. A Put option provides insurance against drops in commodity prices. A Call option can insure against unfavorable jumps. One can choose a proper strike price, K and adjust the “level” as well as the cost of this insurance.

The use of such options attached to low income countries loans made by the World Bank may be straightforward, but there is one significant problem. Vanilla options on commodities are expensive. For example, consider vanilla European options on Copper, oil and Gold. The relevant price data for at-the-money (ATM) options are given in Table 4 below.

Table 4

The relevant price data for at-the-money (ATM) options on some selected commodities. These are options with strike price equaling the current spot (or futures) price. The Notional amount is selected as 100. Hence option prices can be interpreted as percentages.

Commodity	Strike	Vol.	Price 1-Yr Expiration	Price 3-Yr Exp.
Copper	100	29%	9.4	14.7
Oil	100	45%	16.9	26.1
Gold	100	33%	13.5	19.4

These prices were obtained by inserting the relevant parameters in the Black-Scholes formula. For a Call option this formula is given by:

$$d_1(x_t, \sigma, k, T-t, Y) = \frac{Y(T-t) + \log(x_t/k)}{\sigma(T-t)} + \frac{\sigma\sqrt{T-t}}{2}$$

$$d_2(x_t, \sigma, k, T-t, Y) = d_1(x_t, \sigma, k, T-t, Y) - \sigma\sqrt{T-t}$$

$$C(x_t, \sigma, k, T, Y, t) = x_t N[d_1] - k e^{-r(T-t)} N[d_2]$$

Where the $N[z]$ indicates the cumulative distribution function for a standard normal random variable evaluated at z . In terms

of the parameters in the formula we selected the risk-free rate as 5%. In addition, a convenience yield of 5% was used.¹⁷

The relevant volatilities are given in Table 4 were obtained from the Reuters for the month of November 2004. The prices in Table 4 indicate that buying at-the money (ATM) commodity Put (or Call) options may be quite expensive for Low income countries. On the other hand, 20% out-of-the-money (OTM) options are somewhat cheaper as Table 5 shows.¹⁸

Table 5

The relevant price data for 20% out-of-the-money (OTM) options.

Commodity	Strike	Vol.	Price 1-Yr Expiration	Price 3-Yr Exp.
Copper	80	29%	2.2	6.4
Oil	80	45%	7.5	15.8
Gold	80	33%	4.1	10.1

¹⁷ Convenience yield is an imputed yield on the underlying instrument. Supposedly, warehousing of commodities is a convenient facility for the user of the commodity and the imputed yield accounts for this.

¹⁸ A 20% out-of-the-money Put will start providing insurance only after the commodity prices fall more than 20%, starting from the "current" level.

According to these tables, buying a three-year, 20% out-of-the-money option for insuring an underlying portfolio of \$500 millions will cost about \$50 millions for Gold, close to \$79 million for Oil and \$32 millions for Copper. At-the-money options are at least twice as expensive. Consequently, a low income countries government can be quite reluctant to invest such resources for managing the commodity risk that they face. ¹⁹ These high costs need to be overcome in order for options to be used in commodity price risk management.

7.2: Risk Reversals

The traditional way to cut such costs is the following. Under similar circumstances, the client will sell "some other option" when they buy an option. The revenue from the short position would then lower the insurance cost of the long option position. An important example is the so-called *zero-cost structure*. Risk Reversal (RR) is one such example. We will explain this structure using a real case study.

7.3 The Case of Zambia

¹⁹ However, the case study for Ghana and Gold discussed in a later section, below, indicate that even such vanilla options would have been beneficial for the country.

The high costs associated with vanilla options can be reduced significantly using various option structures. To fix the ideas, we consider a low income country, Zambia. Zambia's economy is heavily dependent on exports of a single commodity, the copper. When copper prices plunge, this may have severe effects on the volatility of Zambian markets and on the macroeconomic indicators.

Let the current copper price index be 100. If one buys a long-dated 2% out-of-the-money Put with strike K_P on copper, then, in order for this to be a proper economy-wide hedge, the position should have a minimum size of, say, \$0.5 billion. The cost of such a 3-year option position would then be \$32 million. The option position is shown in Figure 1.

In order to cut the cost of this Put option, the government of Zambia could sell an out-of-the money Call with strike price $k_c = \$120$. The logic is clear. The sale of the 20% out-of-the-money Call will raise, under ideal conditions, a sum around \$32 million and the net cost of the portfolio²⁰:

$$\text{Structure} = 80\text{-Put} + 120\text{-Call}$$

²⁰ Here we ignore the complications that are introduced by potential *volatility smiles*.

will be close to zero. Figure 1 shows this structure.

However, this structure comes with a risk. If copper prices climb steeply and exceed K_c , the option will lose money. Of course, one can claim that the price jump would, at the same time, make the country earn new revenues and that some proportion of these revenues could be used to close the Call-option position. Yet, from the point of view of the Zambian government officials, the risk of losing millions of dollars during a favorable move in copper prices may be both politically and financially unacceptable. From this angle, one can claim that zero-cost structures such as Risk Reversals are “flawed” instruments for commodity price hedging by *public* entities.²¹

7.4 Barrier option structures

New generations of exotic options fix exactly this “defect” of Risk Reversal type approaches. This is done by introducing various *barriers* in standard vanilla contracts. Options with

²¹ On the other hand, a private corporation may knowingly take such risks and there may not be any problem.

such barriers are known as exotics.²² We can explain these instruments using the Risk Reversal case.

A Risk Reversal is made of two options. One sells, say, a Call option and simultaneously buys a Put. This lowers the overall hedging cost but, at the same time subjects the Public entity to potentially severe and unacceptable (mark-to-market) losses. Now consider the following alternative. Zambia buys a (possibly out-of-the-money) Put option with a *knock-out barrier* H . We have $k_p < H$ as shown in Figure 2. This option knocks-out, or ceases to exist, if the underlying asset price, x_t exceeds H , during the life of the contract. Otherwise, the option will have all the properties of a plain vanilla Put.

Figure 2 shows the price of the knock-out along with a plain vanilla option. Note that as $x_t \rightarrow H$, the knock-out, Put price goes to zero. Hence, at time t_0 the option will be worth P^H which is about a third of the price of the original vanilla option. Hence, the introduction of the barrier has made the vanilla option significantly *cheaper*.

The logic behind engineering such barrier options is important. The Risk Reversal is not usable from the point of

²² The term “exotic” is a misnomer. Many of the exotics are trading as vanilla options in the markets.

view of a Public entity. Because as x_t exceeds K_c , the position starts to suffer from significant losses. The barrier option “fixes” this problem as follows.

Consider a market maker. The market maker buys a vanilla K_p -Put. But, at the same time sells a K_c -Call with the property that, if X_t reaches the point,

$$X_t = H$$

one would have,

$$\text{Price (} K_p \text{- Put)} = \text{Price (} K_c \text{- Call)}$$

According to this, given the information and quotes of time t_0 , when X_t is near the barrier H , the two options will have the same value. This means that as $x_t \rightarrow H$, the value of the Put will converge to the value of the short Call. Now, at H , the market maker could, at zero cost, thus sell the Put and close the corresponding Call position.²³

In other words, given time information at time t_0 , the market maker can *liquidate* the portfolio at zero-cost. Thus, a knock-out Put is quite similar to a dynamically-managed Risk Reversal with the property that as x_t approaches H the position

²³ This is of course the ideal case, in real life there may be some slippages.

will be liquidated at zero cost. This way, the position will, at worse, suffer from some liquidation (gap risk) losses but these will be small. There will be no significant losses faced by the market maker.

The point here is that, this process of dynamically managing the option portfolio can be sold to a retail client as a knock-out option. In other words, this process will be the “hedge” of the exotic option. Accordingly, knock-out or knock-in features make options affordable for clients, without suffering from the “defects” of Risk Reversals. As such, they form a class of instruments that can be used reasonably safely by Public entities for hedging purposes. Low income countries may be some of the main beneficiaries of such option structures. It should be clear that by using similar structures one can have several types of knock-in or knock out options with different costs and different risk management uses.

Session 8: A digression on Exotics Options

We need to discuss exotics in more detail. A “vanilla” Knock-Out option is an option that ceases to exist whenever the underlying risk attains a pre-specified level, called the *barrier*. A Knock-In is an option that comes into existence if a barrier is attained. When this happens, the knock-in mutates into a vanilla option. Instruments that have similar properties are called *barrier options*. Various specifications exist.²⁴

1. *Barrier type* may be different and may define the option.

For example we may have:

- (a) Down-and-out, or
- (b) Up-and-out structures.

2. Also the imbedded barrier *position* may be different:

The barrier may be in the out-of-the-money (OTM) region. Such options normally have benign hedge ratios and Greeks.²⁵

²⁴One can show that Knock-In and Knock-Out European options are linked:

$$\text{Knock-In} + \text{Knock-Out} = \text{Vanilla option}$$

This applies to single barriers.

²⁵ Greeks is a term that summarizes the sensitivity of the option price with respect to changes in various parameters and variables. They are used in hedging the exotic. The “smoother” Greeks are, the easier to hedge the option.

- (a) But the barrier may also be in the in-the-money (ITM) region. The sensitivities of such options will be discontinuous. This may lead to hedging difficulties.

Some exotics are more difficult to hedge. Consider the up-and-out call, where the barrier H is greater than the strike K . This is a product combining a discontinuous pay-off at the barrier with a positive or negative gamma²⁶ depending on current spot and time to maturity.

8.1 Uses of barrier options

We consider two examples to the uses of barrier options within a setting that deals with commodity prices.

Example 1

You think copper prices would go down during the next 3 months. You could, (1) Sell copper futures. This would "make money" if prices decline. But you could also, (2) buy OTM-Puts. This would act as insurance and may expire in-the-money. But there is another possibility, (3) you could buy OTM puts, and sell OTM

²⁶ Gamma is the second derivative of the option price formula with respect to the underlying price. It represents the curvature of the option. Delta is the first derivative of the option price with respect to the underlying risk.

calls. This would be the case of the risk Reversal mentioned above. Better than all of these is to buy an up-and-out put.

Example 2

You need to buy Oil sometime during the next 6 months. Current price is \$35 per barrel. You would be willing to pay \$37, but no more than this price. One solution is to buy an ATM call on oil. This will act as insurance but also, will be very expensive. A second and more affordable solution is to buy a down-and-out Call with strike \$37, and a barrier, say, at \$32. In this latter case, there will be at least two possibilities during the next 6 months. First scenario: Oil never goes below \$32. Then we have guaranteed a maximum price of \$37. Second scenario: Oil goes below \$32. We lose the protection, but we can buy oil for $S_t < \$37$, *assuming* that oil prices do not rebound in the mean time.

There are several variations of standard barrier options. One can talk about *double* barrier options. Here, up-and-out and down-and-out barriers can be combined into one product, the double No-Touch Knock-Out. This option dies if price touches any of the barriers. More importantly for our purposes, we can have *partial*

barriers. In this product, the barrier might exist only during a certain period of time. For examples, on a 1 year option, barrier can become active after 6M. This is illustrated in Figures 3 and 4. This type of feature is quite relevant for our case, and will be incorporated in the examples discussed below. The main advantage of such a product is that they will lower the costs of hedging.

8.2 Digital options

We will make use of digital options as well in the structures we propose below. Digital options have a fixed payout of \$1 or 1 unit of a certain asset if underlying is above (or below) a threshold, or strike, H . Digital option may pay cash, or an asset if they expire in-the-money. There are two types of digitals. *European digital* where only the final spot counts and the *American digital* where you can lock-in your \$1 (or your asset) at any time. The American digitals can also be called Knock-In digital, where you have to reach the barrier to get paid.

Alternatively, you can be interested in Knock-Out digital, which pays \$1 *unless* you touch barrier. Note that such products can be very cheap, as the spot has to go down and then up for the option to pay out.

8.3 Complex Barrier Options

We have thus far only discussed the most common barrier options. These are perhaps the more liquid ones, but depending on the needs of a client, the industry can actually provide much more complicated products. It may be a good idea to summarize these briefly, since products provided to Low income countries may eventually make use of them.

All the barrier options discussed above can be combined to produce more complex products. Two interesting examples that are relevant for our case are the *Multi-underlying barrier Options* and the *Amortizing barrier option*. In the case of the former, there may be more than one barrier. The option may be “in” or “out” conditional on more than one commodity price crossing barriers. Given that there are several Low income countries where the macroeconomic variables depend significantly on at least two commodity prices (e.g. oil and copper), these structures may be particularly relevant for this study. However, below we will discuss single barrier options, since extensions to multi-barrier options are straightforward.

The amortizing barrier option may also be useful to Low income countries. In this case every day (month) you spend above a barrier, you may gain a fraction of your final Call. Some Low income countries may have exposure to *sustained* movements in commodity prices and the amortizing feature may be quite relevant to them. Again, this is also a quite straightforward extension and is not discussed further in this paper.

Finally we can modify the barrier options further by adding more complicated barriers. A *Resettable barrier option* would be one such case. For example, as soon as a level L is touched, another barrier H , known in advance, may get activated. Again, this may be a relevant feature for low income countries commodity risk. In other cases a barrier may “start” in 6 months at 5% out-of-the money. We now consider a specific structured instrument that can be used to hedge commodity price risk.

Session 9: An affordable structured product

Suppose we decide to use barrier options in mitigating the commodity price risk and that we would like to embed these options in low income countries bonds. There are (at least) two ways to proceed here. The first strategy is to write options on commodity prices, structure them so that they become "affordable", and then attach them to some sort of fixed-income instrument.

The second strategy is to make the option payoffs as a function of *credit spreads* of Low income countries and then link these options to commodity prices or their volatilities. This approach would have the additional advantage that it would help market-making for low income countries credit instruments, which will be an important step towards establishing some sort of capital market activity for this group of countries.

We start with options that have payoffs that depend directly on commodity prices. The specific contract discussed below can be modified in many different ways. We begin with a simple version. A 5-year coupon bond is contemplated by a low income country at time t_0 . The coupon is given as,

$$Libor + c_t$$

Where the C_t is the credit spread associated with this particular low income countries. This spread may very well be prohibitively high for making a market for such bonds. The size of the issue, the newness of the issuer to capital markets and the potentially very high default risk may be detrimental in this respect. As a result a market for such bonds may *not* exist. The structure that we put together intends to generate some demand for such bonds, while at the same time hedge against extreme commodity price volatility. The low income countries has an economy highly dependent on a commodity price X_t or its volatility σ_t ²⁷. This dependence increases default probability of the low income countries to unacceptable levels and the issuer is priced out of International Capital Markets. The paper does not address other reasons that may very well exist for such high spreads.

We now describe a way to eliminate the high dependence of this low income countries spread on the X_t . Essentially we restructure the bond, imbed a credit-linked option and lower the associated credit risk. It is hoped that this

²⁷ In this paper, we address only the problem of high default risk associated with commodity prices.

will be done inexpensively. Also, it is hoped that this will create some rudimentary investor base for these bonds. This could be useful in starting a normal issuance process or the beginning of a new asset class on Low income countries.

9.1 The instruments

In order to strip out some of the commodity price risk faced by the low income countries we intend to use an option imbedded in this bond. We deal with a particular case that can be modified if desired.

Suppose the Bond contains a European Knock-In Put option where the barrier H gets activated with movements in X_t . In particular, we assume that if, say, copper prices, X_t , fall below a pre-determined level H sometime during $t \in [T_1, T_2]$, $t \leq T$, the bond holder receives a *Digital Put option* with strike K . We have $H < K$. Hence this is what the market calls a *reverse Knock-In*. The expiration date of the digital is the same as T , in case the options are “in”.

Now we consider the second step of the structure. At expiration, if the digital is in-the-money, the bond (option) holder has the right to receive a Credit Default Swap (CDS) at the CDS rate $s_{t,T}$. We have,

$$C_{t_0} \leq S_{t_1}$$

At issuance, the digital knock-in Put would be out-of-the-money.

This structure should be considered only as a prototype. The major parameters can be easily modified. The main idea is that this structure will provide the bond holder with default protection if a particular *event* happened. There can be many structures and there can be many events. The structure mentioned here provides default protection if commodity price X_t falls significantly *and* stays at that level. This instrument is shown in *Figure 5*.

9.2 Pricing

A major point of such a product is that the protection against commodity price volatility will be inexpensive. Another point is that this protection is provided by making use of a credit instrument. Hence, it acts both as insurance *and* as means of kick-starting some fixed income market for the low income countries. In this section we estimate the cost of such a structure. We calculate the cost using Monte Carlo methods within a relative simple model. More advanced methods such as *Libor Market Model* are not used.

Barriers are obviously path dependent options. This means that knowing final spot is not sufficient to determine the pay-out. Path-dependent options are usually priced forward fashion. When they are of “European style” Monte Carlo method is the natural way to price them.²⁸

The model used in the pricing needs to consider the dynamics of (at least) two stochastic processes. We formulate it as follows. There are two equations, describing the dynamics of the commodity price X_t and the dynamics of the underlying low income countries credit spread S_t , We write these as:

$$dx_t = \mu(x_t, t)dt + \sigma_1 x_t dw_t^1$$

$$ds_t = \beta(x_t, t)dt + \sigma_2 s_t dw_t^2$$

Where $\mu(\cdot)$, $\beta(\cdot)$ are the respective drift components and the w_t^1, w_t^2 are two Wiener processes.²⁹ The σ_i $i=1,2$ are the relevant instantaneous volatilities. They measure the unexpected percentage change in the relevant random variable during one year.

²⁸ For insurance products related to bonds, most of the structures will be European style. The LIC will probably have few outstanding bonds and the maturity date of “the” bond can be selected as the expiration of the option.}

²⁹ A Wiener process is a continuous time stochastic process that has mean zero and variance t

Due to high dependence of the low income country economy on X_t we need to postulate a significant correlation between the two Wiener processes:

$$dw_t^2 dw_t^1 = \rho dt$$

Pricing within this context involves, (1) specifying the drifts, (2) selecting volatilities and correlations and then (3) generating Monte Carlo paths for this bi-variate process. Once this is done we can use the Monte Carlo paths to calculate the expected value of the payoff. In the simple case we selected the payoff is given by :

$$payoff = E(t_0, \tau) [(S_\tau - S_{t_0})^+ N((T - \tau))] (1_{N_{\tau, H, H_0}(\tau, T)})$$

Here N is the number of times the CDS fee will be paid once the option become "in".³⁰ If the CDS maturity is 1-year, we can assume without any loss of generality that $N=1$. The τ is the time the option becomes "in", i.e. when the event,

$$\Omega = \inf [X_u \leq H, u \in [T_1, T]]$$

occurs. The function $1_{N_{\tau, H, H_0}(\tau, T)}$ equals 1 if the option has knocked-in, otherwise it is zero. This function can become 1 only when the commodity price falls below the barrier H

³⁰ Normally, half of the CDS fee is paid every 6 months. However, here we will assume annual settlements

during the period $[T_1, T]$. First time his happens is denoted by τ . The S_τ is then the CDS rate observed for that time period. Finally, the $B(t_0, \tau)$ is the appropriate discount factor.

According to this payoff function, the CDS is valued at the time τ CDS rate and then the value of the payoff is the S_τ minus the S_{t_0} , the CDS rate agreed at time S_{t_0} . This needs to be multiplied by $T - \tau$ to get the right accrual factor. Note that the notional amount is selected as 1.

9.3 A characterization

We can characterize the structure as follows. The low income countries is exposed to sharp falls in a commodity price. An option may be purchased as a protection against such events. Yet, such an option is needed only if, (1) the commodity price falls (rises) *sharply* and (2) if this price drop is *persistent*. Otherwise, the economy will proceed on its own implied path and mild fluctuations in commodity prices will be a minor factor. Thus a knock-in feature is added to make the option inexpensive.

The option is digital and the payoff of the digital is a Credit default Swap. This protects the bond holder against a potential default when commodity prices fall sharply and when this price drop is not temporary. In fact, the whole structure

can be regarded as a knock-in CDS. The knock-in feature being linked to a commodity price.

This approach uses CDSs in order to mitigate commodity price and volatility risks in Low income countries. As discussed above, this need not be so. One can write more complex barrier options in a way, such that the relevant payoffs are a function of commodity prices and/or their volatilities directly. Yet, introduction of CDSs in such products may be much more advantageous in the long term.

In fact, to the best of our knowledge, not even a rudimentary CDS market exists for a large majority of Low income countries. Contribution of supranational in introducing such markets may be significant. No matter how illiquid or “artificial” at the start, once a market in CDSs starts functioning, this may in the long run lead to a genuine market in low income countries bonds. A market that is initially held together with the help of supranational may eventually start functioning on its own. The use of CDSs in hedging commodity price risk may help to start such markets as well as mitigate commodity price and volatility risk.

However, introduction of CDSs in hedging instruments for Low income countries also add some pricing difficulties. At the moment, no market for such CDSs exists. This means that market data such as a *CDS rate curve* or the relevant *volatilities* are not observed. It is quite unrealistic to obtain any type of benchmark credit prices for Low income countries. Hence pricing has to be done using conservative estimates, by selecting plausible upper bounds for credit spreads and the related second moments.

Session 10: Pricing issues

Accordingly, the data required for pricing the instruments that we discuss here need to be decided a-priori. In particular, we need to choose conservative upper bounds for (1) The current CDS rates, (2) Their volatilities (3) The correlations between commodity prices and credit spreads and the (4) Market prices for the underlying risks.

The most straightforward among these are correlations. We assume *one factor* models. This makes the correlation between the two wiener processes W_t^1, W_t^2 equal one. We can then let the market price of the commodity price risk be defined by:

$$\gamma = \frac{\mu(\sigma)(r - q)}{\sigma_1}$$

Here q is the convenience yield and the μ is the expected (long-run) percentage increase in the commodity price. Given that commodity prices are set in USD, during the pricing below we

select this parameter as 3 %. The q is set equal to zero and the r is picked as 5 %.³¹

Next, the current values of CDS rates and volatilities are selected from a *grid* on a priori basis, and a table of prices is provided. This Table should give a reasonable idea about the cost of the instrument that we have discussed above.

The last point needed for the calculation of prices is the market value of the risk due to this single factor. Note that because of the assumption of one factor, this price is also easy to determine since the underlying risk essentially becomes a commodity price risk.

Under such conservative assumptions it is not difficult to obtain some upper bounds on the prices for the instrument introduced above. If these upper bounds are found to be reasonable, the work along this direction can then proceed further.

³¹ These are conservative numbers for the case under consideration. Under these conditions the γ will be negative and hence the risk-neutral drift of the credit spread will be greater than the real world drift.

10.1 Calculating upper bounds on prices

During the process of calculating, some upper bounds on the above mentioned options to be embedded in low income countries bonds the system:

$$dX_t = \mu(X_t, t)dt + \sigma_1 X_t dW_t^1$$

$$dS_t = \gamma(s_t, t)dt + \sigma_2 S_t dW_t^2$$

needs first to be discretized. We use a first order Euler scheme to do this and ignore higher level discretization methods. This way we obtain the two-equation system

$$X_{t+\Delta} = (r - q)X_t \Delta + \sigma_1 X_t \epsilon_t$$

$$S_{t+\Delta} = \lambda(\mu - s_t + \gamma \sigma_2 S_t) \Delta + \sigma_2 S_t \epsilon_t$$

where we have the γ to represent the market price of ϵ_t risk. The $\{\epsilon_t\}$ are pseudo-random numbers that are assumed to be normally distributed with mean zero and variance equal to Δ . the discretization time step. Note that we made the disturbance terms perfectly, but negatively correlated. The low income country runs into trouble, when the commodity price falls.³²

The drift component of the credit spread S_t is modeled as a mean reverting process. The θ is the long-run mean for the low income countries CDS rate. The λ is the rate of adjustment

³² The LIC is assumed to export this commodity

to long-run mean. We set these two parameters at extreme levels so that upper bounds on prices are obtained. Because we are using pre-determined values for all parameters under consideration, we prefer to provide prices at different values of these parameters.³³

Finally, as discussed above we let,

$$T = 5\text{-years}$$

$$T_1 = 4\text{-years}$$

According to this the option can become in only during the last year of a 5-year maturity bond.

We basically selected 3 base scenarios for the credit spread dynamics. The initial point of the credit spread was taken as 700. This can be regarded as a (subsidized) strike price on a CDS rate. Essentially, the buyer of the low income countries bond will pay this CDS rate and receive the CDS on the low income countries bond *immediately* as soon as the commodity price falls below a level H . The time this event occurs is denoted by τ .

The scenarios in question assume three different levels for the “normal” (or long-run) CDS spread for the . These are 900, 1000 and 1200 respectively. According to this latter, the LIC is assumed to have a long-run risk premium of about

³³ Obviously, this pricing method can be made significantly more complicated by adopting the recent work on defaultable Market Models.

12% over the 5-year USD swap rate. Considering that this is a *one* year CDS rate, this number is somewhat conservative.³⁴

The results of the Monte Carlo runs are shown in Tables 6, 7 and 8. All these tables deal with an H that corresponds to a 20% drop in the commodity price relative to the current spot. Table 6 is the case for $\lambda = .9$. Table 7 keeps the same parameters but changes the λ to .5. Finally, Table 8 keeps the λ as .9, but lowers the credit spread volatility from 70% to 50% per annum.

In all the results presented in these tables, the initial value of the credit spread is selected as 700. This may be low in historical standards, but it is reasonable given the current state of the credit markets³⁵. For example, Brazil CDS rates are approaching 300bp for 5-year maturities. Here, we have essentially a 1-year (or lower) maturity.

The initial point for the commodity price was set as,

$$X_{t_0} = 100.$$

Finally, the option that we evaluate becomes "in" if X_t falls below the level³⁶

³⁴ It corresponds roughly to a USD interest rate of about 21-22% for a 5-year LIC bond.

³⁵ The market will price these CDSs according to *that* time's benchmark prices.

³⁶ We tried several other scenarios with different barrier levels, $\$H$. For example, when the barrier level is set at a 10% drop in the spot price, options

$$H = 80$$

is the rate of adjustment to long-run mean for the LIC CDS spread.

Table 6

The simulated option premium under different parameters. λ is the rate of adjustment to long run mean for the LIC CDS spread. θ is the long-run mean for the LIC CDS spread.

Barrier	λ	Vol	θ	Option Premium
80	0.9	0.7	900	2.13%
80	0.9	0.7	1000	2.48%
80	0.9	0.7	1200	3.37%

become more expensive by a factor of around 1.8. Yet, such a drop in commodity prices does not really correspond to a crisis situation for Low income countries.

Table 7

The simulated option premium under different parameters when λ is changed to 0.7

Barrier	λ	Vol	θ	Option Premium
80	0.5	0.7	900	2.10%
80	0.5	0.7	1000	2.27%
80	0.5	0.7	1200	3.29%

Table 8

The simulated option premium when volatility is reduced.

Barrier	λ	Vol	θ	Option Premium
80	0.9	0.5	900	1.65%
80	0.9	0.5	1000	2.30%
80	0.9	0.5	1200	3.28%

According to these tables, the cost of the options incorporated in the LIC bonds would be somewhere from 1.5% to 3.5%. Of these tables the most representative may be Table

8 which assumes a 50 % annual volatility for the LIC CDS rate. The base scenario of $\theta = 900$ gives the cost of the option as 1.65%.

Notice that the 50% volatility assumed in this scenario would be the case *once* the World Bank starts writing such options on the LIC bond. One would expect that the existence of the options themselves would lower the LIC credit spread volatility. Needless to say, several more complicated scenarios can be incorporated in the definition of the barrier as mentioned earlier in the paper. In particular, the barrier may be *triggered* only when the drop in commodity prices is sustained. This would make the options even cheaper.

10.2 The role of World Bank

What would be the role of World Bank in marketing this structure? Figure 9 summarizes the role of the World Bank at the simplest level. Essentially the instrument is structured such that the World Bank buys CDSs on the LIC credits from the industry and then sells them individually to LIC countries. Arguably, during this process, World Bank would need to subsidize the CDS rates in linking them to LIC bonds. Given that

the Low income countries have very high default risk, the industry would sell the associated CDSs only at prohibitively high rates, even if they are contingent on extreme commodity price movements. The World Bank will need to subsidize these CDSs when attaching them to LIC bonds; otherwise the structured bonds may be too expensive for international investors to buy.³⁷

The World Bank will, this way, reach two objectives. First, some protection against commodity price volatility is supplied to the LIC; and second the whole process would create a favorable environment for the LIC-issued bonds and for the associated CDSs. It is plausible that some of the associated CDSs would start trading on their own given enough time. At the end, this role is quite similar to lending to Low income countries funds obtained from World Bank-issued debt securities as discussed in earlier sections.

The main difference between a standard CDS and the structure we have is that, in our case the associated World Bank guarantee is conditional on commodity price risk and that the structure intends to introduce LIC-linked CDSs in the market place.

³⁷ In the above setup, the parameter S_{t0} would be set so that the options are not too expensive.

Session 11: An example of back-testing

In this last section we would like to consider the effects of hedging commodity price risks using *vanilla* options. Surprisingly, back-testing exercises show that even vanilla options could be useful to mitigate commodity price risks.

The more complex instruments that we discussed above are representative approaches that one may use in mitigating the commodity price and volatility exposure of Low income countries at an affordable cost. However, back-testing exercises are needed to see the effects of such hedging programs. Yet, if we limit ourselves to the instruments discussed above, this will be quite difficult to implement.

Instead, we use vanilla instruments in back-testing because these options are more amenable to such exercises. The more affordable complex exotics that we discussed in the above sections do not exist at the moment and hence finding *past data* on their performance is impossible. With vanilla options this problem does not exist, past data can easily be obtained. Also, as we will see below, the contribution of such vanilla options in stabilizing the macroeconomic performance of some Low income countries is already quite impressive, at least in the case study considered here.

We consider the case of Ghana and the gold. Ghana is a gold exporter and, in the past, Gold prices have gone down persistently for long periods of time. The negative effect of such drops is visible in the total export data for Ghana shown in Figure 9. When gold prices declined, Ghana exports suffered significantly, and this had significant impact on GNP. The question is that how much a vanilla Put option written on gold would have stabilized Ghana's exports. In order to answer this question we considered the following backtesting exercise.

We let Ghana authorities buy an ATM Put option with expiration of 1-year and a notional amount of \$100 millions at the beginning of the calendar year. The option position is rolled over every year, for 13 years. This amounts to 13 insurance contracts against the gold price drop. If the option is in-the-money at expiration, the option holder, which in this case is the Government of Ghana, will receive:

$$100,000,000 \max\left[\frac{(K - S_T)}{S_T}, 0\right]$$

where S_T is the gold price at the end of the year. Because the option positions are rolled over the strike price K will be the

observed gold price on January 1st, or the following business day.³⁸

In order to find the cost of these ATM Puts, we use the observed implied volatility for that particular year, as reported in reported by the NYMEX, where such options trade. The observed implied volatilities for this sample period are obtained, and then plugged in the Black-Scholes formula along with an (average) risk-free interest rate of 5% and a gold interest yield of, 2.3%. The average Put option premium during the 1987-2000 is calculated as \$1.6 millions. The highest price is \$3.1 millions during 1998, and the lowest is \$1.0 million during 1991.³⁹

We calculate the value of the insured exports or the “hedged portfolio”. The hedged “portfolio” consists of the exports plus the option payoff at the end of the year, minus the cost of the option. The net value of the hedged exports is shown in Figure 10.

³⁸ These options are purchased sequentially over time, and not in a forward-setting fashion, as they would be in a cliquet-type of structure. This latter would be more expensive.

³⁹ We did not use a further convenience yield for Gold and assumed that these rates are constant during the sample period. Changing these assumptions would not alter the results significantly.

It is interesting to see that Ghana economy would have realized significant hedging gains during the year 1988-2000, if such a hedging program was conducted.

Of course, this period is a special one for Gold, since during this period Gold price mostly decreased due to gold sales by major Central Banks around the world. Market participants and Gold producers had during much of the 1990's shorted the Gold on the futures Exchanges. Being a gold producer Ghana suffered significantly due to these price movements. This is main reason why the Put option turns out to be beneficial for Ghana. During other time periods, or other commodities, back-testing may not indicate similar gains. But, it mostly be pointed out that the total cost of hedging is not prohibitive and when there are no insurance gains, in the long run such hedging exercises may be beneficial. Showing this empirically, however, requires further back-testing which is beyond the scope of this paper.

Session 12: Conclusions

Some preliminary conclusions are as follows. Commodity prices are quite volatile. Through fiscal balances and exports almost all the Low income countries considered in this paper have significant exposure to commodity price volatility. This leads to severe macroeconomic instability. Modern financial instruments can be exploited in this respect, and this exposure can be reduced significantly.

Our results indicate that even simple vanilla options can be quite useful in reducing the effects of commodity price volatility. However, these vanilla options can also be regarded as quite expensive by a public entity. We devise cheaper alternatives and show that some barrier option structures discussed in the paper can be much more affordable in this respect. On a notional amount of \$100 millions, these barrier options cost approximately 1-2 million dollars for various parameter values that are selected conservatively. This cost may go down further if such options are purchased wholesale from the industry. In fact, if the World Bank buys baskets of CDSs from the industry and then sells them to a group of Low

income countries, the total cost of such a project could be quite reasonable.

A side advantage of the approach described here will be to help establish some rudimentary capital market activity for the Low income countries. Given enough time, the instruments described in this paper can create a favorable environment for LIC-linked bonds and CDSs.

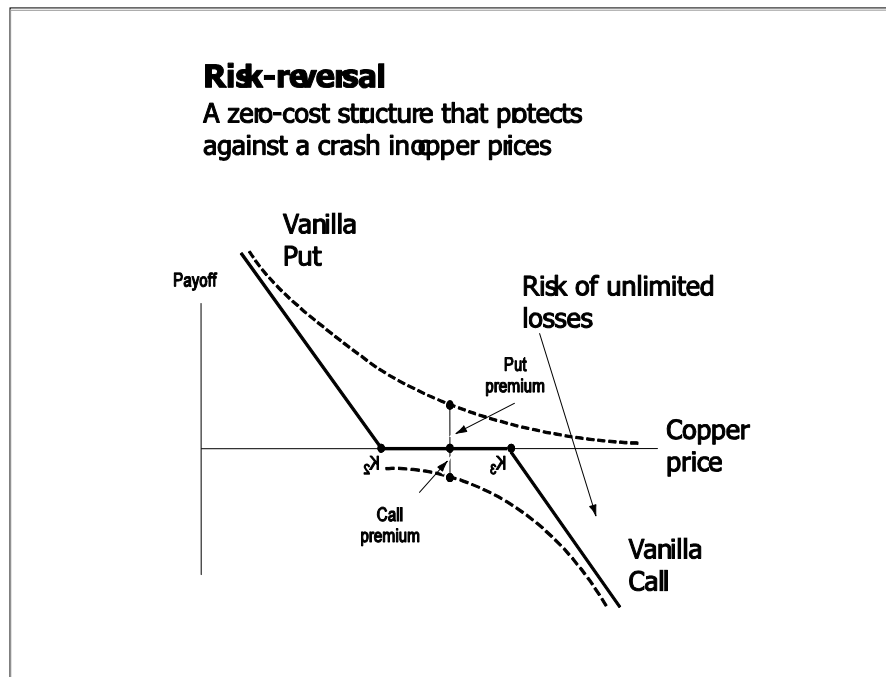


Figure 1: A standard Risk Reversal. Note that the static exposure of the short call

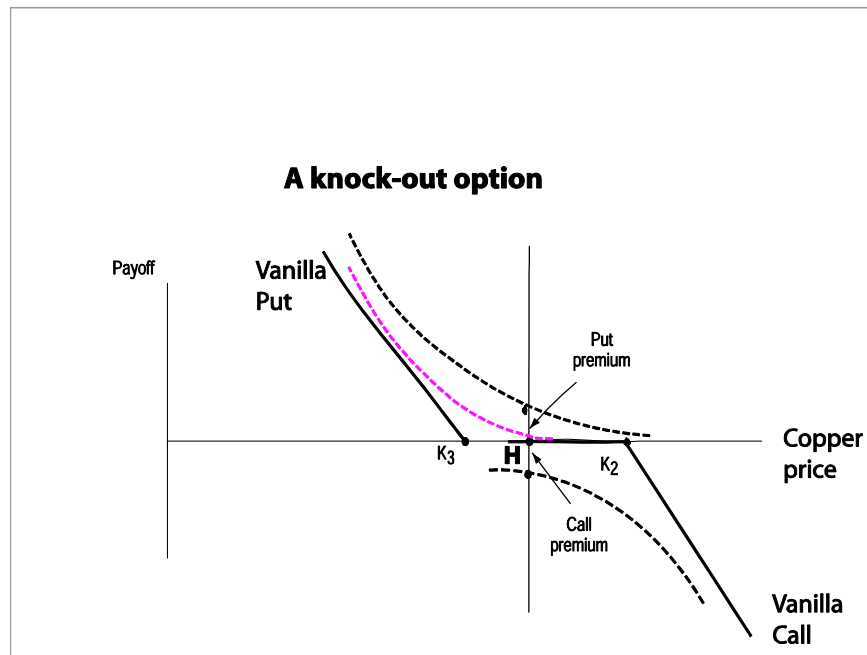


Figure 2: A knock-out long option seen from market maker's perspective. Note that the short option exposure will be liquidated as the underlying price approaches H .

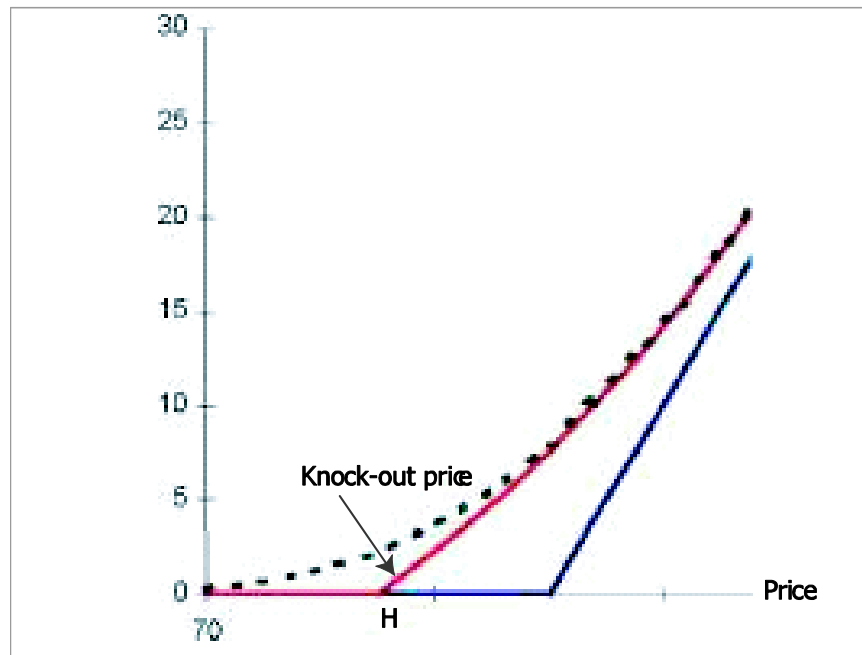


Figure 3: A standard knock-out log call option. Note that the price is well below the price of a vanilla call near the H

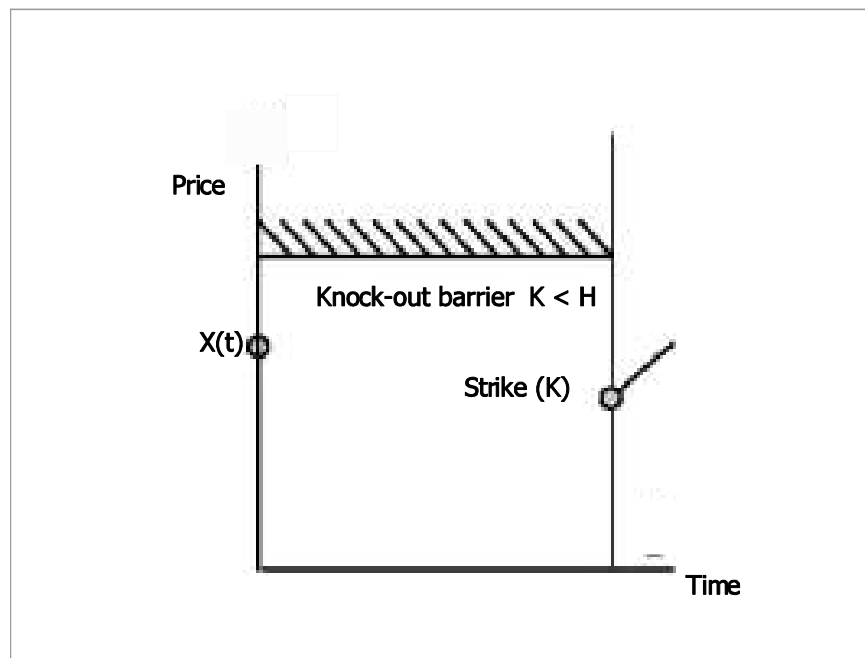


Figure 4: The structure of a knock out option with $K < H$ as time passes.

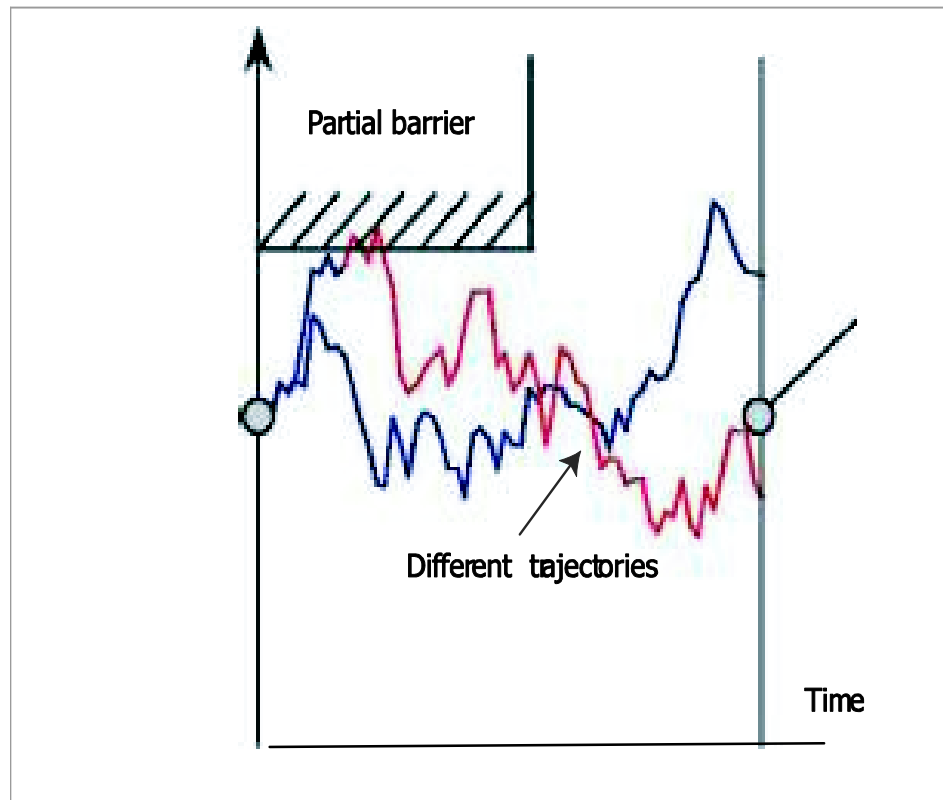


Figure 5: Same structures as in Figure 4, except that the barrier applies only part of the option's life.

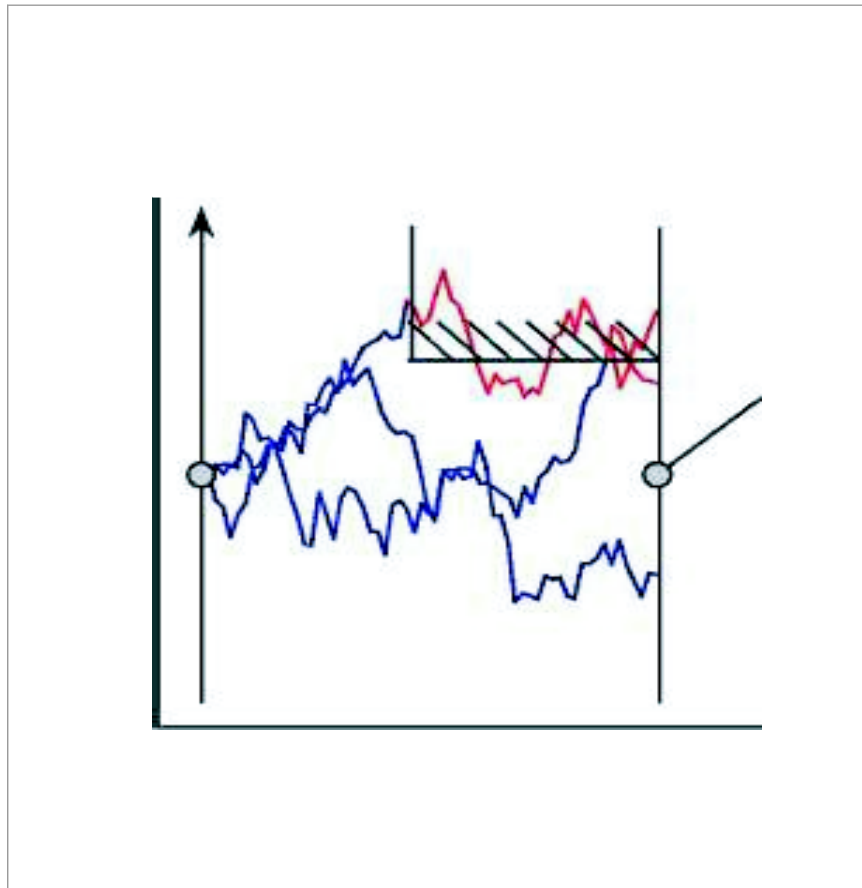


Figure 6: Another position for the partial barrier. Note that this is more relevant to our case.

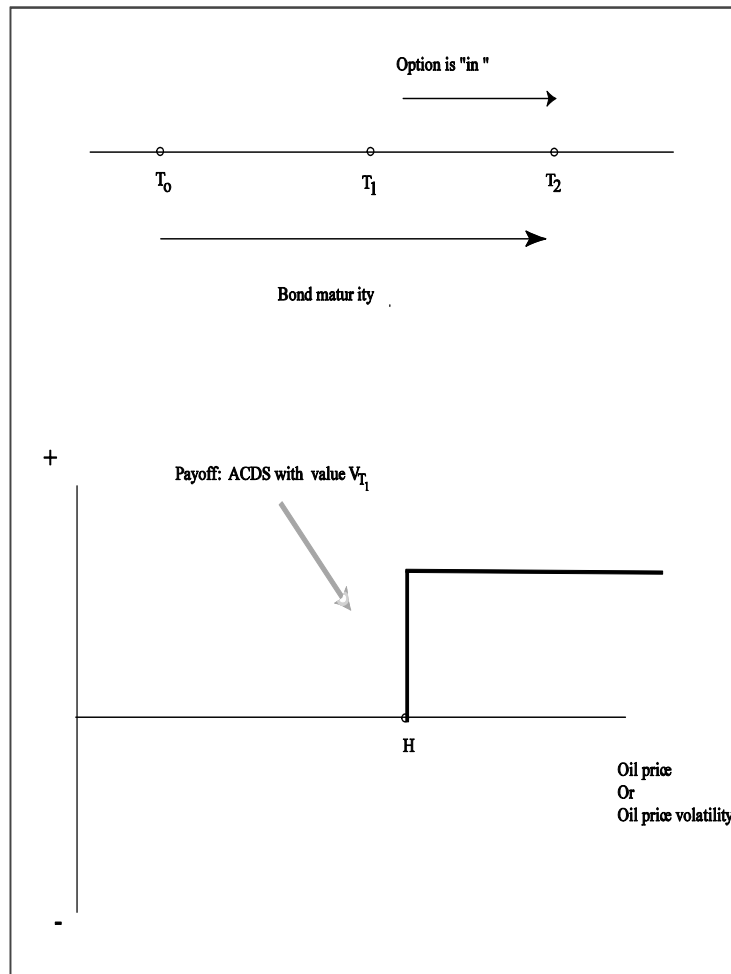


Figure 7: The proposed instruments applied to hedge for jumps in oil price

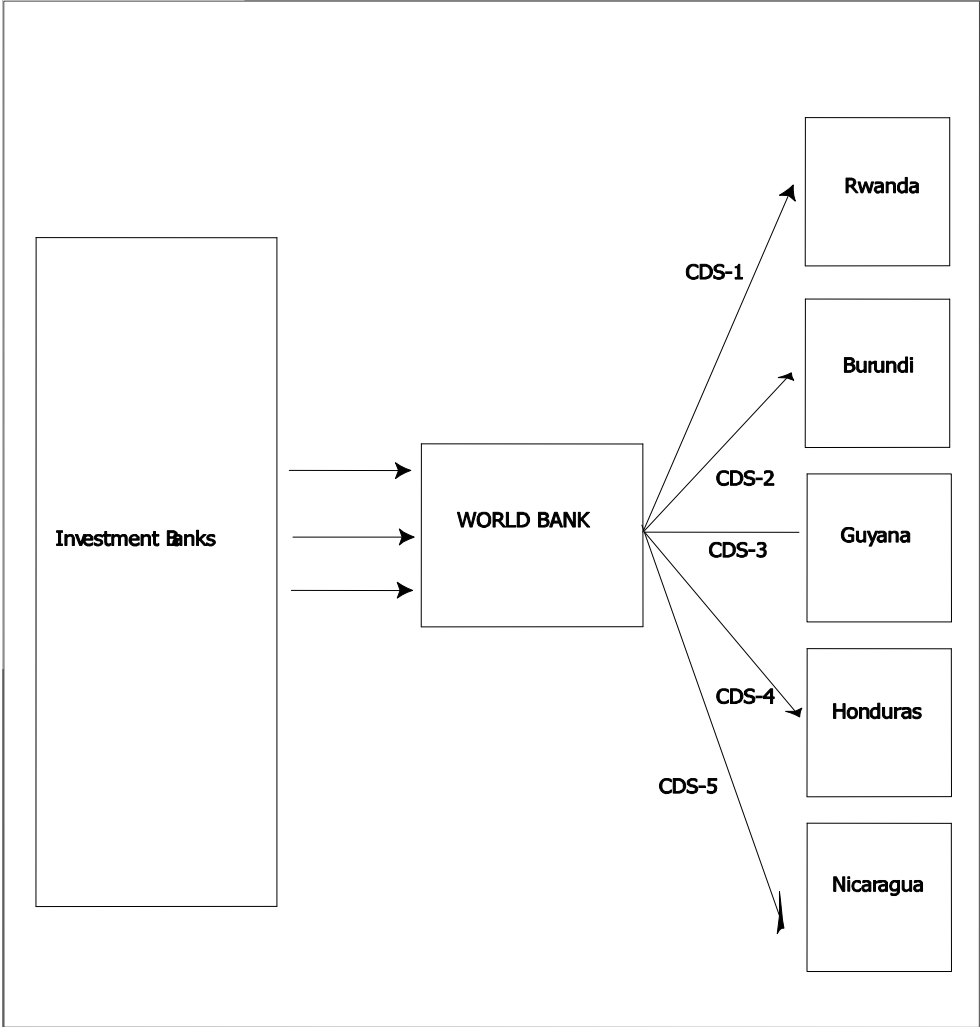


Figure 8: World Bank is an Intermediary

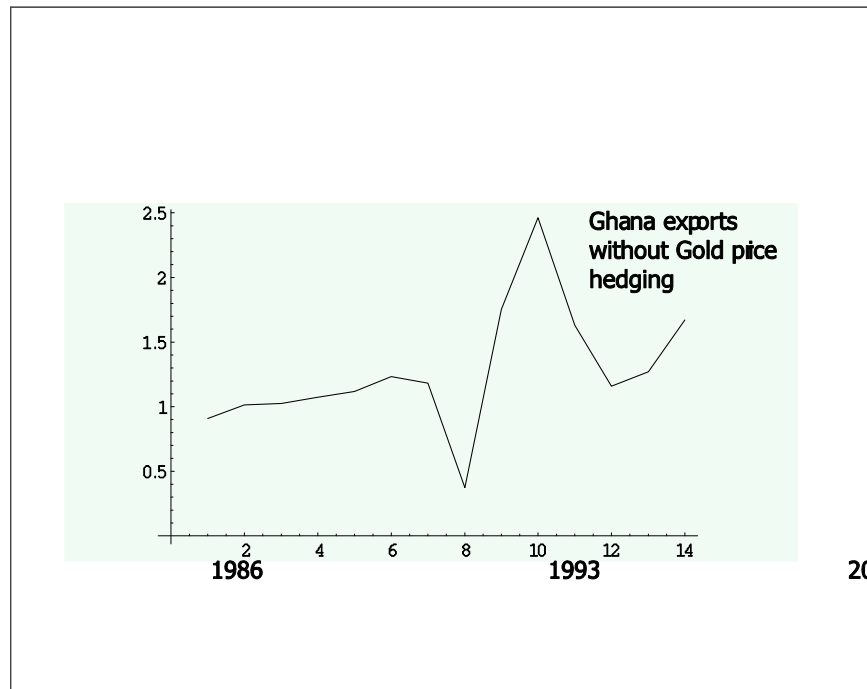


Figure 9: The initial point of the back-testing exercise

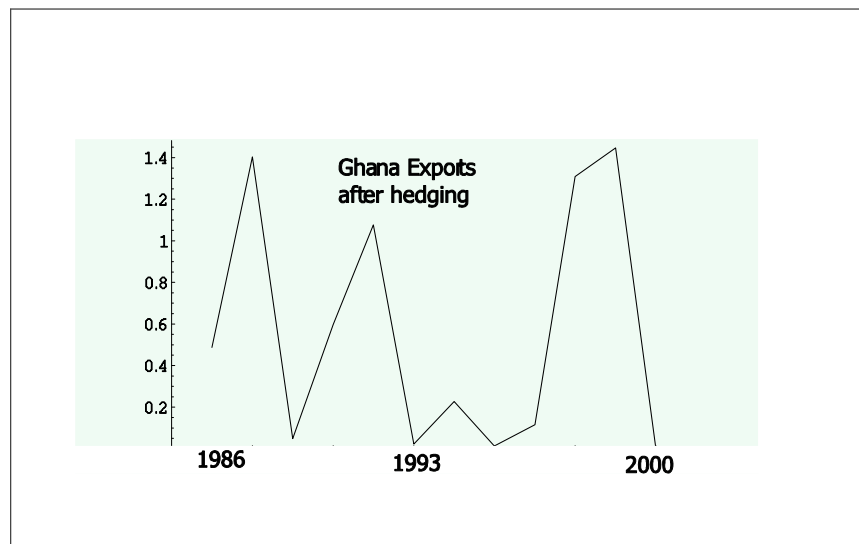


Figure 10: Back-testing after Gold Price hedging

Appendix

Appendix 1: The correlation of government revenue and the deficit of the LIC on commodities

Ivory Coast

	COCOANY LONDON1	COCOA NYLON DON2	COFFEE COMPOS ITE1	COFFEEC OMPOSIT E2	COFFE EOTH ER2	COFFEEROB USTAS1
D E F	0.00	0.15	-0.32	-0.33	-0.29	-0.34
R E V	-0.09	-0.17	0.19	0.20	0.31	0.05

(Continued)

	COFFEER OBUSTAS 2	IVCODE F	IVCORE V	PETROLE UMDUBB RENT
D E F	-0.34	1.00	-0.48	-0.64
R E V	0.05	-0.48	1.00	0.36

Ghana

	ALUMINI UMHIGHG RADE	COCOA NYLON DON1	COCOAN YLONDO N2	GHANDEF	GHAN REV	GOLDFINE
D E F	0.46	0.01	-0.02	1.00	-0.30	0.01
R E V	0.25	0.24	0.07	-0.30	1.00	0.17

Malawi

	LEAFTOB ACCO	MALAD EF	MALARE V	SUGARCA RIBBEAN	TEASL ONDO N	TEASLONDO NAUCTIONP RICES
D E F R E V	-0.48	1.00	-0.75	-0.25	-0.36	-0.41
	0.53	-0.75	1.00	0.20	0.46	0.46

Appendix 2: Import and export shares of leading commodities on total imports, total exports and GDP

Burundi	Commodity Imports		Commodity Exports	
	Total Imports		Total Exports	
334 Petroleum products, refined	11.67%	071 Coffee and substitutes	68.84%	
541 Medicinal, pharmaceutical prdts	5.00%	971 Gold, non-monetary nes	15.52%	
048 Cereal etc preparations	3.85%	074 Tea and mate	4.98%	
	Commodity Imports		Commodity Exports	
	GDP		GDP	
334 Petroleum products, refined	2.53%	071 Coffee and substitutes	6.62%	
541 Medicinal, pharmaceutical prdts	1.17%	971 Gold, non-monetary nes	3.35%	
048 Cereal etc preparations	0.93%	074 Tea and mate	0.33%	
All Imports	20.07%	All Exports	11.25%	
Central African Republic	Commodity Imports		Commodity Exports	
	Total Imports		Total Exports	
334 Petroleum products, refined	7.95%	667 Pearl, prec, semi-prec stones	42.27%	
541 Medicinal, pharmaceutical prdts	6.27%	277 Natural abrasives nes	19.60%	
782 Lorries, spec motor vehicl nes	4.82%	263 Cotton	11.75%	
	Commodity Imports		Commodity Exports	
	GDP		GDP	
334 Petroleum products, refined	1.28%	667 Pearl, prec, semi-prec stones	5.56%	
541 Medicinal, pharmaceutical prdts	1.17%	277 Natural abrasives nes	2.40%	
782 Lorries, spec motor vehicl nes	0.93%	263 Cotton	1.45%	
All Imports	17.04%	All Exports	11.67%	
Côte d'Ivoire	Commodity Imports		Commodity Exports	
	Total Imports		Total Exports	
333 Crude petroleum	15.13%	072 Cocoa	36.47%	
541 Medicinal, pharmaceutical prdts	4.56%	071 Coffee and substitutes	10.33%	
034 Fish, fresh, chilled, frozen	3.87%	334 Petroleum products, refined	7.44%	
	Commodity Imports		Commodity Exports	
	GDP		GDP	
333 Crude petroleum	4.04%	072 Cocoa	12.55%	
541 Medicinal, pharmaceutical prdts	1.11%	071 Coffee and substitutes	2.94%	
034 Fish, fresh, chilled, frozen	1.14%	334 Petroleum products, refined	2.99%	
All Imports	24.29%	All Exports	33.79%	
	Commodity Imports		Commodity Exports	

(Appendix 2 Continued)		Total Imports		Total Exports	
Eritrea					
782 Lorries, spec motor vehicl nes	5.92%	971 Gold, non-monetary nes		26.70%	
723 Civil engineering equip, etc	6.10%	424 Other fixed vegetable oils		19.24%	
	4.91%			8.26%	
041 Wheat etc, unmilled		054 Vegtb etc fresh, simply prsrvd			
	Commodity Imports			Commodity Exports	
	GDP			GDP	
782 Lorries, spec motor vehicl nes	4.34%	971 Gold, non-monetary nes		2.10%	
723 Civil engineering equip, etc	4.39%	424 Other fixed vegetable oils		2.18%	
	3.48%	054 Vegtb etc fresh, simply prsrvd		0.96%	
041 Wheat etc, unmilled					
All Imports	72.63%	All Exports		8.85%	
	Commodity Imports			Commodity Exports	
	Total Imports			Total Exports	
Ghana					
333 Crude petroleum	8.38%	072 Cocoa		33.47%	
334 Petroleum products, refined	4.20%	971 Gold, non-monetary nes		22.60%	
782 Lorries, spec motor vehicl nes	4.84%	684 Aluminium		9.55%	
	Commodity Imports			Commodity Exports	
	GDP			GDP	
333 Crude petroleum	2.75%	072 Cocoa		6.45%	
334 Petroleum products, refined	2.40%	971 Gold, non-monetary nes		5.55%	
782 Lorries, spec motor vehicl nes	1.91%	684 Aluminium		1.60%	
All Imports	34.62%	All Exports		21.82%	
	Commodity Imports			Commodity Exports	
	Total Imports			Total Exports	
Malawi					
334 Petroleum products, refined	9.93%	121 Tobacco, unmanufactd, refuse		66.70%	
562 Fertilizers, manufactured	7.78%	074 Tea and mate		9.07%	
782 Lorries, spec motor vehicl nes	4.39%	061 Sugar and honey		6.41%	
	Commodity Imports			Commodity Exports	
	GDP			GDP	
334 Petroleum products, refined	3.18%	121 Tobacco, unmanufactd, refuse		15.56%	
	2.24%	074 Tea and mate		1.92%	
562 Fertilizers, manufactured					
782 Lorries, spec motor vehicl nes	1.81%	061 Sugar and honey		1.25%	

(Appendix 2 Continued)	34.54%	All Exports	23.51%
All Imports			
	Commodity Imports		Commodity Exports
Tanzania	Total Imports		Total Exports
781 Passengr motor vehicl, exc bus	5.71%	071 Coffee and substitutes	21.90%
334 Petroleum products, refined	5.06%	263 Cotton	16.33%
782 Lorries, spec motor vehicl nes	3.59%	057 Fruit, nuts, fresh, dried	8.82%
	Commodity Imports		Commodity Exports
	GDP		GDP
781 Passengr motor vehicl, exc bus	1.82%	071 Coffee and substitutes	1.77%
334 Petroleum products, refined	1.20%	263 Cotton	1.46%
782 Lorries, spec motor vehicl nes	1.02%	057 Fruit, nuts, fresh, dried	1.09%
All Imports	24.71%	All Exports	9.54%
	Commodity Imports		Commodity Exports
Zambia	Total Imports		Total Exports
333 Crude petroleum	4.21%	682 Copper	80.33%
782 Lorries, spec motor vehicl nes	3.25%	689 Non-fer base metals nes	5.32%
723 Civil engineering equip, etc	2.72%	651 Textile yarn	1.81%
	Commodity Imports		Commodity Exports
	GDP		GDP
333 Crude petroleum	1.17%	682 Copper	22.25%
782 Lorries, spec motor vehicl nes	0.72%	689 Non-fer base metals nes	1.81%
723 Civil engineering equip, etc	0.59%	651 Textile yarn	0.78%
All Imports	22.16%	All Exports	28.97%
	Commodity Imports		Commodity Exports
Bangladesh	Total Imports		Total Exports
652 Cotton fabrics, woven	5.81%	842 Men's outerwear non-knit	16.72%
653 Woven man-made fib fabric	5.26%	844 Under garments non-knit	17.36%
651 Textile yarn	4.65%	843 Women's outerwear non-knit	9.98%
	Commodity Imports		Commodity Exports
	GDP		GDP
652 Cotton fabrics, woven	1.08%	842 Men's outerwear non-knit	1.72%
653 Woven man-made fib fabric	0.83%	844 Under garments non-knit	1.64%
651 Textile yarn	0.84%	843 Women's outerwear non-knit	0.97%
All Imports	14.63%	All Exports	8.63%
	Commodity Imports		Commodity Exports
Cambodia	Total Imports		Total Exports
122 Tobacco, manufactured	16.22%	845 Outer garments knit	12.58%
334 Petroleum products, refined	6.15%	842 Men's outerwear non-knit	7.94%
785 Cycles, etc, motorized or not	6.06%	843 Women's outerwear non-knit	5.82%
	Commodity Imports		Commodity Exports
	GDP		GDP
122 Tobacco, manufactured	3.09%	845 Outer garments knit	5.28%
334 Petroleum products, refined	2.77%	842 Men's outerwear non-knit	2.82%
785 Cycles, etc, motorized or not	1.78%	843 Women's outerwear non-knit	2.10%
All Imports	26.37%	All Exports	21.43%

(Appendix 2 Continued)	Commodity Imports		Commodity Exports	
Sao Tome and Principe	Total Imports		Total Exports	
792 Aircraft, etc	8.23%	072 Cocoa	58.30%	
112 Alcoholic beverages	5.34%	034 Fish, fresh, chilled, frozen	10.06%	
781 Passengr motor vehicl, exc bus	3.30%	334 Petroleum products, refined	8.88%	
	Commodity Imports		Commodity Exports	
	GDP		GDP	
792 Aircraft, etc	2.68%	072 Cocoa	6.23%	
112 Alcoholic beverages	3.14%	034 Fish, fresh, chilled, frozen	1.28%	
781 Passengr motor vehicl, exc bus	1.45%	334 Petroleum products, refined	1.65%	
All Imports	46.95%	All Exports	13.11%	
	Commodity Imports		Commodity Exports	
Togo	Total Imports		Total Exports	
334 Petroleum products, refined	17.23%	271 Fertilizers, crude	37.89%	
652 Cotton fabrics, woven	6.59%	263 Cotton	24.20%	
661 Lime, cement and building prdts	3.64%	071 Coffee and substitutes	7.78%	
	Commodity Imports		Commodity Exports	
	GDP		GDP	
334 Petroleum products, refined	9.28%	271 Fertilizers, crude	5.61%	
652 Cotton fabrics, woven	1.57%	263 Cotton	4.89%	
661 Lime, cement and building prdts	1.51%	071 Coffee and substitutes	1.30%	
All Imports	34.74%	All Exports	17.66%	
	Commodity Imports		Commodity Exports	
Guyana	Total Imports		Total Exports	
334 Petroleum products, refined	14.99%	061 Sugar and honey	27.14%	
728 Oth machy for spec industries	2.89%	287 Base metals ores, conc nes	21.97%	
931 Special transactions	2.37%	971 Gold, non-monetary nes	15.67%	
	Commodity Imports		Commodity Exports	
	GDP		GDP	
334 Petroleum products, refined	11.27%	061 Sugar and honey	19.24%	
728 Oth machy for spec industries	3.75%	287 Base metals ores, conc nes	13.32%	
931 Special transactions	3.06%	971 Gold, non-monetary nes	16.32%	
All Imports	89.57%	All Exports	80.36%	
	Commodity Imports		Commodity Exports	
Honduras	Total Imports		Total Exports	
334 Petroleum products, refined	9.47%	071 Coffee and substitutes	31.02%	
541 Medicinal, pharmaceutical prdts	4.90%	057 Fruit, nuts, fresh, dried	27.97%	
782 Lorries, spec motor vehicl nes	3.39%	036 Shell fish fresh, frozen	6.14%	
	Commodity Imports		Commodity Exports	
	GDP		GDP	
334 Petroleum products, refined	4.68%	071 Coffee and substitutes	5.94%	
541 Medicinal, pharmaceutical prdts	1.83%	057 Fruit, nuts, fresh, dried	4.37%	
782 Lorries, spec motor vehicl nes	1.96%	036 Shell fish fresh, frozen	1.20%	

Appendix 3: Commodity Price Plots, Monthly Percentage Changes

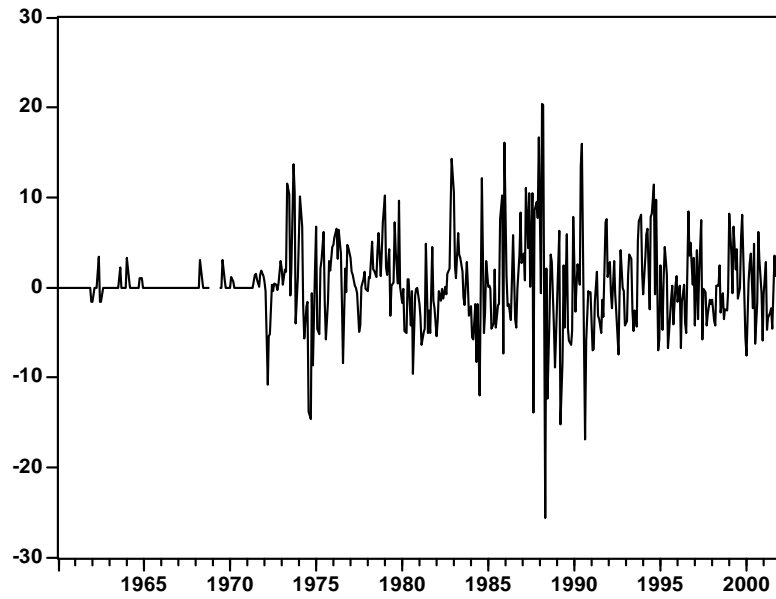


Figure 1: Aluminium price monthly percentage changes, 1960:1 - 2001:12

(Aluminium high grade, LME, cash; Source: UNCTAD Trade Database 2003)

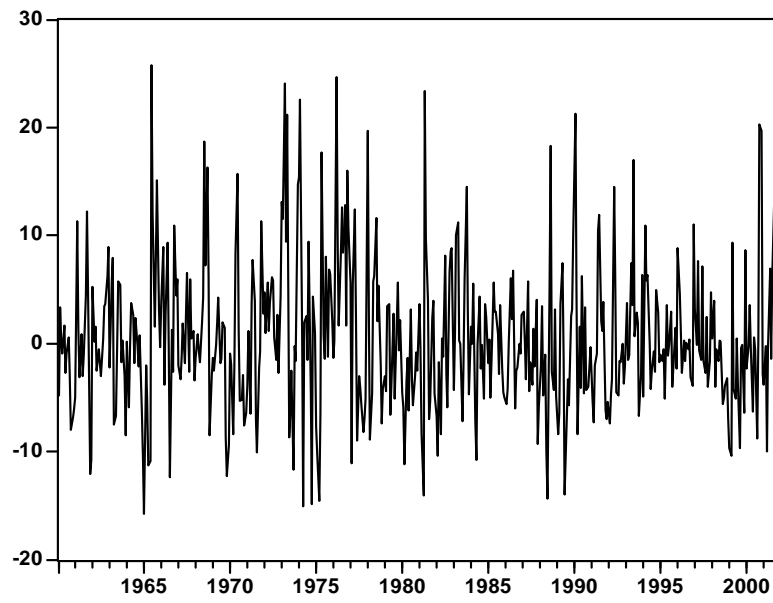


Figure 2: Cocoa price monthly percentage changes, 1960:1 - 2001:12

(Cocoa, average daily prices NY/London (¢/lb.);

Source: UNCTAD Trade Database 2003)

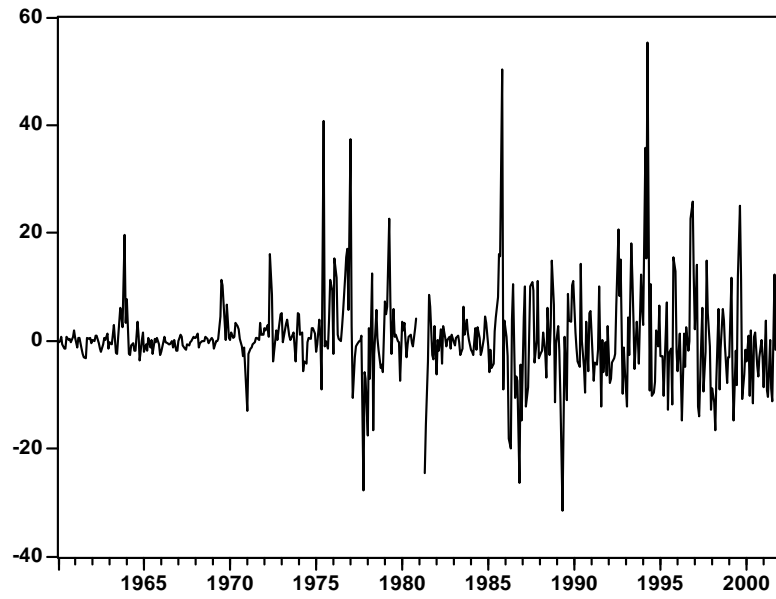


Figure 3: Coffee price monthly percentage changes, 1960:1 - 2001:12

(Coffee, Brazilian and other natural Arabicas, ex-dock NY (¢/lb.);

Source: UNCTAD Trade Database 2003)

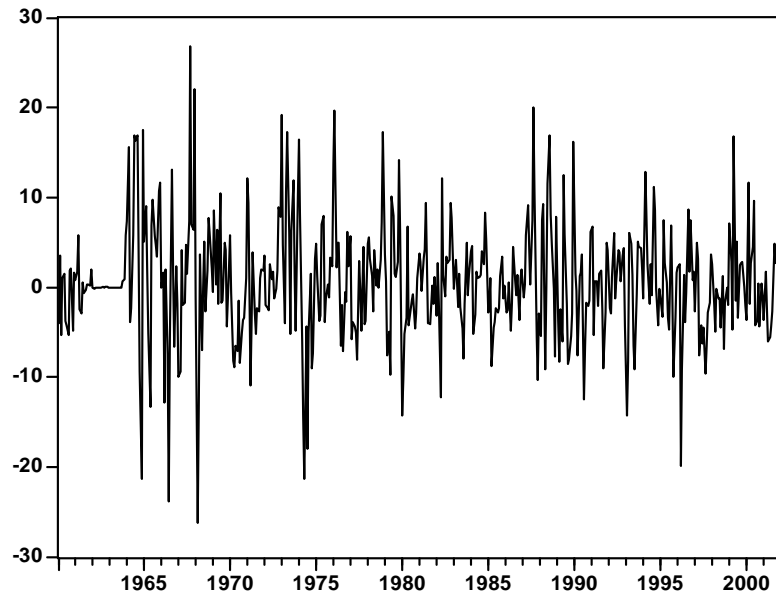


Figure 4: Copper price monthly percentage changes, 1960:1 - 2001:12

(Copper, grade A, LME, cash (£/t); Source: UNCTAD Trade Database 2003)

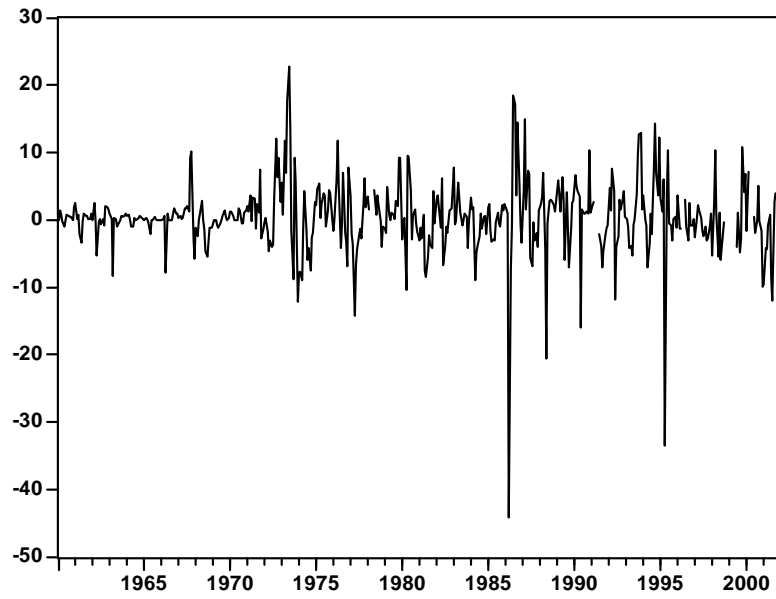


Figure 5: Cotton price monthly percentage changes, 1960:1 - 2001:12

(Cotton, US Memphis/Eastern, Midd.1-3/32", c.i.f. (¢/lb.);

Source: UNCTAD Trade Database 2003)

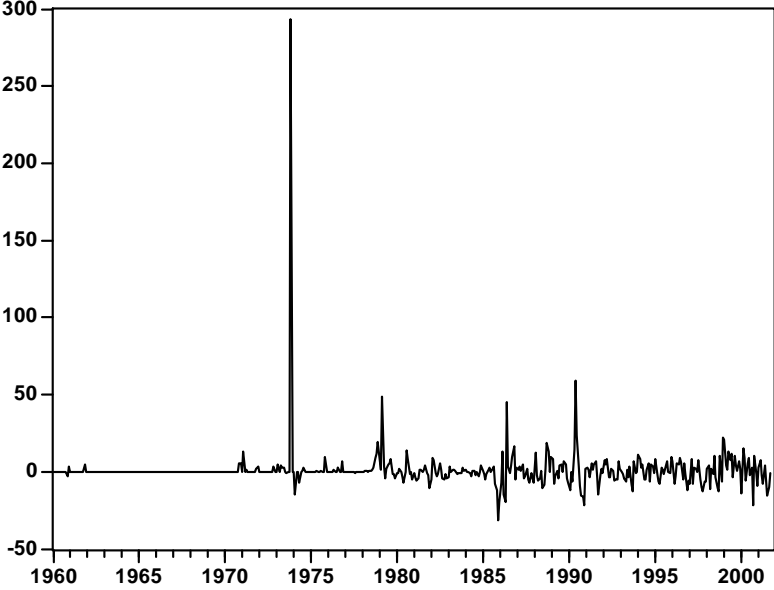


Figure 6: Petroleum price monthly percentage changes, 1960:1 - 2001:12
(Petroleum Dubai/Brent/Texas (\$/barrel);Source: UNCTAD Trade Database 2003)

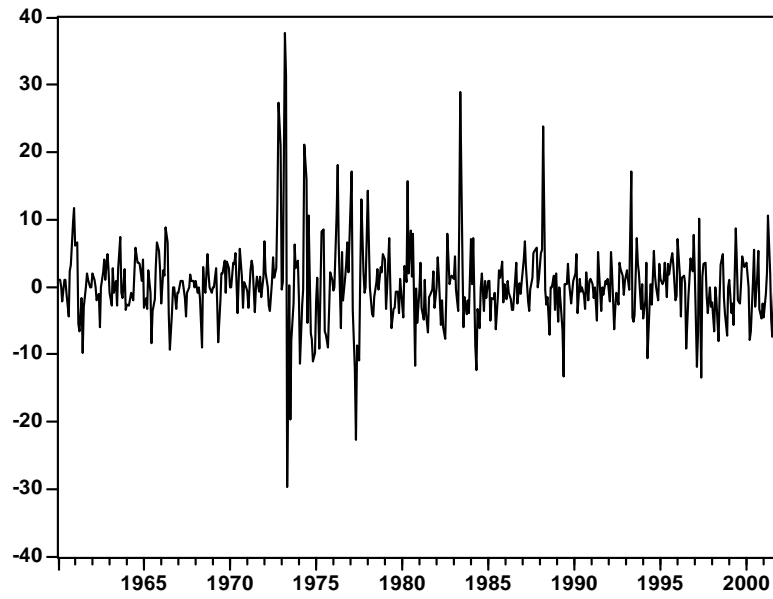


Figure 7: Soybean price monthly percentage changes, 1960:1 - 2001:12

(Yellow soybeans, n° 2, US, c.i.f. Rotterdam; Source: UNCTAD Trade Database 2003)

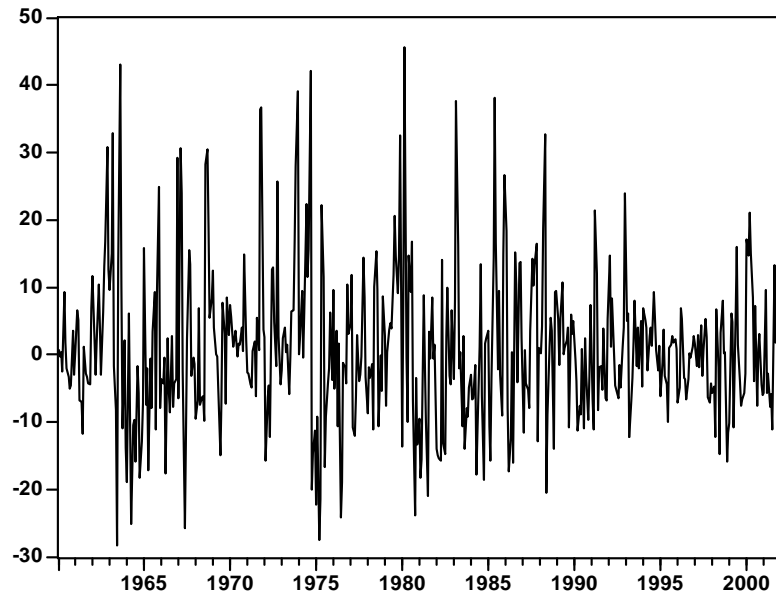


Figure 8: Sugar price monthly percentage changes, 1960:1 - 2001:12

(Sugar in bulk, Caribbean ports, f.o.b. (I.S.A.)" (¢/lb.);

Source: UNCTAD Trade Database 2003)

Appendix 4: Commodity price volatility

Commodity Price	Standard Deviation	Variance	Commodity Price	Standard Deviation	Variance
PCALUMINIUM	4.78	22.8	PCPHOSPAT	9.78	95.63
vPCBANANAECUADOR	15.22	231.55	PCPLYWOOD1	6.39	40.78
PCBEEFAUSTRALIA	4.78	22.82	PCPLYWOOD2	6.39	40.78
PCCATTLE	6.97	48.6	PCRICETHAI	4.94	24.39
PCCOCOALONDON	6.79	46.16	PCRUBBERDMIP	5.2	27.01
PCCOCONUTPHILLIPPENES	8.01	64.19	PCRUBBERNY	6.22	38.68
PCCOFFEEARABICA	7.64	58.33	PCRUBBERSINGAPORE	5.38	28.98
PCCOFFEEBRAZIL	8.22	67.6	PCRUBBERSINGAPORE2	5.49	30.12
PCCOFFEECOLOMBIA	7.91	62.65	PCSILVER	9.03	81.49
PCCOFFEECOMP	7.04	49.59	PCSISALLONDON	4.82	23.23
PCCOFFEEROBUSTA	7.05	49.66	PCSISALTANZANIA	4.1	16.77
PCCOPPER	6.5	42.21	PCSOYBEANDUTCH	6.57	43.23
PCCOPPER2	6.56	42.99	PCSOYBEANHAMBURG	6.62	43.85
PCCOPPERWIRE	4.8	23.08	PCSOYBEANROTTERDAM	5.93	35.11
PCCOPRAPHILLIPPENES	7.72	59.63	PCSUGARCARRIBEAN	11.31	127.92
PCCOTTONEGYPT	2.93	8.6	PCSUNFLOWER	6.65	44.28
PCCOTTONMEMPHIS	5.3	28.07	PCTEALONDON	8.45	71.33
PCCOTTONPAKISTAN	5.1	26.03	PCTEALONDONAUCTION	8.34	69.52
PCCOTTONSEEDUSGULF	6.75	45.63	PCTIN	4.85	23.52
PCCOTTONSUDAN	3.73	13.89	PCTINKUALALUMPUR	4.24	17.94
PCCOTTONTXAS	5.67	32.17	PCTINKUALALUMPUR2	4.24	17.99
PCFISHHAMBURG	6.53	42.69	PCTOBACCO	2.45	6
PCGOLDLONDON	6.03	36.35	PCTUNGSTEN	7.02	49.23
PCIRONAUSTRALIA	2.68	7.17	PCWHEATARGENTINA	7.87	61.91
PCIRONBRAZIL	4.55	20.72	PCWHEATUSGULF	4.98	24.75
PCJUTEBANGLADESH	7.24	52.46	PCWOODMALAY	4.2	17.63
PCLEAD	6.16	37.97	PCWOODSUKIMPORT	2.75	7.58

(Appendix 4 continued)					
PCLEAD2	6.08	37	PCWOODTROPICALGABON	5.24	27.44
PCLEADREFINED					
	4.63	21.39	PCWOODTROPICALUK	6.41	41.04
PCLINSEED	6.94	48.15	PCWOOL	5.89	34.7
PCMAIZEARGENTINA	5.68	32.25	PCWOOL23AUSTRALIA	4.53	20.54
PCMAIZEROTTERDAM	4.79	22.95	PCWOOL48UK	5.14	26.43
PCMANGANEEU	3.53	12.49	PCWOOL48UK2	4.45	19.83
PCNICKEL	7.4	54.79	PCWOOL64UK	6.09	37.1
PCNICKELCATHNY	6.4	40.93	PCZINCUK	5.92	35.06
PCNUTOILROTTERDAM	6.08	36.96	PCZINCUS	4.23	17.88
PCPALMKERNEL	8.54	72.92			
PCPALMOIL	7.39	54.64			
PCPEPPERSINGAPORE	7.88	62.17			
PCPETROLEUM	14.79	218.67			

Table 1: Commodity Price Volatility

Appendix 5: Covariances and correlation coefficients for selected commodity prices

COVARIANCE

Growth Rates	Alu	Cocoa	Coffee	Cotton	Maize	Petroleum	Rice	Soybean	Tea	Wood	Copper	Sugar
ALUMINIUM	22.76	1.88	6.51	3.24	1.72	1.93	1.39	2.83	-0.42	-0.63	9.47	2.00
COCOA LONDON	1.88	46.06	2.61	0.89	2.24	-2.81	-0.68	3.12	1.47	4.47	6.78	8.85
COFFEE BRAZIL	6.51	2.61	67.47	-0.14	2.41	-0.64	-0.59	2.96	11.26	0.93	5.40	1.27
COTTON MEMPHIS	3.24	0.89	-0.14	28.01	4.41	4.85	0.63	5.15	2.10	2.70	3.89	4.71
MAIZE ROTTERDAM	1.72	2.24	2.41	4.41	22.90	-0.31	2.51	15.51	-2.04	-1.01	1.58	10.44
PETROLEUM	1.93	-2.81	-0.64	4.85	-0.31	218.23	-0.96	1.41	1.04	-4.22	-0.74	15.15
RICE THAI	1.39	-0.68	-0.59	0.63	2.51	-0.96	24.34	0.80	-0.05	0.62	1.13	-0.34
SOYBEAN ROTTERDAM	2.83	3.12	2.96	5.15	15.51	1.41	0.80	35.04	1.98	2.79	1.97	11.12
TEA LONDON	-0.42	1.47	11.26	2.10	-2.04	1.04	-0.05	1.98	71.17	3.94	4.20	2.17
WOOD TROPICAL UK	-0.63	4.47	0.93	2.70	-1.01	-4.22	0.62	2.79	3.94	40.93	2.62	0.33
COPPER	9.47	6.78	5.40	3.89	1.58	-0.74	1.13	1.97	4.20	2.62	42.13	4.56
SUGAR CARIBBEAN	2.00	8.85	1.27	4.71	10.44	15.15	-0.34	11.12	2.17	0.33	4.56	127.66

Table 2: Covariances between selected commodity prices

Source: UNCTAD Trade Database 2003

CORRELATION

Growth Rates	Alu	Cocoa	Coffee	Cotton	Maize	Petroleum	Rice	Soybean	Tea	Wood	Copper	Sugar
ALUMINIUM	1.00	0.06	0.16	0.13	0.07	0.03	0.06	0.10	-0.01	-0.02	0.30	0.04
COCALONDON	0.06	1.00	0.05	0.02	0.07	-0.03	-0.02	0.08	0.03	0.10	0.15	0.12
COFFEEBRAZIL	0.16	0.05	1.00	0.00	0.06	-0.01	-0.01	0.06	0.16	0.02	0.10	0.01
COTTONMEMPHIS	0.13	0.02	0.00	1.00	0.17	0.06	0.02	0.16	0.05	0.07	0.11	0.08
MAIZEROTTERDAM	0.07	0.07	0.06	0.17	1.00	0.00	0.11	0.55	-0.05	-0.03	0.05	0.19
PETROLEUM	0.03	-0.03	-0.01	0.06	0.00	1.00	-0.01	0.02	0.01	-0.04	-0.01	0.09
RICETHAI	0.06	-0.02	-0.01	0.02	0.11	-0.01	1.00	0.03	0.00	0.02	0.04	-0.01
SOYBEANROTTERDAM	0.10	0.08	0.06	0.16	0.55	0.02	0.03	1.00	0.04	0.07	0.05	0.17
TEALONDON	-0.01	0.03	0.16	0.05	-0.05	0.01	0.00	0.04	1.00	0.07	0.08	0.02
WOODTROPICALUK	-0.02	0.10	0.02	0.07	-0.03	-0.04	0.02	0.07	0.07	1.00	0.07	0.00
COPPER	0.30	0.15	0.10	0.11	0.05	-0.01	0.04	0.05	0.08	0.07	1.00	0.06
SUGARCARRIBEAN	0.04	0.12	0.01	0.08	0.19	0.09	-0.01	0.17	0.02	0.00	0.06	1.00

Table 3: Correlation coefficients between selected commodity prices

Source: UNCTAD Trade Database 2003

Appendix 5: Covariances and correlations between LIC's and commodity prices

Table 1: Covariance's between macroeconomic indicators of LIC's and selected commodity prices

	#	Aluminium	Cocoa	Coconut-Oil	Coffee	Copper	Cotton	Gold
BANGLADESH, Exports	30	67.19	148.74	110.92	181.83	114.10	248.37	-14.57
BANGLADESH, GDP	29	-51.76	-102.06	-41.18	-170.92	-62.53	-55.01	145.70
BANGLADESH, Imports	30	-5.65	-24.25	91.49	59.86	48.60	119.94	204.10
BURUNDI, Exports	40	560.75	187.46	84.80	1301.19	433.13	91.95	-289.01
BURUNDI, GDP	42	33.12	36.25	32.59	100.62	-4.73	27.33	46.02
BURUNDI, Imports	40	44.70	-75.74	-76.86	52.85	30.46	182.25	68.31
CAMBODIA, Exports	18	7741.52	5712.23	19604.25	1560.35	2278.41	-240.39	18084.38
CAMBODIA, GDP	15	-5.97	-10.17	69.40	2.93	25.86	-232.20	195.96
CAMBODIA, Imports	19	-677.43	173.84	345.66	84.89	-134.97	517.82	573.61
Central African Rep., Exports	42	12.67	159.09	211.67	423.81	135.00	282.07	-14.20
Central African Rep., GDP	42	37.16	26.69	20.05	98.87	9.58	38.50	63.47
Central African Rep., Imports	42	-110.24	67.89	59.69	329.28	-5.89	107.01	-59.74
Cote d'Ivoire, Exports	42	86.31	317.54	356.74	495.80	95.13	104.80	60.66
Cote d'Ivoire, GDP	42	76.23	195.34	168.56	298.88	44.54	36.10	58.65
Cote d'Ivoire, Imports	42	140.22	224.06	268.60	386.88	140.89	153.11	164.29
ERITREA, Exports	8	227.14	147.40	-358.14	1192.45	274.29	1597.86	395.65
ERITREA, Imports	8	53.88	142.27	248.70	464.57	21.78	-106.91	60.37

(Table 1 continued)

GHANA, Exports	35	635.01	-47.51	532.22	170.60	285.22	155.31	69.57
GHANA, GDP	37	122.10	47.95	182.12	-14.43	12.60	-10.62	54.14
GHANA, Imports	38	389.71	36.49	672.58	-419.76	-26.79	75.26	-36.49
GUYANA, Exports	42	-121.57	-185.63	244.22	-393.79	-20.92	-56.32	118.73
GUYANA, GDP	37	-183.47	-195.30	50.94	-275.65	-26.91	-33.11	-151.26
GUYANA, Imports	38	-227.15	-228.58	164.62	-492.62	72.37	135.13	-78.68
HONDURAS, Exports	42	118.41	130.98	111.70	182.18	134.38	188.86	124.90
HONDURAS, GDP	42	13.76	41.87	36.72	80.55	14.28	39.29	-6.30
HONDURAS, Imports	42	170.26	155.10	298.65	80.99	133.46	93.34	200.83
MALAWI, Exports	38	146.49	108.53	231.06	254.44	107.81	161.96	-2.60
MALAWI, GDP	40	13.96	-66.57	-29.07	-59.46	14.60	-26.35	-112.00
MALAWI, Imports	38	117.05	-147.80	130.64	-68.70	121.46	-164.05	-53.34
NICARAGUA, Exports	42	87.52	149.74	87.74	184.02	76.34	177.36	-8.57
NICARAGUA, GDP	11	254.84	177.68	334.28	802.76	220.06	210.40	123.33
NICARAGUA, Imports	42	108.82	152.90	253.68	228.85	87.56	83.56	523.51
SAOTP, Exports	20	319.07	1011.68	717.37	1173.69	-50.18	-491.73	-81.16
SAOTP, Imports	20	-252.72	-13.32	-79.82	137.24	-254.11	-310.08	-98.55
TANZANIA, Exports	42	72.74	-27.79	-111.80	190.40	117.21	61.34	-76.09
TANZANIA, GDP	38	102.59	-16.14	122.59	-39.96	102.00	46.26	-30.33
TANZANIA, Imports	42	96.98	-133.95	-43.33	-101.95	107.86	-32.28	83.12
TOGO, Exports	41	516.37	486.69	936.08	1103.31	348.20	249.07	512.46
TOGO, GDP	42	86.49	97.63	140.23	182.50	77.60	-7.23	86.53
TOGO, Imports	42	223.03	179.39	170.12	497.36	227.13	215.16	57.88
ZAMBIA, Exports	37	-105.90	-81.57	-173.89	213.65	101.92	-35.94	-197.97
ZAMBIA, GDP	37	-199.18	-160.76	-119.50	-137.72	-5.14	-86.81	-316.37
ZAMBIA, Imports	37	-351.95	-345.69	-528.64	-379.91	-272.36	-187.81	-260.02

(Table 1 continued)

	#	Groundnut-Oil	Iron	Maize	Manganese	Nickel	Palmoil
BANGLADESH, Exports	30	1.00	42.53	67.68	32.38	115.60	73.71
BANGLADESH, GDP	29	146.61	250.03	54.66	172.47	-27.14	31.24
BANGLADESH, Imports	30	55.70	232.15	138.37	114.25	136.17	75.19
BURUNDI, Exports	40	228.14	-	946.39	-95.06	-88.71	302.84
BURUNDI, GDP	42	37.97	-	155.63	-4.25	41.09	1.22
BURUNDI, Imports	40	54.66	-	223.35	-95.06	77.94	9.48
CAMBODIA, Exports	18	19997.11	6153.44	7029.76	11038.22	1767.00	16007.11
CAMBODIA, GDP	15	330.26	143.61	246.94	189.68	15.69	217.62
CAMBODIA, Imports	19	-218.19	817.45	467.77	542.07	68.87	-284.30
Central African Rep., Exports	42	130.83	149.29	-94.13	29.34	-	108.33
Central African Rep., GDP	42	67.87	93.96	2.24	18.15	42.51	56.85
Central African Rep., Imports	42	-14.83	510.19	-67.79	-58.10	-	114.13
Cote d'Ivoire, Exports	42	250.90	357.72	61.29	-41.47	-16.76	258.35
Cote d'Ivoire, GDP	42	118.72	212.24	34.02	-5.35	7.19	141.68
Cote d'Ivoire, Imports	42	206.63	157.58	103.00	20.50	11.46	283.12

(Table 1 continued)

ERITREA, Exports	8	659.79	225.78	340.29	-550.80	188.95	19.55
ERITREA, Imports	8	156.29	-33.51	96.62	-45.90	-4.93	154.89
	3						
GHANA, Exports	5	133.01	-89.82	145.82	-206.81	19.33	157.75
	3		-				
GHANA, GDP	7	179.40	524.12	73.20	-4.88	-4.08	77.75
	3		-			-	
GHANA, Imports	8	299.22	836.77	175.43	-185.65	392.19	79.73
	4						
GUYANA, Exports	2	268.18	4.44	-9.54	370.84	-95.27	169.07
	3		-				
GUYANA, GDP	7	167.51	219.92	8.44	325.34	-35.83	35.12
	3		-			-	
GUYANA, Imports	8	154.41	553.12	31.36	518.05	162.36	90.63
	4						
HONDURAS, Exports	2	43.63	201.11	71.59	25.91	59.63	92.34
	4		-				
HONDURAS, GDP	2	28.05	104.53	12.16	1.73	-1.82	39.06
	4						
HONDURAS, Imports	2	137.62	57.53	152.67	50.28	93.82	213.28
	3		-				
MALAWI, Exports	8	138.02	675.98	93.77	7.85	143.27	266.87
	4		-				
MALAWI, GDP	0	16.57	387.06	41.73	17.17	86.08	13.80
	3		-				
MALAWI, Imports	8	26.59	227.21	38.08	24.50	297.18	101.03
	4						
NICARAGUA, Exports	2	183.39	11.55	45.56	46.75	-8.76	114.71
	1						
NICARAGUA, GDP	1	309.61	11.65	139.13	-43.67	191.72	335.92
	4		-				
NICARAGUA, Imports	2	203.02	458.86	157.71	130.82	48.75	235.86

((Table 1 continued)

	2		-	-			
SAOTP, Exports	0	38.69	455.49	216.96	-358.00	16.79	508.72
	2						
SAOTP, Imports	0	93.19	3.60	-89.69	-47.72	-81.61	-6.46
	4						
TANZANIA, Exports	2	-108.88	707.84	-36.70	79.61	52.09	-135.65
	3						
TANZANIA, GDP	8	-19.05	351.40	-6.41	26.97	152.81	103.17
	4						
TANZANIA, Imports	2	79.07	294.55	-19.42	231.11	-11.80	44.21
	4						
TOGO, Exports	1	923.90	-65.18	234.99	67.90	190.07	923.49
	4						
TOGO, GDP	2	137.30	146.67	32.88	23.91	62.50	123.06
	4						
TOGO, Imports	2	204.61	174.76	79.07	-8.12	248.54	290.51
	3						
ZAMBIA, Exports	7	-111.84	732.49	-80.88	-29.34	363.93	-299.68
	3						
ZAMBIA, GDP	7	-46.63	752.37	-73.36	7.76	209.93	-127.59
	3						
ZAMBIA, Imports	7	-100.28	779.55	200.80	181.18	478.68	-302.42

Table 1 Source: Macroeconomic Indicators, Annual percentage changes, 1960
– 2001,

International Financial Statistics, <http://ifs.apdi.net/imf/>

Commodity Prices, Annual percentage changes, 1960 – 2001, UNCTAD Trade
Database 2003

(Authors calculation)

Table 2: Correlation coefficients between macroeconomic indicators of LIC's and selected commodity prices

	#	Petroleum	Rice	Silver	Sisal	Soybean	Sugar
BANGLADESH, Exports	30	11.47	-56.00	-4.72	-3.05	121.79	-184.28
BANGLADESH, GDP	29	388.57	142.63	104.66	77.81	-73.99	282.13
BANGLADESH, Imports	30	97.32	85.75	135.38	91.48	95.93	146.52
BURUNDI, Exports	40	-184.78	-157.59	-121.75	-422.39	75.13	-956.32
BURUNDI, GDP	42	74.41	-7.61	86.59	1.44	1.51	25.18
BURUNDI, Imports	40	290.93	-19.16	136.03	-105.21	-105.47	-261.41
CAMBODIA, Exports	18	55290.33	22495.55	34640.99	20727.40	2566.85	44577.39
CAMBODIA, GDP	15	-132.00	177.62	18.09	227.71	295.13	176.01
CAMBODIA, Imports	19	-130.10	203.11	288.42	411.43	475.86	-521.11
Central African Rep., Exports	42	338.37	50.39	199.18	21.16	-119.62	434.46
Central African Rep., GDP	42	128.33	64.75	77.01	23.54	-26.16	138.80
Central African Rep., Imports	42	-91.60	22.36	-85.85	-30.73	-43.20	-171.09
Cote d'Ivoire, Exports	42	206.05	192.05	173.50	155.81	54.06	197.20
Cote d'Ivoire, GDP	42	111.09	87.92	112.73	75.85	46.25	91.66
Cote d'Ivoire, Imports	42	189.75	215.08	242.57	142.94	88.09	216.64
ERITREA, Exports	8	179.30	244.77	243.37	334.63	434.56	950.04

(table 2 continued)							
ERITREA, Imports	8	-49.02	229.91	101.41	29.20	45.25	38.78
GHANA, Exports	35	-302.28	-83.80	524.51	-223.41	87.27	-330.49
GHANA, GDP	37	4.94	77.55	121.58	5.36	32.38	-25.20
GHANA, Imports	38	83.29	-97.44	568.56	-29.84	57.64	57.30
GUYANA, Exports	42	598.86	304.19	102.15	155.11	-150.95	507.83
GUYANA, GDP	37	176.28	142.50	-163.98	35.54	-119.42	17.59
GUYANA, Imports	38	383.59	157.43	-56.51	63.94	-124.71	63.64
HONDURAS, Exports	42	78.18	74.01	155.46	72.89	104.96	9.61
HONDURAS, GDP	42	22.50	18.40	23.65	15.02	14.83	-43.70
HONDURAS, Imports	42	260.32	181.85	287.94	212.20	112.46	297.59
MALAWI, Exports	38	100.78	67.50	92.91	97.11	21.01	60.03
MALAWI, GDP	40	52.24	-51.97	-84.54	14.76	-23.47	-71.91
MALAWI, Imports	38	90.14	88.34	23.80	-52.81	-42.96	-20.59
NICARAGUA, Exports	42	228.41	96.58	56.94	121.71	47.63	115.84
NICARAGUA, GDP	11	15.29	309.92	223.33	49.83	78.97	200.77
NICARAGUA, Imports	42	334.68	369.67	457.72	231.90	109.47	896.64
SAOTP, Exports	20	-414.12	-14.23	-82.56	165.26	271.12	-581.72

(table 2 continued)

SAOTP, Imports	20	-155.44	47.89	-349.07	-93.80	-43.49	-333.62
TANZANIA, Exports	42	-178.58	-5.13	-157.71	54.20	1.60	265.84
TANZANIA, GDP	38	10.16	32.50	-4.07	0.92	16.31	-13.04
TANZANIA, Imports	42	123.12	157.39	-19.67	127.38	-55.62	353.30
TOGO, Exports	41	1176.86	932.18	869.20	434.98	-2.22	1269.22
TOGO, GDP	42	220.21	148.94	135.53	69.54	-0.01	176.90
TOGO, Imports	42	153.30	116.15	105.33	14.55	13.94	61.71
ZAMBIA, Exports	37	-283.92	-84.85	-160.86	125.14	-54.55	27.41
ZAMBIA, GDP	37	-250.13	-51.25	-281.05	-73.24	-78.53	-153.42
ZAMBIA, Imports	37	61.74	-181.37	-391.65	-101.53	-288.65	-26.24

(Table 2 continued)

	#	Sunflower- Oil	Tea	Tin	Wheat	Wood, Tropical	Wool
BANGLADESH, Exports	30	-1.55	78.83	43.01	67.18	169.25	229.10
BANGLADESH, GDP	29	126.98	-77.02	32.91	39.08	-4.85	-123.57
BANGLADESH, Imports	30	64.30	16.31	89.36	158.76	113.67	136.24
BURUNDI, Exports	40	194.26	369.34	264.42	-145.44	115.73	326.97
BURUNDI, GDP	42	19.69	68.53	41.93	-11.88	14.13	-6.34
BURUNDI, Imports	40	103.75	-21.18	92.78	-61.28	-17.80	-143.29
CAMBODIA, Exports	18	21575.71	7198.50	13529.52	6085.10	13621.21	7664.21
CAMBODIA, GDP	15	324.70	68.75	-166.57	20.63	309.50	-113.16
CAMBODIA, Imports	19	-240.26	-79.05	-213.32	598.47	1054.83	958.56
Central African Rep., Exports	42	19.11	229.03	243.76	33.12	-31.53	240.15
Central African Rep., GDP	42	42.16	4.47	49.53	9.91	-7.86	44.69
Central A frican Rep., Imports	42	-27.34	29.08	-4.17	36.13	45.38	259.98
Cote d'Ivoire, Exports	42	175.42	208.49	172.10	67.00	47.29	269.60
Cote d'Ivoire, GDP	42	94.57	118.89	121.49	23.64	38.63	103.60
Cote d'Ivoire, Imports	42	213.50	31.47	229.16	113.41	91.48	153.58
ERITREA, Exports	8	254.81	601.94	-119.07	365.99	97.03	573.08
ERITREA, Imports	8	41.59	51.19	26.46	88.55	-28.70	255.31

(Table 2 continued)

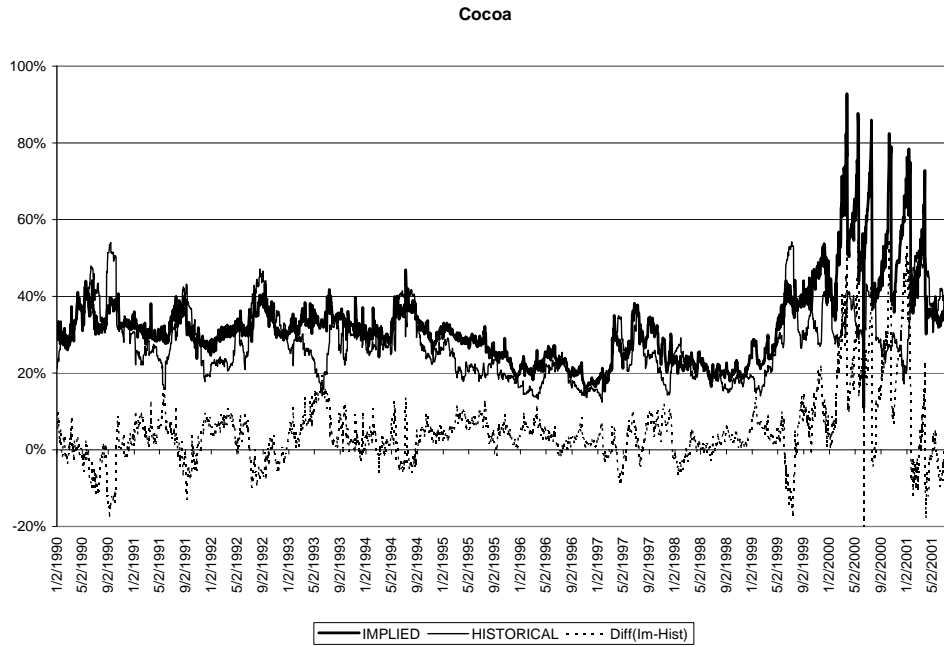
GHANA, Exports	35	25.26	147.91	-114.75	-81.95	-9.82	93.39
GHANA, GDP	37	36.14	135.60	22.58	3.46	-81.86	12.57
GHANA, Imports	38	103.08	511.50	-79.57	-57.72	-235.01	-311.81
GUYANA, Exports	42	138.94	33.47	25.82	10.51	-33.76	-276.04
GUYANA, GDP	37	64.72	-30.02	3.34	19.04	-103.59	-263.71
GUYANA, Imports	38	40.55	-74.54	48.33	76.87	84.01	-287.55
HONDURAS, Exports	42	50.83	41.08	119.07	77.04	129.37	90.42
HONDURAS, GDP	42	5.75	15.46	19.65	4.46	0.00	-2.70
HONDURAS, Imports	42	165.32	65.35	163.59	123.18	92.46	47.35
MALAWI, Exports	38	169.21	-18.30	47.46	45.97	102.57	104.88
MALAWI, GDP	40	22.21	-24.89	29.02	6.95	-118.29	-124.13
MALAWI, Imports	38	53.83	-146.66	73.24	36.34	-124.02	28.85
NICARAGUA, Exports	42	101.82	128.56	140.79	35.19	52.17	116.76
NICARAGUA, GDP	11	158.16	-44.47	149.62	120.00	109.05	476.96
NICARAGUA, Imports	42	127.99	117.93	203.89	111.53	147.65	112.43
SAOTP, Exports	20	280.77	1079.28	222.74	-257.79	-9.46	185.00
SAOTP, Imports	20	8.23	248.02	38.92	-54.45	-112.79	-52.97
TANZANIA, Exports	42	-159.91	-17.54	-131.94	21.17	151.15	25.10
TANZANIA, GDP	38	-4.69	-61.63	-36.28	6.19	50.25	122.89
TANZANIA, Imports	42	65.75	-208.14	-28.75	20.98	157.54	-115.86
TOGO, Exports	41	747.33	232.57	580.16	218.84	-92.76	366.22
TOGO, GDP	42	102.20	52.81	107.18	30.01	-32.97	54.32
TOGO, Imports	42	151.44	6.37	228.68	87.70	19.31	219.41
ZAMBIA, Exports	37	-151.46	-205.58	-344.57	-77.75	207.73	-323.56

(Table 2 continued)

ZAMBIA, GDP	37	-72.43	-107.04	-201.02	-46.19	-17.65	-235.94
ZAMBIA, Imports	37	-128.65	-120.70	-297.94	-176.41	-67.37	-622.86

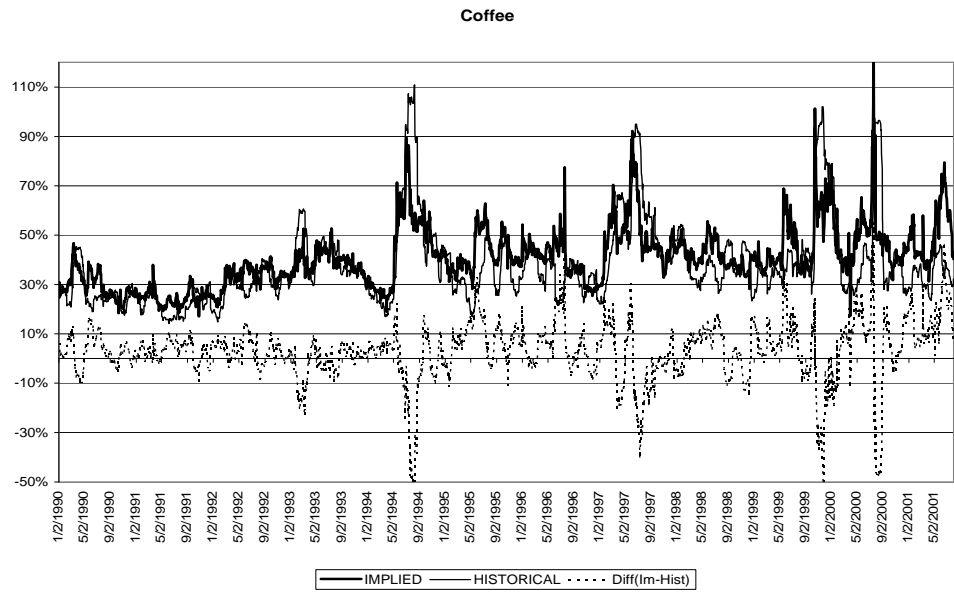
Table 2 Source: Macroeconomic Indicators, Annual percentage changes, 1960 – 2001, International Financial Statistics, <http://ifs.apdi.net/imf/>, Commodity Prices, Annual percentage changes, 1960 – 2001, UNCTAD Trade Database 2003

Appendix 6: Implied and historical volatilities of selected commodity futures



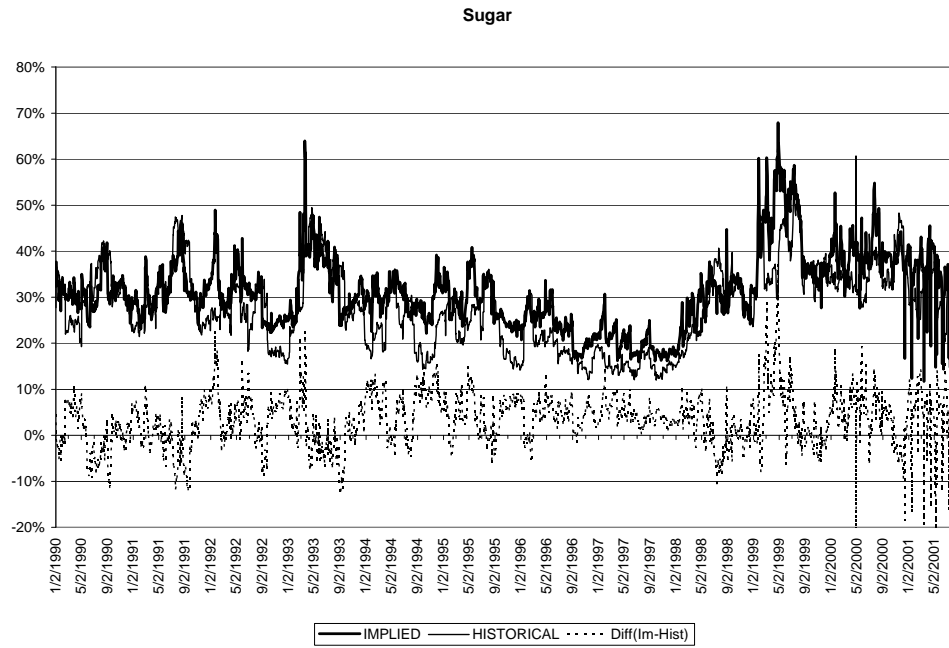
Correlation 57.34

Covariance 0.0053



Correlation 69.38

Covariance 0.0143



Correlation **77.51**

Covariance **0.0056**

Bibliography

Atta-Mensah, J. (2004). The commodity Linked Bonds: A potential Means for Less-Developed Countries to Raise Foreign Capital . *Working paper* .

Catao, L. A. (n.d.). Volatility and the debt intolerance Paradox. *IMF Paper* , 190-218.

G.Zhang, P. (1998). *Exotic Options:A guide to Second Generation Options* . World Scientific Pub .

Grossman, H. I. (1999). Sovereign debt and consumption smoothing . *Journal of Monetary economics* , 149-158.

Hull, J. (2002). *Options,Futures and other derivatives*. new jersey: Prentice hall.

Kapu, L. C. (2004). Missing link:volatility and the debt intolerance paradox.IMF Working paper

Kat, H. M. (2001). *Structured Equity Derivatives: The definitive Guide to Exotic options and structured Notes*. New York: wiley .

Neftci, S. (2004). *Principles of Financial Engineering* . New York: Academic Press.

Reinhar, C. M. (2003). Debt intolerance. *NBER Working paper* .

Suthiphongchai, F. P. (2003). sovereign credit default swap. *BIS quarterly review* ,December .

Taleb, N. N. (1997). *Dynamic Hedging:Managing Vanilla and Exotic Options* . New York: Wiley.

The policy development and review department,IMF. (2003). *Fund Assistance for countries facing exogenous shocks*.

The Staffs of the IMF And The World Bank. (2004). debt sustainability in low income countries -Proposal for an operational framework and policy implications.

W.Malone, S. (2005). Managing default risk for commodity dependent countries: Price hedging in an optimizing model. *University of Oxford discussion paper serial* .