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Managing Price Risks in the Coffee Sector of Costa Rica Via Futures Trading Strategies

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MANAGING PRICE RISKS IN THE COFFEE SECTOR OF COSTA RICA VIA FUTURES TRADING STRATEGIES

By

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ABSTRACT

MANAGING PRICE RISKS IN THE COFFEE SECTOR OF COSTA RICA VIA FUTURES TRADING STRATEGIES

By

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Price risks cause adverse impacts to economies that depend on a handful of commodities for most of their foreign currency earnings. This paper describes the main types of price risks faced by Costa Rican coffee farmers, millers and exporters, discusses potential risk management alternatives and estimates optimal hedge rules for exporters who may want to hedge a fixed cash position using New York "C" futures contracts.

The optimal hedge ratio (OHR) stems from a standard Mean-Variance model and is defined as the ratio of the conditional covariance between spot and futures prices to the conditional variance of futures prices. In order to obtain the OHR a bivariate model with equations for the Costa Rican coffee price basis and the futures price is estimated via maximum likelihood. The performance of the OHR is evaluated by both ex-ante and ex-post percentage reduction in the variance of per unit profits as compared with the no hedge option. It is shown that the OHR of 0.76 provides a significant reduction in the conditional variance of per unit profits.

A mis padres.

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CHAPTER I.

INTRODUCTION

Coffee has been the single most important economic activity in Costa Rica in terms of foreign currency generation and contribution to GNP for over a century. Revenue from coffee exports accounted for 21% of total Costa Rican exports in 1989. The share of coffee in total gross agricultural product is approximately 23%. Furthermore, the production structure of the crop is characterized by the predominant participation of small and medium farms. The average farm size is 2.5 hectares and 72% of the farms have a size below 10 hectares. This production structure and the labor-intensive nature of the activity enhance the importance of coffee from a national income distribution perspective.

The recent instability of the international coffee market has caused great concern among Costa Rican policy makers, especially since the collapse of the International Coffee Agreement (ICA) in 1989. Coffee price fluctuations have an adverse impact on the Costa Rican economy. There is reason to believe that they impair the economic performance and welfare not only of those directly involved in the industry but also of the nation as a whole. The tax mechanisms established for the activity and the prominent role of coffee as a hard currency generator cause negative shocks to expand beyond the subsector into the macroeconomy.

The need to improve the efficiency of the Coffee subsector has increased as a result of the absence of the ICA. There is little doubt that the agreement stabilized prices, and thus was an institution that provided some risk management against adverse price fluctuations. Even though Costa Rica has also developed mechanisms that distribute the risk of price fluctuations within the subsector, these pricing mechanisms shift most of the risk towards the farmers (Bornemisza, Jaramillo, Myers).

Risk management in the Costa Rican coffee subsector is a topic that deserves more attention than that given in the past. This paper focuses primarily on one aspect of risk management, namely, the use of futures markets as a hedging tool against the risk of coffee price fluctuations. In particular, this study develops and estimates optimal hedging strategies for Costa Rican coffee exporters who may want to hedge a given cash position. This is done in the framework of a Mean-Variance model. A second concern of the analysis is the evaluation of the performance of the hedging rules estimated.

More formally, the objectives of the study are:

1. To provide the reader with a basic understanding and appreciation for how futures and options markets could be beneficial to Costa Rican coffee market participants.
2. To describe the main types of price risks faced by coffee market participants and to identify potential price risk management

alternatives available to farmers, millers and exporters under the current coffee marketing system in Costa Rica.

3. To develop and estimate optimal hedge ratios for Costa Rican coffee exporters wanting to hedge a fixed position in the cash market.

4. To evaluate the performance of the hedging rules.

The remainder of the study proceeds as follows. Chapter 2 introduces the concepts of risk and risk management, provides an understanding of futures and options markets, and discusses expected utility and the Mean-Variance approach. Chapter 3 expands on the Costa Rican coffee subsector and analyzes risk management alternatives for farmers, millers and exporters. Chapter 4 lays out the theoretical models to be estimated. Chapter 5 contains the empirical results of the models from the previous chapter and evaluates the performance of the optimal hedging rules. Chapter 6 summarizes the results and concludes the paper. Finally, the Appendix provides a brief introduction to the economics of coffee worldwide for those who are unfamiliar with the coffee industry.

CHAPTER II.

BACKGROUND

This thesis deals with the risks stemming from price fluctuations in the coffee market, and proposes that futures and options markets can be used by Costa Rican exporters and millers as part of their risk management programs. In order to understand the role of hedging, this background chapter introduces the concepts of risk analysis, futures and options markets and basis risk. The chapter concludes with a discussion of the expected utility hypothesis and the Mean-Variance approach to modelling a decision maker's objectives.

A. RISK AND RISK MANAGEMENT

Risk is defined in Webster's as "a hazard; a peril; exposure to loss or injury". Thus, when the individual is uncertain about the consequences of his choice because of stochastic states of nature, the decision maker is said to be in a risky situation (Robison and Barry). Hence, the concept of risk is measured by a probability distribution over outcomes, some of which are favorable to the investor and some of which may cause losses or adversity.

Decision makers use a wide range of tools to deal with risk. Marketing strategies used as risk management tools include: inventory management, sequential marketing, forward contracting, hedging, government commodity programs, and vertical integration (Hanson). Financial strategies to deal with risk include holding liquid assets to meet unexpected cash demands, holding liquid credit reserves, and maintaining formal insurance. The type of risk a decision maker faces from agricultural price uncertainty is determined by the possibility of loss in income due to unfavorable price changes.

The concepts of risk aversion, risk premiums, and certainty equivalents play a central role in risk analysis. **Risk aversion** means that decision makers must be compensated for taking risks in the form of a premium over and above the return on a completely certain investment (Robison and Barry). Therefore a risky decision must yield an expected return high enough to compensate the risk averse individual for accepting risk. The more risk averse an investor is, the higher the compensation on the risky investments must be in order for these investments to become preferred to riskless alternatives.

It follows that a risk averse decision maker facing two alternatives with the same expected value will prefer the less risky one. Faced with a risky alternative and a riskless one, there is some level of expected return on the risky investment, larger than the return on the safe investment, at which the decision maker is indifferent between the expected return on the risky and the riskless alternatives. This difference is called a **risk premium**. The return on the risk-free investment, equal to the expected return on the risky investment less the risk premium, is defined as the **certainty equivalent** of the return on the risky investment. The deterministic certainty equivalent and the risky return yield the same level of well-being.

For risk averse decision makers, the risk premium is always positive in order to compensate for bearing the risk. For risk-neutral decision makers, the risk premium is zero; for risk-preferring decision makers, the risk premium is negative, which indicates their willingness to pay a premium for the opportunity to bear risk.

B. FUTURES AND OPTIONS

1. Contracts

A futures contract is a legally binding commitment to take or make delivery of a given quantity and quality of a commodity, at a price agreed upon when the contract is made, with delivery at the seller's prerogative sometime during the specified future delivery month (Ferris). With the exception of the contract price, all futures contract terms are established by the exchange on which the futures contract trades.

All futures contracts trade on designated futures exchanges. Coffee futures contracts are traded, for instance, in the Coffee, Sugar and Cocoa Exchange (CSCE) in New York. In the U.S. the Commodity Futures Trading Commission (CFTC) regulates the exchanges. A less standardized counterpart to futures contracts is forward contracts. Forward contracts, like futures contracts, are contracts for deferred delivery.

Unlike futures, forward contracts are customized to individual traders' needs, which makes them useful for certain commercial transactions but also makes them difficult to liquidate.

Option contracts are of two types --**calls** and **puts**. Put (call) options grant the option purchaser the right, but not the obligation, to sell (purchase) the underlying asset at a designated price called the **strike price** for a specified period of time. Like futures, listed options trade on organized exchanges. Again, there are less-standardized counterparts that trade in the over-the-counter (OTC) markets. Like forward contracts, OTC options are customized or tailored to individual purchasers' needs. Also, OTC options are difficult to liquidate.

The **option holder** purchases an option sold by the **option writer**. During the life of the contract, the option holder is said to be long the option, and the option writer is said to be short the option. The **option premium** is the price the purchaser pays the writer for the exercise privilege of the option. Finally, the underlying asset for an option can be a futures contract or it can be the asset underlying the futures. This gives rise to the terms **options on futures** and **options on actuals**. For instance, coffee options traded in New York are options on futures.

One of the features that distinguishes the futures and listed option markets from other derivative assets is the extreme standardization of the contract terms, all of which, with the exception of the contract price, are established by the exchange on which the contract trades.

Contract standardization, together with the intermediary role of the clearing association, allows the contracting parties to terminate their obligations by taking offsetting positions.

2. Markets

Assets are traded in markets. An **asset** is something having or perceived to have value. An asset may be of a financial or a nonfinancial nature. For regulatory purposes, assets and markets have long been divided into two categories: securities and commodities. In traditional usage, the term securities refers to homogeneous financial assets such as specific stocks and bonds. The term commodities is most often used to describe homogeneous physical goods such as coffee, pork bellies, and tin.

Derivative instruments are assets whose value is derived from some other asset. The derivative instrument markets include the futures markets, the option markets, the forward markets, and the swap markets. Derivative instruments share some common characteristics. First, they are all defined on other assets and could not exist in the absence of these other assets. The asset on which the derivative instrument is defined is called the **underlying asset**. Second, trading in the derivative instrument is a zero-sum game. That is, ignoring transaction costs, utility considerations and possible externalities, the profits that accrue to the winners approximately equal the losses that accrue to the losers. Third, the instruments may be used as effective tools in the management of price risk. Finally, derivative instruments are all time-specific, so the instruments have a limited life.

The market classification of Table 1 shows how derivative instruments relate to financial and nonfinancial assets.

TABLE 1. MARKET CLASSIFICATION BY ASSET TYPE

FINANCIAL MARKETS AND ASSETS	DERIVATIVE INSTRUMENTS
CAPITAL MARKETS	FUTURES CONTRACTS
Common stock	Commodities
Preferred stock	Agricultural futures
Partnership interests	Industrial Material futures
Bonds	Precious metal futures
Mortgages and related securities	Financial assets
MONEY MARKETS	Bond and other interest rate futures
Federal funds	Bond-index futures
Commercial paper	Stock-index futures
Certificates of deposit	Currency futures
Treasury bills	Miscellaneous futures
Banker's acceptances	Price-index futures
CURRENCY MARKETS	Freight-index futures
	OPTIONS CONTRACTS
NONFINANCIAL MARKETS AND ASSETS	OTC options
Commodities (spot)	Listed options
Real estate	Options on commodities
Collectibles	Options on stocks
	Options on bonds
	Options on bond and stock indexes
	Options on futures
	SWAP CONTRACTS

In any market, someone wishing to purchase an asset must purchase it from someone willing to sell it. The party wishing to buy the asset gives a bid price, and the party wishing to sell the asset gives an

asked price. Exchanges provide the trading floor where some sort of auction system takes place. For a particular instrument, the order flow to the floor can exceed an exchange's ability to match buyers and sellers efficiently. This situation can lead to unmatched trades, poor handling of customer orders, and mistakes in the reporting and recording of transactions. Increasing incidence of order "overflow" has led some exchanges to experiment with computer entry and matching of orders --at least on a limited basis (Marshall).

When trading volume in a market for an asset is heavy, the market for the asset is said to be **liquid**. When trading volume is light, the market for the asset is said to be **thin** or **illiquid**. The bid-asked spread, as a percentage of the asset's price, will typically be narrow (small) in a liquid market and wide (large) in a thin market.

In a futures market, the seller is said to be **short** the futures contract; the buyer is said to be **long** the futures contract. When a position, either a short or a long, is first put on by a trader, the trade that establishes the position is called an **opening trade**, which gives rise to an **open position**.

Each futures exchange provides for a clearing association. The clearing association serves as a passive party to all trades and a guarantor of the financial integrity of all positions. On the floor of the exchange, two parties, through the auction process, agree to a contract price. Although they contract with each other, the relationship of each to the other is immediately replaced by identical relationships between each contracting party and the clearing association. Thus the clearing association becomes long to the short, and short to the long. This arrangement relieves each party of any concern about the commitment and financial integrity of the other party. Since the clearing association will always be long and short the same number of contracts, it bears no price risk.

Nevertheless, the clearing association faces **default risk**, the risk that one or more holders of open futures positions will default on their obligations to the clearing association. The clearing association manages its exposure to default risk by requiring each party carrying an open futures position to secure that position by posting a performance bond called **margin**. In futures contracting, margin is usually 10 percent or less of a contract's value (Ferris), although this may vary with respect to a number of factors including the size of the trader's position and whether the position is a speculation or a hedge.

When a position is opened, the trader is required to put up **initial margin**. As long as a position is held, the trader is required to maintain some minimum amount of margin, called maintenance margin. Should the trader's margin fall below the maintenance requirement, the trader receives a margin call. Margin requirements may always be satisfied with cash, but as a general rule, they may also be met in whole or in part with Treasury bills (T-bills). Some exchanges permit traders to meet margin calls with other securities and/or bank letters of credit. The use of income-generating assets has implications for the risk-return trade-off associated with futures trading.

Although delivery provisions are part of the futures contracts, it is generally not the intention of the seller to make delivery nor the intention of the buyer to take delivery. A position may be closed in either of two ways: by offset or by delivery. In most cases, positions are closed by the taking of an offsetting position; that is, a trader with an open short (long) position would buy (sell) contracts.

In the U.S., option markets were banned for agricultural commodities in the late 1930s and were reintroduced in 1984 on a pilot basis. Options provide an alternative forward pricing mechanism that grant their users: (a) downside price protection; (b) limited exposure to cash losses with the broker, i.e. no margin calls; and (c) the opportunity to profit from favorable price movements.

3. Participants

Market participants can be classified according to their motivations. There are two dominant motives for futures and options trading: risk management and profit. Hedgers are motivated by the reduction of the price risk associated with an actuals' position.[1] In the classic example, the producer of a commodity takes a position in futures or

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[1] Some have disputed this strict risk-avoidance view of hedging. Working has written extensively challenging the standard assumption that hedging is undertaken solely for the purpose of risk avoidance. A further development of Working's ideas is found in Williams.

options (goes short) to offset either a current or an anticipated position in actuals (in which he is long).

On the other hand, speculation occurs as a result of the desire to earn speculative profits. To earn speculative profits, speculators must bear risk. They must forecast the direction of futures prices or option premiums and then take a position in these derivative instruments that provide a gain from the correct forecast. Speculators can be classified according to their forecasting time horizons. Position traders have a longer-term horizon than scalpers, pit traders, and day traders.

In reality, however, agents might trade pursuing the partial objectives of hedging and earning speculative profits. This study deals with hedgers, and in Chapter 3 will show that a Costa Rican coffee exporter or miller could hedge his long cash position by selling futures or buying put options. This paper assumes that Costa Rican market participants will not use the futures markets for speculative purposes.

C. HEDGING AND BASIS RISK

The **basis** is the difference between a current localized spot price and a futures price. As a futures contract approaches delivery, the futures price should converge toward the spot price. At the moment of the futures contract's delivery, the **maturity** or **delivery basis**, may not be exactly zero, depending on the geographic and quality differences between the commodity specified in the futures contract and the actual commodity that is the subject of the hedge. In order to understand hedging it is important to understand the behavior of the basis.

The definition of the word hedging is "to adopt a strategy designed to reduce risk". Futures hedging has been described as a risk-shifting activity. In reality, futures hedging creates a second market position having its own price risk. The effectiveness of a hedge depends on the degree to which the price risk associated with the futures position does indeed offset the price risk associated with the position in physicals. Futures hedges are rarely perfectly effective; that is, even after a hedge is established, some risk, called basis risk, remains. If the basis risk is less than the price risk associated with the cash market position alone, then the hedge is at least partially effective.

Basis risk is measured by the variance of the basis at the time the hedge is lifted, as it is perceived at the time the hedge is placed. The variance of the basis tends to decline as the futures instrument approaches delivery, but this decline may not be linear (Marshall).

Yamey (1951) and Graf (1953) were among the early investigators of routine hedging performance in futures markets. They considered whether profits and losses resulting from price movements were smaller with hedging than without. This question was generally answered affirmatively, especially when spot price changes were large.

The important question of "optimal hedging", that is, the ratio in which agents hold spot and futures contracts was analyzed from a portfolio theoretic viewpoint by Stein (1961, 1964), Johnson (1960) and Ward and Fletcher (1971). More recent studies by Rolfo (1980), Berck (1981), Anderson and Danthine (1983), Myers and Thompson (1989), and others have continued to study the optimal hedge of an individual agent in a partial equilibrium setting.

In a series of papers beginning in 1948, Holbrook Working emphasized hedging carried out by hedgers with the expectation of making profits. He argued strongly that agents in these markets pursue the joint objectives of profit making and risk reduction (Working, 1953). This type of carrying-charge or arbitrage hedging, is said to be motivated by the prospects of profit resulting from changes in the basis relative to the cost of carrying inventory over time. Working emphasized that this sort of hedging "is not properly comparable with insurance". It is not done "from any special desire to minimize risks".

Yamey (1986) tries to blend the views of hedging as arbitrage and risk avoidance by stating that "hedging is the simultaneous making of offsetting, but not necessarily equal, transactions in related actuals and futures markets so as to reduce the risk of loss on adverse price changes, and sometimes with the intention of profiting from expected favorable basis changes".[2]

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[2] Yamey (1986), p. 88.

D. PREFERENCES REPRESENTATION AND RISK AVERSION

A commonly accepted theory of asset choice under uncertainty is the expected utility hypothesis. Under this hypothesis, each individual's consumption and investment decision is characterized as if he determines the probabilities of possible asset payoffs, assigns an index to each possible consumption outcome, and chooses the consumption and investment policy to maximize the expected value of the index. More formally, an individual's preferences have an expected utility representation if there exists a function u such that the probability distribution of $\tilde{x}$ is preferred to that of $\tilde{y}$ if and only if

$$E[u(\tilde{x})] \geq E[u(\tilde{y})], \tag{2.1}$$

where $E[\cdot]$ is the expectation under the individual's probability belief.

An individual is represented by his preference relation $\succeq$ defined on a set of consumption plans. It is desirable to represent an individual's preferences by a utility function U, such that the individual prefers x to x' if and only if $U(x) \geq U(x')$, where x and x' are two different consumption plans. Under some regularity conditions, a preference relation can always be represented this way.[3]

When the number of states is very large, the consumption plan x is a vector of large dimension and the function U will be difficult to analyze. It would be convenient if there existed a function u that

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[3] See Huang and Litzenberger, pp.5-6,31, for a discussion on how to prove this point and additional conditions required.

allowed comparison among consumption plans that are certain and a probability P that gave the relative likelihood of states of nature such that the preference relation can be represented by expected utility.

A consumption plan is certain if the number of units of consumption does not vary across different states of nature. Not all preference relations have an expected utility representation. In general, there are two approaches for a preference relation to have an expected utility representation, depending on whether one treats the probabilities of the states of nature as objective or subjective. The former approach was introduced by von Neumann and Morgenstern (1953) and the resulting function u is thus called the von Neumann-Morgenstern utility function. The latter approach was taken by Savage (1972), who views probability assessments as part of an investor's preferences and thus purely subjective. In this analysis the distinction is not made and the function u defined on sure things is always a von Neumann-Morgenstern utility function.

In dealing with economies under uncertainty, it is important to characterize an individual's behavior when he is facing risk. An individual is said to be **risk averse** if he is unwilling to accept or is indifferent to any actuarially fair gamble. A gamble is **actuarially fair** if its expected payoff is zero. An individual is said to be strictly risk averse if he is unwilling to accept any actuarially fair gamble.

Consider the gamble that has a positive return, h_1, with probability p and a negative return, h_2, with probability $(1-p)$. The gamble is actuarially fair if

$$ph_1 + (1 - p)h_2 = 0 \tag{2.2}$$

Let $u(\cdot)$ be the utility function of an individual. Risk aversion requires

$$u(W_0) \geq p\ u(W_0 + h_1) + (1 - p)\ u(W_0 + h_2), \tag{2.3}$$

Where: W_0 denotes the individual's initial wealth.

Similarly, strict risk aversion requires

$$u(W_0) > p\ u(W_0 + h_1) + (1 - p)\ u(W_0 + h_2), \tag{2.4}$$

It can be shown that risk aversion implies a concave utility function and that strict risk aversion implies a strictly concave utility function. Similarly, a concave utility function implies risk aversion and a strictly concave utility function implies strict risk aversion.

Risk aversion can be measured by the coefficient of absolute risk aversion defined by Arrow (1970) and Pratt (1964) as

$$R_A(z) = -u''(z)/u'(z) \tag{2.5}$$

The coefficient is not dimensionless, it depends on the level of income or wealth, z, and on the units in which income is measured. The higher an individual's absolute risk aversion, the higher the minimum risk premium required to induce full investment in a risky asset. Intuitively, the curvature of an individual's utility function would be related to the minimum risk premium required to induce full investment on the risky asset. The absolute risk aversion is a measure of the curvature of an individual's utility function.

The Arrow-Pratt coefficient of relative risk aversion is defined as

$$R_R(z) = -z[u''(z)/u'(z)], \tag{2.6}$$

it is the elasticity of the marginal utility of income. As an elasticity $R_R(z)$ it is dimensionless but it is still valued at a particular level of income. The relation between the two measures is

$$R_R(z) = zR_A(z) \tag{2.7}$$

A single utility function can display different coefficients of risk aversion over different parts of its domain. Arrow (1970) showed that constant absolute risk aversion over the entire domain of $R_A(\cdot)$ implies that the individual's demand for the risky asset is invariant with respect to his initial level of wealth.

Several special utility functions are frequently used because of their mathematical tractability and their risk properties. The logarithmic utility function is a special case of a class of utility functions which have constant relative risk aversion. The logarithmic function is written as

$$u(z) = \log z. \tag{2.8}$$

For this function $R_A(z) = 1/z$ and $R_R(z) = 1$, thus the level of absolute risk aversion is a decreasing function of income and the measure of relative risk aversion indicates a unit elasticity of marginal utility which is constant over all levels of income.

The negative exponential utility function exhibits constant absolute risk aversion. The exponential utility function is written as

$$u(z) = -e^{-bz}, \quad b \geq 0. \tag{2.9}$$

The absolute risk aversion measure is simply b and the relative risk aversion measure is zb. Thus the level of absolute risk aversion is independent of the level of wealth and the level of relative risk aversion is an increasing function of the level of initial wealth.

A quadratic utility function is useful in that expected utility can always be expressed in terms of the first two moments of the risky attribute's distribution for a given action choice. The function can be expressed as

$$u(z) = z - (b/2)z^2, \qquad b > 0; \tag{2.10}$$

For the marginal utility to be non-negative, z has to be less than $1/b$. The quadratic utility function displays increasing absolute risk aversion:

$$R_A(z) = b/(1-bz), \qquad \partial R_A(z)/\partial z = b^2/(1-bz)^2 > 0.$$

Thus, a quadratic function implies that the risky asset is an inferior good.

Higher order polynomials, such as the cubic function exhibit results analogous to the quadratic utility function and by application of Taylor's theorem can be useful in describing the preferences of an individual in terms of the moments of the underlying distribution. The k-th order polynomial utility function can be represented by the first k

moments of the underlying distribution of the utility function's attribute.

The power utility function,

$$u(z) = z^x \quad \forall\ 0 < x < 1, \tag{2.11}$$

exhibits constant relative risk aversion and decreasing absolute risk aversion:

$$R_A(z) = (x\text{-}1)/z\ ; \qquad R_R(z) = x\text{-}1.$$

E. MEAN-VARIANCE APPROACH

The Mean-Variance (MV) efficient set is defined as the choices that provide minimum variance for alternative levels of expected returns. The efficient set is considered to contain the preferred choice for a well-defined set of investors.

Robison and Barry summarize the conditions under which the MV approach is justified:[4] (1) quadratic utility function, (2) a concave utility function and a normally distributed random attribute, (3) choices involving a single random variable, and (4) choices involving linear combinations of the random variable. These conditions have been identified only as sufficient.

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[4] It has been shown by Tobin (1958), Samuelson (1970), and Meyer (1987) that each one of the conditions is sufficient for a MV representation of the expected utility function to be consistent with the expected utility hypothesis.

Quadratic utility is a very restrictive assumption since it implies that marginal utility becomes negative beyond some level of monetary outcome and that the investor being modeled has increasing absolute risk aversion. Other shortcomings of conditions underlying the MV approach have also contributed to make its justification in empirical analysis dependent on its ability to approximate results obtained with the more general Expected Utility (EU) framework. In this direction, Porter showed that MV sets of randomly constructed stock portfolios were consistent with the EU models. Tsiang indicated that various restrictions on skewness could yield a close correspondence between the MV and EU results. Levy and Markowitz exhibited similar effects of MV models as a useful method for portfolio selection. Further, the appropriateness of quadratic utility has been defended as a second-order Taylor series approximation to all risk-averse utility functions (Robison and Barry).

However, the tractability of the quadratic utility function is a desirable property. A quadratic utility function produces linear demand functions and the expected utility function can be expressed in terms of the first two moments of the underlying attribute's distribution. Most studies have viewed the assumption of a quadratic utility function as unreasonable and thus have tended to rely on the condition that the utility function is concave and the attribute is normally distributed.

The negative exponential utility function with a normally distributed attribute will yield the standard linear MV model as it is found in many studies. This common approach typically involves the following objective function:

$$\underset{x}{Max}\ u = \mu_y - (\frac{\lambda}{2})\sigma_y^2 \tag{2.12}$$

Where: μ_y - expected value of end-of-period income;
λ - Arrow-Pratt measure of absolute risk aversion;
σ_y^2 - variance of end-of-period income;
x - vector of choice variables.

The following are sufficient conditions of the model:

1. Utility is negative exponential:

$$u(y) = a - be^{-\lambda y}, \quad b \geq 0. \tag{2.13}$$

2. Income, y, is normally distributed with mean μ_y and variance σ_y^2.

The negative exponential utility function exhibits constant absolute risk aversion defined by λ, and increasing relative risk aversion. The tractability of the analytical results and their computational properties have made the standard MV model popular.

CHAPTER III.

COFFEE IN COSTA RICA

This chapter focuses exclusively on the Costa Rican coffee subsector. An introduction to the world coffee economy is useful to understand the sets of opportunities that Costa Rican market participants face and is included as an Appendix. The second part of the chapter deals with different price risk management alternatives that Costa Rican industry participants could use.

A. THE COSTA RICAN COFFEE SUBSECTOR

1. Importance

"Coffee has changed several times the destiny of the Costa Rican society, and since more than a century ago it has constituted the key variable of its economy..." (Stone). Coffee has been the single most important economic activity in Costa Rica for over a century. Coffee has played a leading role in the Costa Rican economy and is still a major source of export earnings for the country; revenue from coffee exports accounted for 21% of total Costa Rican exports in 1989.

Between 1957 and 1989 the share of coffee as a percentage of the Gross Agricultural Product of Costa Rica ranged from 13.5 to 32.7%. The figure for 1989 was 19.3%. In that year bananas was the highest contributor to the Gross Agricultural Product. Coffee contributes on the average 4.8% of the Gross National Product (Bornemisza). Table 2 shows Gross Agricultural Product percentages for the main agricultural activities from 1983 to 1989.

2. Historical Background

Any attempt to understand the dynamics of the Costa Rican coffee sector should take into account the role this crop has played in the Costa Rican society since the second half of the nineteenth century.

TABLE 2. GROSS AGRICULTURAL PRODUCT SHARES FOR COSTA RICA

	1983	1984	1985	1986	1987	1988	1989
Coffee	18.2%	20.7%	21.1%	28.8%	21.8%	23.9%	19.3%
Bananas	25.0	23.3	20.4	17.8	20.3	20.5	22.3
Sugar Cane	5.7	5.1	4.8	4.0	3.7	3.7	4.0
Cocoa	0.4	0.9	0.8	0.5	0.5	0.5	0.3
Rice	6.7	5.3	4.6	3.6	2.9	3.4	3.5
Corn	2.5	2.2	2.6	2.5	2.0	1.4	1.1
Beans	1.1	1.4	1.4	1.7	1.6	0.9	1.1
Sorghum	0.9	0.9	1.1	0.7	0.4	0.1	0.1
Cotton	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Cattle	8.7	8.9	8.0	7.2	8.7	8.5	7.8
Milk	9.8	9.0	9.9	8.3	9.4	8.8	8.8
Other	20.8	22.1	25.1	24.8	28.6	28.2	31.6
TOTAL	100%	100%	100%	100%	100%	100%	100%

Source: ICAFE

The first coffee seeds were introduced to the country in 1779 (Jiménez). In 1832 the first coffee export, to Chile, took place (Stone). Coffee rapidly became the greatest cash generating activity in the country. Coffee production created a strong socioeconomic class, dedicated to milling and exporting the commodity, farming their own land and buying from many small producers. This financially strong class eventually acquired political power (Facio). With the introduction of banana plantations in the late nineteenth century the relative importance of coffee decreased.

Until 1930 the coffee activity was carried out with little or no State intervention. This situation would change in response to the world crisis of 1929, when low coffee prices severely affected small Costa Rican producers. As a result, an Act (Ley No. 171, 8/17/33) was promulgated, establishing State regulation on all economic relations between coffee farmers and millers. This modified coffee marketing in Costa Rica radically. Thus the current system can be traced back to 1933, when the basic foundations of the coffee system as Costa Ricans know it today were established.

In 1933, like nowadays, Costa Rican farmers sold their cherry coffee to millers (as opposed to Colombian farmers for instance, who generally take care of the first processing stage themselves). The 1933 Law established that all cherry sales to millers were subject to a later price settlement and that the State would be in charge of determining that settlement price. This mechanism still prevails.

The framework for the current system is a 1965 Act patterned after the previous 1933 Act. "On the spot" coffee sales from growers to millers are therefore outlawed. The settlement price takes into account the export and domestic prices actually received, the miller's manufacturing costs, taxes, and a maximum profit margin allowed to the miller.

3. Production

Costa Rica contains a tremendous variety of climates and ecological systems despite its small size. Almost all of the coffee produced is Arabica and belongs to the Other Milds group. Coffee is mainly grown in the Central Highlands at altitudes between 600 and 1500 m where average temperatures range from 16 to 20°C. The volcanic soils, the temperate highland climate and a rainfall pattern of 1500 - 2500 mm per annum, constitute extremely favorable conditions for coffee growing. These ideal conditions allow Costa Rica to produce some of the highest quality coffee in the world. The crop is harvested mainly from November to February, the official crop year starts on October 1. Costa Rican coffee is classified into eight types according to production zones as characterized in Table 3.

During the last three decades coffee production has experienced significant technological developments. Improved cultural practices together with new high-yielding varieties and "modern" inputs like herbicides, fertilizers and fungicides have placed the Costa Rican coffee sector as the worldwide leader in productivity (Jaramillo). From 1960 to 1988 the area under cultivation expanded by 56% whereas production kept growing at a healthy 3.5% per year for a total increase of 190%.

TABLE 3. CLASSIFICATION OF COFFEE AREAS AND COFFEE BEANS IN COSTA RICA.

TYPE OF COFFEE BEAN (SYMBOL)	Altitude (m)	Rainfall (mm)	Days with rainfall	Temperature (°C)	Sunshine (h/yr)
Strictly Hard (SHB)	1200-1650	2500	155	19	2150
Good Hard (GHB)	1000-1200	2250	160	21.5	2200
Hard Bean (HB)	800-1200	2500	158	22	2100
Medium Hard (MHB)	400-1200	3500	185	22	1800
High Grown Atlantic (HGA)	900-1200	2750	210	20.5	1700
Medium Grown Atlantic (MGA)	600- 900	2900	245	22	1630
Low Grown Atlantic (LGA)	300- 600	4000	245	24.5	1550
Pacific (P)	300-1000	2250	145	24	2400

Source: ICAFE.

The technological improvements have not involved mechanization. The sloping nature of the terrain where most coffee is produced has kept any mechanization efforts unfeasible. Some farmers have introduced irrigation systems in their farms, but their use is not widespread.

As a perennial crop coffee requires long run investment in production capacity. The modern varieties have an economic life of some 15 years. During the first years the trees produce little, then production capacity expands until the trees approach maturity. Yields eventually decline in later years. This pattern makes investment decisions risky, since long run prices in coffee are uncertain at the time when the capital is committed.

Disinvestment decisions are likewise risky and expensive. Although farmers can decide to lower the level of variable inputs, the only disinvestment decision is to uproot the trees and grow something else. The risk of an improvement in coffee prices and the inherent risk of the new crop contribute to hinder most farmers from making such a radical decision.

4. Participants

The coffee marketing system in Costa Rica has four main groups of participants and a regulatory agency. **Farmers** deliver their coffee to **millers** who in turn sell their coffee to **exporters** or to **local roasting firms**. The process is regulated through the Instituto Costarricense del Café (ICAFE). There is control over pricing mechanisms and marketing margins.

ICAFE has the responsibility of overseeing the relationships among producers, processors and exporters. The organization was created with three goals:

a) To provide an equitable system of relations among the different sectors participating in the coffee industry, this action is to be coordinated with other governmental entities;

b) To promote, in collaboration with other government and private entities, the development of the coffee industry in all its stages, as well as the agricultural diversification of the country; and

c) To formulate and suggest to the government those policies that should be implemented in the coffee sector, representing the interests of the coffee industry at the national and international levels.

ICAFE is governed by a Board of Directors, seven in total, nominated every four years and who represent the different parties involved in the industry. Three of the directors are representatives of the coffee producers. The rest of the parties have one representative each, - i.e. millers, exporters, national roasters, and the Ministry of Economy and Commerce. The Board of Directors nominates a technical board, the "Junta de Liquidaciones", a liquidations board in charge of the price settlements. The Board of Directors also fixes the amount to be retained for domestic consumption (normally between 10 and 13% of total production). The domestic price is considerably lower than the international price. The same Board used to fix the proportion of exports to non-ICO members when the International Coffee Agreement was in place, this was done to fulfill export-quota regulations under ICA.

Coffee in Costa Rica is produced by more than 100,000 farmers (ICAFE), the production structure of the crop is shown in Table 4. It is worth noting the predominance of small farms, 37.5% of the total production comes from farms of less than 10 ha which cover 40.9% of the total coffee area.

TABLE 4. PROPORTIONAL DISTRIBUTION BY FARM SIZE IN 1984.			
FARM SIZE	PERCENT	AREA	OUTPUT
Less than 2 ha	41.5%	9.8%	9.3%
From 2 to less than 10 ha	38.0%	31.1%	28.2%
From 10 to less than 50 ha	16.5%	27.8%	26.5%
From 50 to less than 200 ha	3.5%	17.7%	20.6%
Greater than 200 ha	0.6%	13.6%	15.4%
TOTAL	100%	100%	100%
SOURCE: MEIC (1987) in Jaramillo (12).			

All processing of coffee in Costa Rica takes place in 103 processing mills called "beneficios", which carry out activities such as depulping, fermenting, drying, curing and bagging. Approximately 35% of the millers are organized as farmers' cooperatives.

The economic relations between farmers and millers are all regulated by law. Each "beneficio" has a number of collecting stations called "recibidores" spread throughout the countryside where producers have to deliver their cherry coffee within 24 hours after harvest. The 24 hour regulation is aimed at preserving the quality of the coffee, since some undesirable fermentation processes start if the coffee remained longer in its cherry state.[5]

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[5] From an economic point of view the 24 hour regulation poses an interesting question. If farmers are obliged to deliver their coffee in such amount of time, their possibilities for selling to several millers are reduced, then at least there is the potential for some monopsonistic conditions to take place. Farmers, especially in the more retired regions, might have only one or two millers as feasible buyers.

There are about 27 coffee exporters in the country. FEDECOOP, a federation of all the cooperative mills, is the biggest exporter. It exports about 40% of the total for the country.

5. Marketing, Pricing and Risk Distribution within the System

A snapshot of the commodity flow can now be presented. The producer delivers his cherry coffee to a miller at any of the several delivery stations built by the miller in the countryside. After remitting a certain amount to the Instituto del Café for domestic consumption, the millers sell the coffee either directly to foreign markets or to an exporter who in turn will sell the coffee to the foreign client. The quantity reserved for domestic consumption is sold through auctions, either directly to local roasting firms or indirectly through traders. Roasting firms brand the product and sell it through retailers to consumers. The flow is captured in Figure 1, which illustrates these marketing channels.

The pricing process is more complex than just settling on a minimum price for growers. The system requires that the farmer get paid an initial advance that works as a floor price when he delivers his coffee to the processor, and at the end of March and of June, he will receive partial advancements for the coffee already sold by the mill. The settlement price is established at the end of the crop year (September 30). The Junta de Liquidaciones intervenes in the final price settlements and minimum advances. In order to determine the minimum advances, the Junta de Liquidaciones carries out cost studies at

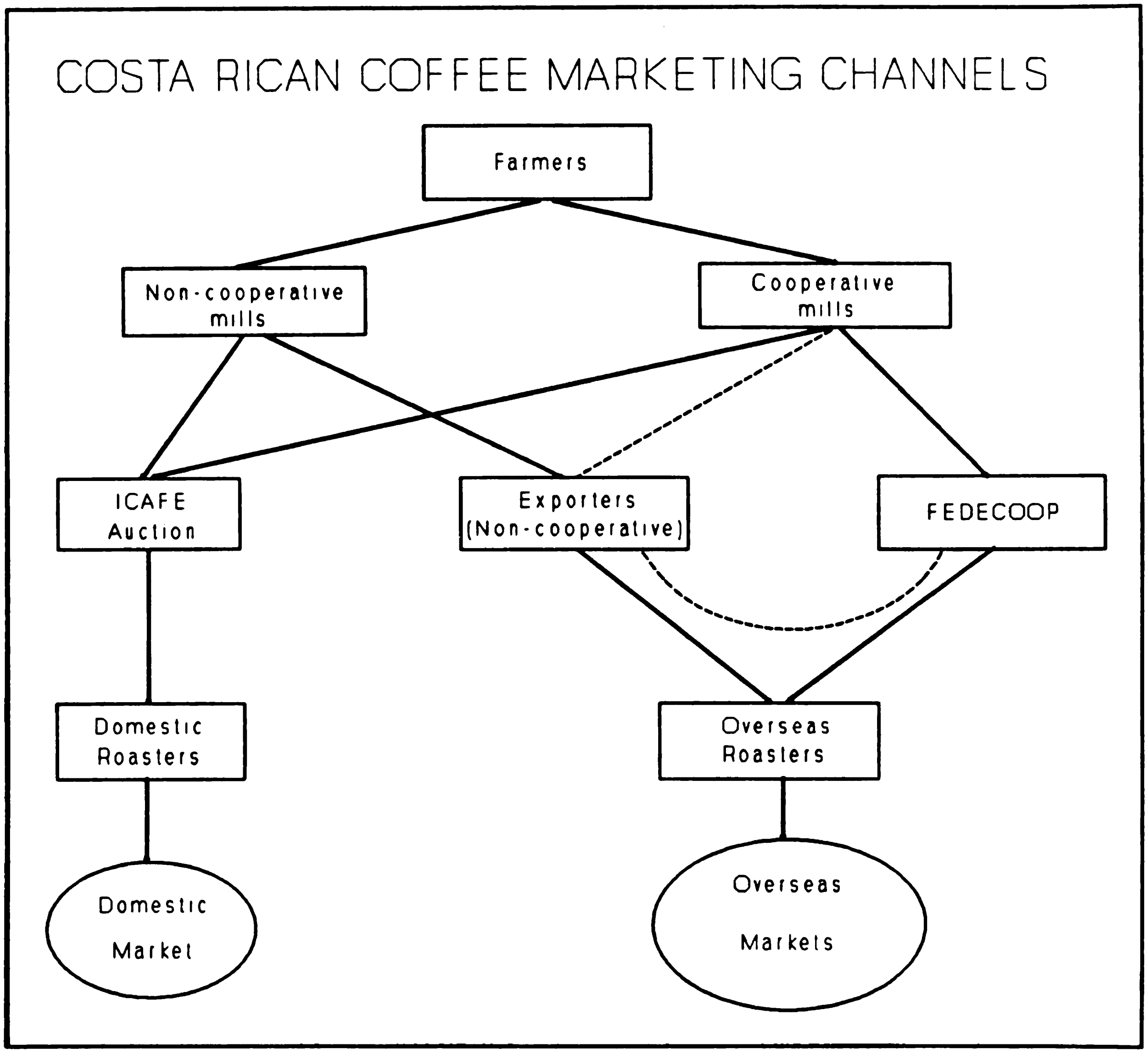

Figure 1. Marketing Channels for coffee in Costa Rica.

different levels in the marketing chain. The initial advance should at least cover the costs of harvest, the most labor-intensive task in coffee.

Each mill has its own pool prices that depend on the prices the mill was able to obtain from selling to exporters and roasters. This mechanism generates competition among mills to attract growers by offering higher initial advances and by trying to achieve higher final prices.

The **precio rieles**, the price that is negotiated between the mill and the exporter, is not subject to direct control by ICAFE. This price is for coffee Free-On-Rail, deposited at the railway station from where it will be transported to the export shipping point. Once this price is negotiated, the margin to the mill (i.e. the difference between the precio rieles and the producer price) is controlled by the formula (Myers, 1990):

$$P_{pT} = e_T r_T - C_m - \alpha(e_T r_T - C_m) - T_p \tag{3.1}$$

Where:

- P_{pT} = producer price used to calculate the grower's final pooled price;
- r_T = price received by a processing mill, i.e. **precio rieles**, at time T quoted in U.S. dollars;
- C_m = per unit processing costs for the mill;
- T_p = production tax per quantity unit (currently zero); and
- α = fixed return to the mill (currently α = .09 or 9%); and
- e_T = exchange rate at time T (Colones/US dollar).

The final price growers receive at the end of the year is an average of all producer prices obtained by the mill throughout the year. The mill must pay all of its growers the same price for coffee of similar quality. Processing costs are calculated by ICAFE and generally differ by region and by mill.

The relationship between prices received by exporters and those paid to the mills can be calculated (Myers, 1990) by:

$$e_t r_t = e_T p_T - C_x - \beta(e_T p_T - C_x) - e_T T_x \quad (3.2)$$

Where:
C_x = per unit cost to the exporter in colones;
p_T = FOB price received by the exporter in U.S. dollars.
β = return to the exporter;
T_x = export tax revenue in US dollars (currently 1%, T_x=.01p_T).

ICAFE carries out detailed cost studies for mills in order to ensure that their return does not exceed the 9% limit. The maximum return allowed to exporters is 2.5%, ICAFE acknowledges $1.65/100lb as the average exporting cost.

This pricing mechanism shifts a substantial amount of risk towards the producer; the risk borne by millers and processors is more limited than that borne by farmers (Bornemisza 1986, Jaramillo 1989, Myers 1990). The initial advance works as a floor price. If the calculated final price to growers is lower than the initial advance, millers will take the loss. In reality, however, the floor price is so low that it has only a minimal impact on the probability distribution of the grower's returns without the initial advance. That is, the probability that the initial advance may end up being greater than the calculated final price is very low. Therefore, farmers lack an effective hedging tool against risks arising from short term price fluctuations.

The low initial advances offered to growers have another drawback. Growers have to make investment decisions on the next crop even before they know the final price they will receive on the current harvest. This increased uncertainty may reduce the efficiency of resource allocation decisions.

The returns to the mill can be represented as follows (Myers, 1990):

$$R_m(t,T) = \alpha(e_T r_T - C_m) - i_t A_t \tag{3.3}$$

Where: $R_m(t,T)$ = return to the mill at time T per unit of output for coffee delivered at time t, (t = T-1);
i_t = interest rate on borrowed funds;
A_t = initial advance to growers at time t and

That is, there is very limited risk to the mill since the initial advance is always lower than the final price. Assuming that the initial advance paid by the mill is raised so that it becomes an effective floor price, relationship (3.3) becomes:

$$R_m(t,T) = \alpha(e_T r_T - C_m) - i_t A_t - \max(0,\ A_t - P_{pT}) \tag{3.4}$$

If the realized producer price is greater or equal to the initial advance ($P_{pT} \geq A_t$), (3.4) reduces to (3.3). However, if the initial advance is greater than the final price, then the mill would take an additional loss of $A_t - P_{pT}$.

B. RISK MANAGEMENT ALTERNATIVES

This section describes the different sets of opportunities that Costa Rican market participants face in dealing with the risk of coffee price fluctuations.

1. Millers' situation

Millers face very limited risk from price fluctuations. The current market mechanism fixes their margin effectively protecting millers from most of the adverse impact of low prices. On average millers receive a 9% marketing margin. If prices are low, they will get a 9% of the difference between that lower amount and their cost. It is as if they could adjust the cost of their most important input, unprocessed coffee, according to the price they are able to obtain from their product.

In the next section a strategy that could provide risk protection to farmers and in which millers would participate will be discussed. It is included in the farmer's section because the most important innovation would be added price risk protection available to farmers.

2. Farmers

Farmers' objectives include profit maximization, itself a function of quantity, price and costs. In addition, risk reduction may also be present as an objective. This is the case because it is reasonable to expect some degree of risk aversion among coffee farmers. Empirical measurements of risk aversion on Costa Rican farmers have not been conducted. However, results from most studies that have tried to measure risk aversion among farmers support various degrees of risk aversion.[6] For Costa Rican coffee farmers, a lower level of price risk would

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[6] See Hanson, p. 32-35, for a review of empirical studies on farmers' attitudes towards risk.

improve the signaling function of prices and may eventually result in better allocation decisions.

Once farmers deliver their coffee to the collecting stations of the miller, they do not have access to any risk management decisions, yet they are still subject to substantial price risk. They have "sold"[7] their coffee at an uncertain price. At that point they are at the mercy of the marketing decisions of the miller. To the extent that the incentives the miller faces converge with the farmer's objectives the latter can rest assured that the miller's efforts will help accomplish the producer's objectives, depending on the miller's marketing skills.

The only current mechanism that alleviates the impact of coffee price fluctuations in this situation is the taxation system. Production and export tax rates vary according to the coffee price levels. The lower the world price, the lower the tax rate. The lowest production tax rate reaches zero percent as has happened since the break up of the ICA.

In dealing with price risks before farmers deliver their coffee, the only variable they can control is the choice of miller. In theory, they could hedge even if the coffee is stored by the mill by taking short positions in the futures markets, then offsetting those positions when the miller sells their coffee. However, transactions costs and

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[7] Technically it is not a sale, the coffee belongs to the farmer until the miller sells it to an exporter.

information requirements make it difficult for small and medium farmers to trade futures in a foreign exchange.

Quality is not perceived as a variable farmers could use to reduce risk. The current mechanism only discriminates one aspect of quality, the percentage of green coffee cherries. Beyond that, all farmers who deliver to the same mill will receive the same price. If all farmers agreed on improving cultural practices to improve quality, then the mill might be able to get better prices. However, in this situation any farmer faces the incentive of reducing costs at the expense of quality and become a "free rider", benefitting from the better prices without being penalized.

An increase in the initial advance becomes an effective hedging mechanism for farmers when the probability of the initial advance being greater than the final pooled price becomes significant. However, this is not an alternative farmers could force from millers. And millers will not be willing to bear the increased risk that is being directly shifted to them by such a strategy. Furthermore, millers actually borrow from farmers the portion of the commodity whose value is excluded from the initial advance, at no interest. The current situation creates an implicit market for borrowing coffee without incurring financing charges. Millers do not have reason to give up this advantage.

Nevertheless, higher competition among millers increases the likelihood of higher initial advances. In general a higher level of competition for throughput will increase the incentive of millers for making marketing decisions that are beneficial to farmers. Reportedly, there is some competition of this type among millers, as evidenced by the over-the-minimum advances that millers commonly offer. However, rarely has a miller paid an initial advance that is higher than the final pooled price.[8] Also, in the central highlands there is more competition than in the more retired rural areas. The traditional coffee areas, the central highlands, comprise 90% of all the millers (Rodríguez) and have the best transportation infrastructure. In some of the more retired coffee areas, however, farmers only have one or two alternative mills they can deliver their crop to. Besides, recently picked coffee cherries cannot be stored by farmers. With the intent to preserve the quality of the coffee farmers are required by law to deliver the cherries to any collecting station within 24 hours after harvest. This reduces the number of potential buyers.

Another consideration is that apparent competition among millers is mostly based on the final pooled price the mill is able to pay its farmers at the end of the year (Bornemisza, p.28). Thus it is in the best interest of millers to apply the latest exchange rate to its sales in order to obtain a higher pooled price in colones.[9] If the miller

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[8] There have been cases of cooperatives incurring losses of this type in some years.

[9] In Costa Rica, the government has enacted a policy of mini-devaluations, by which at least twice a month the Central Bank approves a small devaluation usually in the range of 0.25 to 0.50%. This means the colón has been devaluating at a rate ranging from 15 to 25% a year with respect to the dollar for the last four years.

paid a higher initial advance, the law would require him to register that amount at the prevailing exchange rate, lowering on average the pooled price in colones for the sake of a higher initial payment. It is not clear how farmers would weigh a higher initial advance against a (nominally) lower final pooled price. Then, it is not clear how much more throughput the miller would attract as a result of such a strategy, and whether or not these increments in quantity would offset his increased financial costs and risks.

Nonetheless, if a miller thinks a higher initial advance would improve substantially his competitiveness, the following risk management alternative could be followed (Myers). Suppose a miller receives coffee at time t to be sold to an exporter at date T. The miller could hedge the risk shifted to him by a high initial advance by buying put options at t with maturity at T or at a posterior date close to T. Since the options are written on futures, if the price of coffee futures at T turns out to be lower than the strike price, the mill will exercise the put, selling at the strike price and buying futures back at the lower price. If the price of futures at T is equal or greater than the strike price, the put is worthless and is not exercised.

According to this mechanism, if prices move unfavorably for the miller to the point where the final pooled price turns out to be lower than the high initial advance, the puts would provide downside risk protection. The strategy relies on the estimation of the relationship between the futures price and the producer price, the latter being a function of the precio rieles. On the other hand if prices move favorably, the puts expire worthless and the mill would still benefit from a rising market. The problem is reduced to finding values for the strike price and the ratio of puts to coffee that need to be bought. The extra costs involved in such a strategy are the higher financial expenses associated with higher initial advances and the cost of the options, that is, the option premiums.

Cooperatives' objectives seem to be more in line with a strategy involving higher initial advances while at the same time buying put options. Cooperatives could do two things. First, they could try to test if this type of strategy is in reality desired by the farmers. Market imperfections might make the strategy unattractive for farmers. Capital markets might be poorly developed and farmers' investment opportunities might be limited. Secondly, given that the final pooled price is a miller's most quoted performance criterion, cooperatives (FEDECOOP) or ICAFE could quote a final pooled price in constant colones that accounts for the depreciation of the col6n throughout the year.

Higher initial advances closer to the true value of the product at the time it is delivered are desirable because: a) they would give farmers, who are the participants that bear most of the risk from short term price fluctuations, protection against such risk; b) they would improve the signaling function of prices; and c) they would be a better decision input for farmers' allocation of resources. If the market imperfections discussed above are not substantial, this strategy seems consistent with the objectives of a miller who wants to become more competitive.

Other strategies to deal with risk involve vertical integration and strategic alliances with millers and exporters. The potential for some of these strategies is discussed at the end of this section. Crop diversification is another long-term alternative, that the government has long tried to encourage, with very limited results, in part due to the lack of cropping alternatives with an expected payoff close to that of coffee. Beans have proved a successful complement when grown as a secondary crop inside the coffee fields.

Finally, some have proposed the creation of buffer funds that could be collected either by the government or by cooperatives in times of high prices, to be used to help farmers in times of low prices. Cooperatives could implement such a strategy in a voluntary basis. However, with the current world price levels it is unlikely that farmers would be willing to think of saving part of their income.

In summary, unless a major change in the coffee marketing system takes place, Costa Rican coffee farmers acting independently will not have ready access to tools for price risk management besides the current marketing regulations and the choice of miller. The current marketing mechanisms do not offer strong protection for the farmer because the probability that the initial advance ends up being greater than the final price is very low. The choice of miller might be very limited in some of the more retired coffee areas where millers are spread out and roads are bad.

However, the current system is perceived to work well. One explanation is that the government might have some kind of social contract with coffee farmers such that it will help them whenever the international market conditions look bleak. In the past, the government has changed legislation and offered subsidized credit and other benefits to coffee producers in times of low prices like those after the break up of the ICA in July 1989. This is evidence suggesting that Costa Rican coffee farmers are somewhat protected against the risk of very low coffee prices.

3. Alternatives for Exporters

The first two cases discussed in this section will be the subject of the empirical research in the following chapters. Exporters buy from mills and sell on the spot market through export contracts. A futures hedging strategy for exporters might proceed as follows.

In the first case a mill wants to sell processed coffee at time t to an exporter who does not yet have an overseas buyer lined up. The exporter buys at time t to sell at date T. Thus he bears the risk of price changes between t and T, normally a lag of less than two months. The hedging strategy in this case would involve selling futures contracts in the New York Exchange maturing at time T or at a posterior date close to T. Basis risk would still be present. The exporter is normally able to pass on the exchange rate risk to the mill by quoting the precio rieles in U.S. dollars.

A second case arises when an exporter has an overseas buyer at time t, for coffee deliverable at T, and mills do not have coffee available until time T. In this case, the exporter, who is short in the spot market could take a long position in the futures market at date t with the idea of lifting the hedge at time T. The next chapter develops optimal decision rules stemming from Mean-Variance Models for these two cases. Exporters could use options contracts as well, and more complex strategies involving mixes of futures and options could also be devised.

A third situation arises when an exporter engages in basis contracts, an acceptable practice in the trade. Basis contracts offer a forward pricing mechanism that ties the localized cash price to the futures price plus or minus a specified amount. For instance, in a situation similar to that of the first case, an exporter buys from the miller at time t coffee that will be exported at T. The exporter could sell his coffee at t through a contract for future delivery at an FOB Limón price equal to the New York C futures price of the contract nearest to T minus, say, $8.00. The exporter is still subject to the risk of fluctuations in the futures price, but he has effectively eliminated any basis risk. In this way basis contracts provide their own hedging mechanism. Yet if the exporter wanted to eliminate all price risk, he could take a short futures position at t deliverable at T equivalent to the cash position. In this way, if the futures price rises, his losses in futures are exactly matched by his gains in the cash market. Likewise, if the futures price drops, his losses in the cash market will be offset by gains in the futures market.

4. Vertical Integration and Strategic Alliances

The last type of strategies discussed involve all categories of market participants. These strategies are not exclusively risk management strategies, but they can certainly provide protection against the risk of short term price fluctuations. Some of these strategies are long-term in nature, others can be implemented in the short run.

Vertical integration could be used to reduced the risk farmers face. The Costa Rican coffee subsector has already experienced two types of vertical integration, namely, that of the cooperative movement and non-cooperative integration. Coffee cooperatives, owned by farmers, are millers and have organized themselves as members of a national federation of cooperatives, FEDECOOP. Although from an ownership point of view cooperatives represent vertical integration, a farmer is currently exposed to approximately the same level of price risk whether or not he belongs to a cooperative, since the same pricing mechanisms apply to cooperative and non-cooperative mills.

About 50% of the millers have their own plantations, although only 4% of the coffee processed by all millers comes from their own farms (Rodríguez). Also, about 50% of the exporters own mills. Several of the more important exporters are partially owned by international companies.

This phenomenon has increased in the last years (Mora, Ledezma and Cubero).

The break up of the ICA has improved the importers' access to coffee from specific origins. The limited access to certain origins of arabicas was a major concern of consuming countries under ICA (Pieterse). It is now more feasible for a specialty coffee importer to have continuous access to a certain origin because quotas are not being allocated by the ICA. As a result, the potential for closer relationships between producers of high quality coffees and importers has increased. These alliances may or may not involve vertical integration.

Recently, for instance, a Costa Rican exporter created an innovation in the marketing system by guaranteeing the producers of a cooperative mill a precio rieles that at least provided a final pooled price as high as the highest paid to farmers in the region if they agreed to sell the whole crop to him. The farmers from this cooperative received the proposal enthusiastically because they used to get lower prices than farmers from other cooperative mills in the region. The exporter wanted guaranteed access to that type of coffee he knows can be sold to a specialty coffee importer in San Francisco at a premium price. In this way the exporter was willing to bear more price risk than otherwise. The producers of high quality coffees increase their bargaining power as demand becomes more segmented according to quality in the consuming countries.

Coffee roasters and retailers in the consuming countries could also play an important role in order to improve information at the consumer level. Arabica coffees produced in different countries have been compared to wines in the way they vary in their aroma and taste (Wrigley). However, consumers are often unaware of coffee quality differences.

The lack of information at the consumer level was pointed out by Wrigley in the following terms, "it must be the only food product sold today where the buyer has no idea what he is purchasing". This lack of information used to favor the coffee houses in the consuming countries as they kept rich supplies of inexpensive coffees to use in their blends. The ICA hampered their ability and incentive to keep consistent high quality blends because it was difficult to have continued access to certain origins. The ICA increased the roaster's risk of not being able to deliver a consistent product to the consumer. There is evidence that manufactures are turning to specialty coffees because they offer growth opportunities and higher profit margins (Restaurant Hospitality, 1987). The role of importers and foreign roasters as educators and information deliverers increases the potential for closer relationships with Costa Rican market participants as the demand becomes more segmented and the consumer develops a taste for specific origins.

There is a range of possibilities to achieve increased coordination in the value added chain, some involving more internalization of functions and some less. There is evidence suggesting that vertical integration in the Costa Rican coffee subsector is on the rise. Other strategies

involving looser forms of strategic alliances like contractual agreements could potentially help small farmers of high quality regions to manage price risks and to market their crops in general.

CHAPTER IV.

A HEDGING MODEL FOR COSTA RICAN COFFEE EXPORTERS

This chapter outlines the specific model for exporters that will be the subject of the empirical research. The results of the empirical research will be presented in Chapter V.

This section develops a standard Mean-Variance model whose objectives are focused on helping Costa Rican coffee exporters with decision rules that could be incorporated as part of their overall coffee trading program. The model derives an Optimal Hedge Ratio for futures trading in the New York Coffee "C" contract. Secondly, the relationship between a basis model and the hedge ratio is explained. The Basis Model which will be estimated in the next chapter accomplishes two objectives. It is a tool that will provide a better understanding of the fluctuations observed in the Costa Rican coffee price basis; and it will serve as a foundation for the implementation of the optimal hedge rules.

As a first case, consider the end of period income Y_T for a Costa Rican exporter who buys coffee from the mill at t and does not have a buyer lined up yet. Thus the coffee will be exported at a future date T. The exporter will hedge the long position in the cash market by selling futures contracts deliverable at T or at a posterior date close to T. At time T he will lift the hedge. Financial costs are not included in order to avoid complexity of the calculations (they can be added with no major effect on the analysis). End of period income is defined as

$$Y_T = (p_T - r_t)Q_t - \varsigma(Q_t) + X_t(f_t - f_T) \tag{4.1}$$

Where:

p_T	-	FOB price at time T in U.S. dollars;
r_t	-	precio rieles paid to the mill at t in U.S. dollars;
Q_t	-	level of commodity stocks;
$\varsigma(Q_t)$	-	cost function in U.S. dollars;
X_t	-	total quantity of contracts sold short in the futures markets (negative if purchases);
f_t	-	futures price at time t in U.S. dollars;
f_T	-	futures price at time T in U.S. dollars.

The exporter is able to pass on the exchange rate risk to the mill. This is reflected in the fact that r_t is quoted in U.S. dollars. The cost function is given in U.S. dollars in order to simplify the notation (a cost function in colones times the exchange rate could be included without affecting the results of the analysis).

Consider then the expected income equation for the exporter when expectations for time T are measured at period t.

$$\mu_y = (\mu_p - r_t)Q_t - \varsigma(Q_t) + X_t\,(f_t - \mu_f) \tag{4.2}$$

Where:

μ_y	-	expectation at t for income to be earned at time T;
μ_p	-	expectation at t for FOB price at time T;
μ_f	-	expectation at t for price of futures at time T.

The MV model now requires:

$$\underset{y}{Max}\ U = \mu_y - \left(\frac{\lambda}{2}\right)\sigma_y^2 \tag{4.3}$$

Where:

λ	-	absolute risk aversion coefficient;
σ_y^2	-	variance of income.

The variance of Y is given by:

$$\sigma_y^2 = Q_t^2\sigma_p^2 - 2Q_tX_t\sigma_{f,p} + X_t^2\sigma_f^2 \qquad (4.4)$$

Where: σ_p^2 = variance of FOB price;
$\sigma_{f,p}$ = covariance between f and p; and
σ_f^2 = variance of futures price.

By making the appropriate substitutions (4.3) turns into:

$$\max_{Q,X} U = Q_t(\mu_p - r_t) - \varsigma(Q_t) + X_t(f_t - \mu_f) - \left(\frac{\lambda}{2}\right)(Q_t^2\sigma_p^2 - 2Q_tX_t\sigma_{f,p} + X_t^2\sigma_f^2) \qquad (4.5)$$

First Order Conditions are:

$$\frac{\partial U}{\partial Q} = \mu_p - r_t - \varsigma' - \lambda Q^*\sigma_p^2 + \lambda X^*\sigma_{f,p} = 0. \qquad (4.6)$$

$$\frac{\partial U}{\partial X} = f_t - \mu_f + \lambda Q^*\sigma_{f,p} - \lambda X^*\sigma_f^2 = 0. \qquad (4.7)$$

Where: Q^* = optimal level of Q;
X^* = optimal level of X;
ς' = $\partial\varsigma(Q)/\partial Q$.

Solving for Q^* and X^* gives the optimal hedge ratio H_1 defined as:

$$H_1 = \frac{X^*}{Q^*} \qquad (4.8)$$

$$H_1 = \frac{(f_t - \mu_f)\sigma_p^2 + (\mu_p - r_t - \varsigma')\sigma_{f,p}}{(f_t - \mu_f)\sigma_{p,f} + (\mu_p - r_t - \varsigma')\sigma_f^2}\ . \qquad (4.9)$$

Therefore, by estimating the variances of the prices in the futures and spot markets and the differences between expected and past futures prices, the optimal hedging rule can be obtained.

Assuming futures market unbiasedness, i.e. $f_t = \mu_f$, the first expression in the numerator and denominator becomes zero, and the hedging rule reduces to:

$$H_1 = \frac{\sigma_{f,p}}{\sigma_f^2} \quad . \tag{4.10}$$

In the second case, a Costa Rican exporter who at time t has an overseas buyer for coffee deliverable at date T is expecting to receive the coffee from the mill also at T. Then the exporter who is short in the spot market takes a long position in futures at time t with the idea of lifting the hedge at T. The end-of-period income for the exporter in this situation is then:

$$Y_T = (p_t - r_T)Q_t - \varsigma(Q_t) + X_t(f_T - f_t) \tag{4.11}$$

Where: $r_T =$ precio rieles to be paid to the mill at T;

Consequently, the expected income is given by:

$$\mu_y = (p_t - \mu_r)Q_t - \varsigma(Q_t) + X_t\ (\mu_f - f_t\ ) \tag{4.12}$$

Where: $\mu_r =$ expectation at t for precio rieles at time T.

And the variance of income is

$$\sigma_y^2 = Q_t^2\sigma_r^2 - 2Q_tX_t\sigma_{f,r} + X_t^2\sigma_f^2 \quad . \tag{4.13}$$

Where: $\sigma_r^2 =$ variance of precio rieles;
$\sigma_{f,r} =$ covariance between futures price and precio rieles.

Under the standard mean variance approach, the decision maker's problem requires:

$$\underset{Q,X}{Max}\ U = Q_t(p_t-\mu_r)-\varsigma(Q_t)+X_t(\mu_f-f_t)-(\frac{\lambda}{2})(Q_t^2\sigma_r^2-2Q_tX_t\sigma_{f,r}+X_t^2\sigma_f^2) \quad (4.14)$$

First Order Conditions are:

$$\frac{\partial U}{\partial Q} = p_t - \mu_r - \varsigma' - \lambda Q^*\sigma_r^2 + \lambda X^*\sigma_{f,r} = 0. \quad (4.15)$$

$$\frac{\partial U}{\partial X} = \mu_f - f_t + \lambda Q^*\sigma_{f,r} - \lambda X^*\sigma_f^2 = 0. \quad (4.16)$$

Solving for the optimal positions X^* and Q^* gives the hedging rule:

$$H_2 = \frac{(\mu_f-f_t)\sigma_r^2 + (p_t-\mu_r-\varsigma')\sigma_{f,r}}{(\mu_f-f_t)\sigma_{r,f} + (p_t-\mu_r-\varsigma')\sigma_f^2} . \quad (4.17)$$

Under the assumption of market unbiasedness, i.e. $f_t = \mu_f$, H_2 reduces to

$$H_2 = \frac{\sigma_{f,r}}{\sigma_f^2} . \quad (4.18)$$

The task of implementing these hedging rules empirically consists of finding appropriate variance and covariance estimators to be used in (4.10) and (4.18). A simplified optimal hedging rule could for (4.10) be obtained from the model (Bond et al, 1987):

$$p_t = \alpha + \beta f_t + \epsilon_t$$

Where: α and β are parameters to be estimated;
ϵ_t is a serially uncorrelated shock.

Running an OLS regression on the slope parameter of this relationship yields a ratio of the unconditional covariance between the dependant and the explanatory variable to the unconditional variance of the explanatory variable. What is required, however, are the variance and covariance conditional upon all available information at time t.

At any point in time, the decision maker's information set will consist of previous futures and cash prices as well as other relevant structural variables. Myers and Thompson have shown how to estimate the required ratio of conditional covariance and variance utilizing a single regression equation. The procedure assumes that the futures and cash price formation processes are similar. If the two processes differ, a two equation simultaneous system is required.

Suppose spot and futures prices are generated by the model:

$$\begin{aligned} p_T &= X_t\alpha + \varepsilon_T \\ f_T &= Z_t\beta + \upsilon_T \end{aligned} \tag{4.19}$$

Where: X_t and Z_t are vectors of variables known at t that help predict p_T and f_T respectively;
ε_T and υ_T are random shocks with zero mean;
α and β are vectors of unknown parameters.

The shocks may be contemporaneously correlated with a constant covariance matrix Ω. In order to implement the optimal hedging rule (4.10) the conditional variances and covariance required are (Myers and Thompson):

$$\sigma_p^2 = \mathrm{var}(\varepsilon_T | X_t, Z_t);$$

$$\sigma_{f,p} = \mathrm{cov}(\varepsilon_T, \upsilon_T | X_t, Z_t);$$

$$\sigma_f^2 = \mathrm{var}(\upsilon_T | X_t, Z_t).$$

If the system of equations is nonlinear, as is the case when moving average terms are included, the system can be estimated by a Maximum Likelihood algorithm. An estimate of the covariance matrix Ω can then be obtained as:

$$\hat{\Omega} = \frac{1}{N}\begin{bmatrix} \hat{\varepsilon}'\hat{\varepsilon} & \hat{\varepsilon}'\hat{\upsilon} \\ \hat{\upsilon}'\hat{\varepsilon} & \hat{\upsilon}'\hat{\upsilon} \end{bmatrix} \tag{4.20}$$

where $\hat{\varepsilon}$ and $\hat{\upsilon}$ are the vectors of residuals from estimating (4.19) via maximum likelihood.

Then, the optimal hedge ratio can be estimated by:

$$H_1 = \frac{\hat{\varepsilon}'\hat{\upsilon}}{\hat{\upsilon}'\hat{\upsilon}} \ . \tag{4.21}$$

In this study in order to arrive at the desired hedge ratio estimation, a model of the price basis will be used. It is now shown how the optimal hedge ratio can be obtained from a basis equation and a futures price equation.

Consider again the hedging rule (4.10) given by:

$$H_1 = \frac{cov(p_T, f_T | X_t, Z_t)}{var(f_T | X_t, Z_t)} \ . \tag{4.22}$$

Now, define the price basis as:

$$b_t = p_t - f_t.$$

Then,

$$H_1 = \frac{cov(b_T + f_T, f_T | X_t, Z_t)}{var(f_T | X_t, Z_t)} \tag{4.23}$$

It follows that

$$H_1 = \frac{cov(\bar{P}_T, f_T | X_t, Z_t)}{var(f_T | X_t, Z_t)} + 1 \quad . \tag{4.24}$$

Now, consider the system of equations

$$\begin{aligned} \bar{P}_T &= X_t\alpha_1 + Z_t\alpha_2 + \epsilon \\ f_T &= Z_t\beta + \upsilon_t \end{aligned} \tag{4.25}$$

Where: α_1 and α_2 are vectors of unknown parameters, and ϵ and υ are disturbance terms.

Again, if the system is nonlinear it can be estimated by a maximum likelihood algorithm. Then an estimator of the covariance matrix of the shocks is given by:

$$\hat{\Omega} = \frac{1}{N}\begin{bmatrix} \hat{\epsilon}'\hat{\epsilon} & \hat{\epsilon}'\hat{\upsilon} \\ \hat{\upsilon}'\epsilon & \hat{\upsilon}'\hat{\upsilon} \end{bmatrix} \tag{4.26}$$

Therefore, the hedging rule (4.10) can be estimated by:

$$H_1 = \frac{\hat{\epsilon}'\hat{\upsilon}}{\hat{\upsilon}'\hat{\upsilon}} + 1 \quad . \tag{4.27}$$

The advantage of this method is that it allows for the explicit modelling of the price basis for Costa Rican coffee, an exercise in which industry participants have expressed considerable interest. Knowledge about the behavior of the price basis for Costa Rican coffee may help exporters with trading decisions. In the next chapter the empirical model for the basis is developed and estimated.

An estimate of the optimal hedge rule (4.18) can be obtained by a similar procedure. Suppose that precio rieles and futures prices are generated by the processes:

$$\begin{aligned} r_T &= X_t\gamma + \upsilon \\ f_T &= Z_t\beta + v \end{aligned} \tag{4.28}$$

Where γ is a vector of unknown parameters; and υ and v are shocks.

Now define the price basis

$$b_t = r_t - f_t,$$

then the hedging rule (4.18):

$$H_2 = \frac{cov(r_T, f_T | X_t, Z_t)}{var(f_T | X_t, Z_t)} \tag{4.29}$$

can be expressed as

$$H_2 = \frac{cov(b_T, f_T | X_t, Z_t)}{var(f_T | X_t, Z_t)} + 1 \ . \tag{4.30}$$

By obtaining estimates from the model

$$\begin{aligned} b_T &= X_t\gamma_1 + Z_t\gamma_2 + u_t \\ f_T &= Z_t\beta + v_t \end{aligned} \tag{4.31}$$

the optimal hedge ratio (4.18) will be estimated by:

$$H_2 = \frac{\hat{u}'\hat{v}}{\hat{v}'\hat{v}} + 1 \ . \tag{4.32}$$

This hedging rule will indicate to the exporter the proportion of futures contracts he needs to buy for every unit of coffee he is short in the cash market.

The estimation problem may require the imposition of restrictions on the coefficients of the explanatory variables. For instance, if unit roots are present in the price processes the model can be expressed in first difference terms. This procedure restricts the coefficient associated with the dependent variable lagged once. The advantage of doing this is that the resulting time series would be stationary. The interpretation of the hedging rule based on the first differences is the same as that of price levels, namely, the proportion of spot positions that should be covered by opposite futures positions.

CHAPTER V.

RESULTS

This chapter presents results from the empirical estimation of the hedge ratios derived from the Mean-Variance model of the previous chapter. A description of the data set used is followed by a preliminary analysis of the variables. The section on estimation lays out the bivariate model. The last section of the chapter evaluates the performance of the hedging rules developed.

A. VARIABLES

In order to estimate the model (4.31) the following variables (names in parenthesis) were used:

i) Costa Rican "precio rieles" (r_t) in U.S. $/100 lb, or free on rail Costa Rican price. This is the negotiated price between the mill and the exporter, for coffee deposited at the railway station from where it will be transported to the export shipping point. The series is composed of average prices over half monthly intervals, from January 1974 to June, 1990. Prices are collected by ICAFE and represent the total income generated by all millers in the country divided by the total volume sold for the first half of the month. This Costa Rican cash price series conditions the way the rest of the data are formatted. Thus each of the following series is depicted in a two-data-points-per-month fashion, corresponding to the first and second halves of each month. The once differenced series $(r_t - r_{t-1})$ is Δr_t.

ii) New York nearest futures price (f_t) in U.S. $/100 lb. This series contains the settle price of the nearest coffee futures "C" contract, which is rolled over on the first day of the expiration month. It goes from January 1974 to April, 1990, and was provided by Commodity Systems Inc., (CSI) Boca Raton, Florida. The series, originally in daily format, was averaged to represent prices for the first and the second halves of each month.

iii) New York second nearest futures price ($f2_t$). This series contains the settle price of the second nearest futures contract. It is rolled over on the first day of the expiration month. The same averaging as in the previous series was carried out.

iv) Interest rate on Three-month Bankers' Acceptances (i_t). This U.S. interest rate series is defined as the rate on short term negotiable discount time drafts financing shipment or storage of goods, the payment being guaranteed by the accepting bank. The series was collected from Barron's National Business and Financial Weekly, Dow Jones and Company, Inc. The once differenced series $(i_t - i_{t-1})$ is Δi_t.

v) Dummy variable for the existence of the International Coffee Agreement with quotas and price mechanisms (ICA_t). The variable lagged one year is ICA_{t-24}.

vi) Index of relative supply of Arabicas (RSA_t). This is an annual index of Arabicas' production shown as a percentage of the total world coffee production. The variable lagged one year is RSA_{t-24}.

vii) First difference for the price of the New York "C" nearest futures contract (Δf_t). At any contract rollover date information from $f2_t$ was used in order to avoid subtracting prices from two consecutive contracts. The procedure is illustrated with the following example. In April, f_t and $f2_t$ contain prices for the May and July contracts respectively. On May 1, f_t is rolled over to the July contract and $f2_t$ is rolled over to the September contract. It would be undesirable to calculate Δf_t where t represents the first half of May as $f_t - f_{t-1}$ since the subtraction would involve two consecutive contracts (July and May) at different stages in their lives. The resulting series would contain jumps at any rollover date caused by the time spreads of the futures contracts. The "jumps" would disturb the price variations which are the object of the modeling. A preferred way of calculating Δf_t for the first half of May is given by $f_t - f2_{t-1}$. In this case f_t and $f2_{t-1}$ are prices from the same contract (July) at time t and at t-1. This is the procedure followed at all contract rollover dates for the series f_t. Linking differences within the life of any single contract with similar observations from contracts of different maturities and expressing them as a single time series allows to capture price movements while at the same time avoiding the undesirable "jump" effects.

viii) Twenty-four seasonal components (S01..S24) corresponding to each half monthly interval were considered in the model as dummy variables.

ix) Price basis, differenced once (Δb_t). The series is defined as $\Delta b_t = \Delta r_t - \Delta f_t$. This procedure is preferred to that of calculating b_t as $b_t = r_t - f_t$ and then Δb_t as $b_t - b_{t-1}$. Such procedure would contain "jumps" resulting from the rolling over of the futures contracts. The behavior of the basis for Costa Rican coffee is of interest to industry participants, that is why one of the equations in the system models the price basis. The equation is used to find hedge ratios but the model in itself, as described later, will be helpful to exporters. Since the basis is measured as the difference between the Costa Rican precio rieles and the New York Exchange Contract "C" price, a negative basis means $r_t < f_t$, which is usually the case.

x) Quantity of Costa Rican Coffee sold by millers to exporters (q_t). The series was collected by ICAFE and refers to the amount of coffee sold by all Costa Rican millers over half monthly intervals. Quantity is measured in one hundred thousand pound units. The lagged variables are $q_{t-1}..q_{t-5}$ corresponding to lags one to five.

B. PRELIMINARY ANALYSIS

This section characterizes the individual distributions for futures and cash prices. The autocorrelation function for each price series is of particular interest in studying price behavior. Figure 2 shows the two series, Precio rieles and nearest futures contract price.

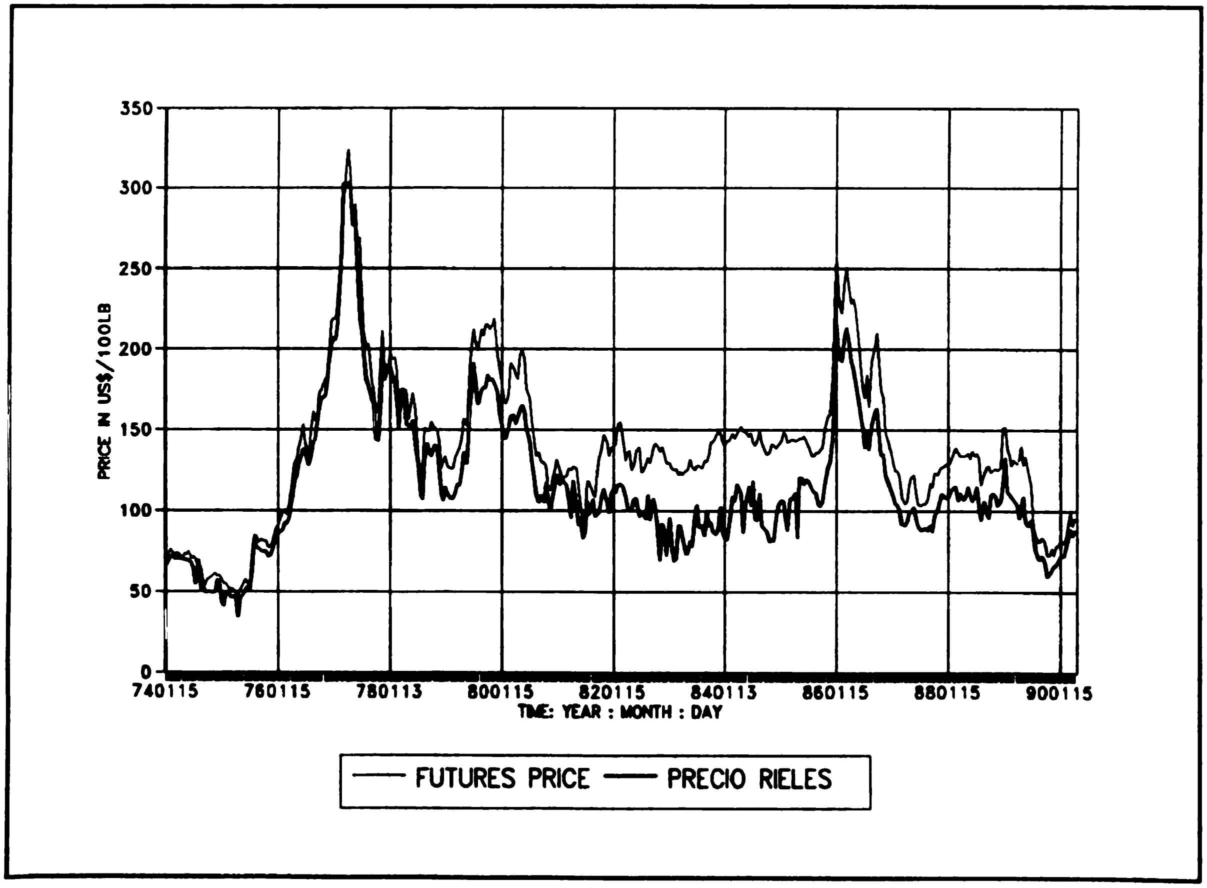

Figure 2. Precio Rieles and Nearest "C" Futures Price.

The precio rieles is almost always below the futures price. Due to a severe frost in Brazil, coffee prices were at a historical high in April 1977, when the New York C contract sold at $3.40/lb. The cause of the price rise of 1986 was a drought in Brazil at the end of 1985.

The autocorrelation function (ACF) coefficients for the New York "C" price and the Costa Rican Precio Rieles showed a typical nonstationary pattern for both variables (slow decay in ACF). Furthermore, by applying the Dickey-Fuller test it was found that each of the price series possess a unit root and thus are nonstationary. Hence, both series were differenced once. The ACF for the first difference of the New York and rieles prices are shown in Tables 5 and 6. The differenced series show no evidence of nonstationarity.

TABLE 5. AUTOCORRELATION FUNCTION FOR THE FIRST DIFFERENCE OF FUTURES PRICES (Δf_t).

LAG	1	2	3	4	5	6	7	8	9
AC COEFF.	.35	.06	.01	.10	.08	-.04	-.04	.03	.02
LAG.	10	11	12	13	14	23	31	32	36
AC COEFF.	-.03	-.09	-.06	.02	-.06	-.10	-.13	-.08	.06

TABLE 6. AUTOCORRELATION FUNCTION FOR THE FIRST DIFFERENCE OF THE PRECIO RIELES (Δr_t).

LAG	1	2	3	4	5	6	7	8	9
AC COEFF.	.002	.04	.05	.03	.07	-.03	-.06	-.00	-.03
LAG.	10	11	12	13	14	18	28	32	36
AC COEFF.	-.07	-.07	.01	-.03	-.07	.18	-.10	-.10	.11

The high first order autocorrelation (0.35) in the New York "C" price difference requires further comment. High autocorrelations in futures prices are usually a sign of some sort of market inefficiency. From a theoretical perspective, a high first order autocorrelation is an unusual result.

To ensure that the observed autocorrelation is a persistent feature of the data several tests were carried out. The presence of significant autocorrelation was observed in weekly and biweekly series for Wednesday settle prices. A consistent result was obtained from weekly and biweekly Monday prices. Although the daily futures prices did not show any individual autocorrelation coefficient of more than 0.06, the magnitude and number of positive autocorrelation coefficients in the first twelve lags clearly outweigh the negative ones. Twelve lags are chosen because two data points per month average approximately twelve trading days.

The analysis of the Costa Rican price basis behavior similarly starts with the ACF. The correlogram for the first difference of the basis is shown in Table 7. Negative autocorrelations for the first two lags and positive partial autocorrelations (not shown in the table) at lags 12 and 36 are the salient features of the ACF and partial ACF.

TABLE 7. AUTOCORRELATION FUNCTION FOR THE FIRST DIFFERENCE OF THE PRICE BASIS (Δb_t).									
LAG	1	2	3	4	5	6	7	8	9
AC COEFF.	-.29	-.08	.002	.01	-.06	.05	-.03	.10	.03
LAG.	10	11	12	13	14	15	16	31	36
AC COEFF.	-.09	.03	.06	.03	.05	.03	-.07	-.06	.09

C. ESTIMATION

1. System of Equations: Basis and Futures Modelling

The general model was represented in equation 4.31 as:

$$\begin{aligned} b_T &= X_t\gamma_1 + Z_t\gamma_2 + u_t \\ f_T &= Z_t\beta + v_t \end{aligned} \tag{5.1}$$

The presence of moving average terms suggested by the autocorrelation functions of Δb_t and Δf_t introduces nonlinearities. The system was thus estimated by a maximum likelihood algorithm in GAUSSX, under the assumption of normality. Then the hedging rule given by

$$H_2 = \frac{\hat{u}'\hat{v}}{\hat{v}'\hat{v}} + 1 \tag{5.2}$$

represents the ratio of the covariance between r_t and f_t to the variance of f_t as shown in Chapter 4. Both covariance and variances are conditional on the union of the two information sets X and Z.

In order to model Δb_t the following variables were considered:

a- Autoregressive and Moving Average (ARMA) terms.

b- Twenty four seasonal components (one for each half monthly interval).

c- A dummy variable for the periods when quotas from the International Coffee Agreement existed.

d- The Three month Bankers' Acceptances interest rate.

e- An annual index of relative production of arabicas as a percentage of the total world coffee production.

f- Futures price levels, to capture the effect of the general world coffee price level.

g- The quantity of coffee bought by exporters.

The final basis equation is given by:

$$\Delta b_t = M_t \xi + \phi_1 \Delta b_{t-12} + \phi_2 \Delta b_{t-36} + \theta_{11}\varepsilon_{t-1} + \theta_{12}\varepsilon_{t-2} + \varepsilon_t \ . \quad (5.3)$$

Where: ξ is a vector of parameters;
ϕ_1, ϕ_2, θ_{11} and θ_{12} are also parameters;
ε is a serially correlated shock term; and
M_t is a row vector containing the following elements:
a constant term (one);
the seasonal terms S01, S04, S05, S06, S09, S10, S11, S13, S20, S22, S23, S24;
RSA_t lagged 1 year;
ICA_t lagged 1 year;
Δi_t lagged 6 periods;
q lagged one, three and four half monthly intervals.

The futures equation is:

$$\Delta f_t = Z_t \beta + \Delta f_{t-27} + \theta_{21}\epsilon_{t-1} + \epsilon_t \ . \quad (5.4)$$

Where ϵ is a serially correlated disturbance term;
Z_t is a row vector containing the following elements:
a constant term (one); and
the seasonal terms S02, S04, S11, S12, S13, S14, S16, S21, S24.

Other variables and lags were considered but not included in the final model because of their low predictive power. Sequential likelihood ratio tests (Harvey, p.186) were carried out in order to obtain a satisfactory model.

The total number of observations for the system of equations was 305. Data from 1974 and part of 1975 were dropped to allow for the long lag in Δb_t. The data set ends in April 15 1990, however, two years of data were left out from any estimations in order to use them for performance evaluation purposes. Thus the last observation for all estimations was April 15 1988. The vector of coefficients, t statistics and standard errors for the two basis and futures equations are shown in Table 8. The Theta (θ) coefficients represent moving average terms, as in (5.3) and (5.4).

The basis (precio rieles minus futures price) is in general negative, this is mainly due to the locations i.e. Costa Rica and New York, where prices are measured. A positive coefficient associated with any regressor means that a higher magnitude in that particular regressor contributes to basis increments, i.e. it contributes to a strengthening of the Costa Rican price relative to the futures price. In this context a basis increment results in a narrower negative basis.

The results in Table 8 suggest that during the first halves of January, March and July the position of the Costa Rican price strengthens relative to the futures price. During the second half of December the

TABLE 8. MODEL RESULTS.

Endogenous Variables... DBS DAN5
Method.. GAUSS BHHH BHHH
Convergence achieved after 35 iterations
Log of Likelihood = -2132.7658
Number of Observations = 305

Var	Coef	Std. Error	t-Stat	P-Value
BASIS EQUATION				
CONSTANT	1.198752	9.355923	0.128128	0.898
S01	5.372316	2.437130	2.204361	0.028
S04	3.626621	3.159636	1.147797	0.252
S05	5.679073	2.108473	2.693453	0.007
S06	1.579715	2.277294	0.693681	0.488
S09	1.144169	1.901395	0.601752	0.548
S10	3.418259	3.170992	1.077978	0.282
S11	4.348995	2.662471	1.633443	0.103
S13	6.964387	3.046073	2.286350	0.023
S20	3.496353	2.431027	1.438221	0.151
S22	3.487801	3.055626	1.141436	0.255
S23	2.937852	2.873891	1.022256	0.307
S24	-2.757171	2.720274	-1.013564	0.312
RSA_{t-24}	-11.939414	21.768446	-0.548473	0.584
ICA_{t-24}	-0.576243	0.895759	-0.643301	0.521
Δi_{t-6}	-0.625967	0.856352	-0.730969	0.465
q_{t-1}	0.012670	0.008507	1.489301	0.137
q_{t-3}	-0.005200	0.009446	-0.550525	0.582
q_{t-4}	0.016845	0.011292	1.491721	0.137
Δb_{t-12}	0.120706	0.061668	1.957363	0.051
Δb_{t-36}	0.111290	0.061644	1.805361	0.072
θ_{11}	0.232259	0.051241	4.532689	0.000
θ_{12}	0.100746	0.065021	1.549438	0.122
FUTURES EQUATION				
CONSTANT	1.008826	0.940515	1.072632	0.284
S02	-5.205731	2.213246	-2.352079	0.019
S04	1.970179	2.806192	0.702083	0.483
S11	-3.008293	1.683927	-1.786474	0.075
S12	-3.332784	3.164048	-1.053329	0.293
S13	-5.541690	3.850038	-1.439386	0.151
S14	-3.599483	2.356408	-1.527530	0.128
S16	6.573960	2.061060	3.189601	0.002
S21	2.643399	2.407729	1.097881	0.273
S24	3.218753	2.134501	1.507965	0.133
Δf_{t-27}	0.062806	0.067673	0.928081	0.354
θ_{21}	-0.342064	0.040574	-8.430576	0.000

Costa Rican price tends to erode relative to the futures price.

The supply of arabicas lagged one year relative to the total world production has a negative coefficient. That is, a previous year of abundant arabica supply tends to erode the position of Costa Rican coffee prices relative to the futures prices. The sign of the coefficient is as expected but its t-statistic is not significant. The existence of the International Coffee Agreement with consensus on quotas and price mechanisms also shows a negative impact on the position of Costa Rican coffee prices relative to the futures prices, but again the corresponding t-statistic is statistically insignificant. The interest rate also carries a negative coefficient and an insignificant t-statistic. The negative coefficient means that higher interest rates tend to contribute to decreases in the basis, i.e. an erosion of the position of the Costa Rican coffee price relative to the futures price.

The quantity sold to exporters exerts lagged effects on the price basis in opposite directions at different lags. At lags one, three and four it shows positive, negative, and positive coefficients respectively. At the time the coffee is exported the amount of coffee that leaves Costa Rica is expected to be inversely related with basis increments. This is not clearly captured by the model, since the negative coefficient is not statistically significant.

The adequacy of the model can be assessed by testing whether the residuals are approximately random. The Box-Pierce Q-Statistic (Harvey, p.28) was used in this type of diagnostic checking. The Q-Statistics of the residuals of both equations were computed for one, six and twelve lags. The autocorrelations and Q-Statistics are shown in Tables 9 and 10. None of the Q-Statistics computed led to a rejection of the hypothesis of correct specification. A probability value under .05 would have resulted in a rejection of the hypothesis of correct specification.

TABLE 9. AUTOCORRELATION FUNCTION AND Q STATISTICS FOR RESIDUALS OF BASIS EQUATION.

LAG	1	2	3	4	5	6
AUTOCORRELATION COEFF.	-.01	-.07	.02	.07	.10	.08
LAG	7	8	9	10	11	12
AUTOCORRELATION COEFF.	.04	.07	.03	.01	.05	.01
Q-STAT., ONE LAG	.04		PROB.:		.84	
Q-STAT., SIX LAGS	10.42		PROB.:		.11	
Q-STAT., TWELVE LAGS	13.70		PROB.:		.32	

TABLE 10. AUTOCORRELATION FUNCTION AND Q STATISTICS FOR RESIDUALS OF FUTURES PRICE EQUATION.

LAG	1	2	3	4	5	6
AUTOCORRELATION COEFF.	.02	.07	-.02	.09	.09	-.05
LAG	7	8	9	10	11	12
AUTOCORRELATION COEFF.	-.02	.03	-.01	.00	-.06	-.08
Q-STAT., ONE LAG	.21		PROB.:		.65	
Q-STAT., SIX LAGS	9.19		PROB.:		.16	
Q-STAT., TWELVE LAGS	13.24		PROB.:		.35	

Likelihood ratio tests were also carried out to compare the model with two other more general models. The first general model included seasonal components on all half monthly intervals for the basis equation and lagged values of quantity sold by millers on all the first five lags. The second general model included seasonal components over all half monthly intervals for the futures price equation. The likelihood ratio test allows to evaluate whether the restriction of zero coefficients on all the added variables is valid. Under the null hypothesis the restriction is valid and the statistic $-2[\ln(L_R) - \ln(L_U)]$ is asymptotically distributed as a Chi-Square with one degree of freedom, where $\ln(L_R)$ and $\ln(L_U)$ denote the value of the log-likelihood function for the restricted and unrestricted models. The null hypothesis of a true restriction could not be rejected on either of the two cases, suggesting that the added variables in each of the general models did not improve significantly the explanatory power of the model. The values of the statistic were 3.59 and 3.12 when the restricted model was compared to the more general basis and futures equation models. The critic value of Chi-Square with one d.f. (α=.05) is 3.84.

Finally, the presence of ARCH errors (Engle) was tested. The test procedure consisted of regressing the squared residuals on a constant and p lags in order to test the statistic nR^2 (n is the number of observations), which under the null hypothesis of non-ARCH disturbances is asymptotically distributed as a Chi-Square with p degrees of freedom. All the results of Table 11 led to a rejection of the null hypothesis. This suggests ARCH errors are present in both equations, thus the assumption of constant variance may not be valid. However, there is a growing body of evidence suggesting that even when ARCH errors are present, typically the improvement in performance obtained by the use of time varying hedge ratios is small when compared with that of constant optimal hedge ratios stemming from sound models (see for instance Cecchetti et al, and Baillie and Myers).

Furthermore, the estimation of time-varying second moments of the errors i.e. ARCH and GARCH (Bollerslev) models, impose high transactions costs to the traders. The additional complexity of the models and the fact that they need to be updated constantly in order to obtain the changing hedge rules at different points in time make these models difficult to apply. From a trader's perspective, the marginal gains of GARCH models are likely to be offset by the additional costs these models impose. Thus the use of a constant optimal hedge ratio stemming from a sound model seems reasonable, especially if its performance proves satisfactory.

TABLE 11. TESTS FOR ARCH ERRORS.

NUMBER OF LAGS CONSIDERED	CRITICAL VALUE OF χ^2 (α = .05)	nR^2 FOR TEST ON BASIS EQUATION	nR^2 FOR TEST ON FUTURES EQUATION
ONE	3.84	14.7	24.3
THREE	7.81	15.0	40.1
SIX	12.59	17.3	41.5

2. **Optimal Hedge Ratios for Exporters**

Two cases were considered in Chapter 4. First, the case of an exporter who has bought coffee from a miller and has not yet contracted a sale. the second case is that of an exporter who has contracted a forward sale, but has no coffee from the miller yet. In the first case, the hedge ratio (4.10) will be determined by:

$$H_1 = \frac{cov(p_t, f_t)}{var(f_t)}$$

Where p_t is the FOB price at which the exporter sells in the Costa Rica seaport and the variances and covariances are conditional on information available at the time the hedge is made. In the second case the corresponding hedge ratio is given by:

$$H_2 = \frac{cov(r_t, f_t)}{var(f_t)} \quad .$$

FOB prices are not available because ICAFE does not maintain the records for a long enough period. However, if the conditional variance of FOB prices can be reasonably approximated by estimating the conditional variance of the precio rieles both hedge ratios will have approximately the same value. That is, although cash and futures positions are opposites in the two cases, the same ratio would be valid for both situations. In this study the conditional variance of r_t was used as a proxy variable for the conditional variance of p_t, as explained as follows.

From equation 3.2 the relationship between the FOB price p_t and the precio rieles r_t is given by:

$$r_t = p_T - C_x - \beta(p_T - C_x) - T_x$$

Where: C_x = per unit cost to the exporter in colones;
β = return to the exporter;
T_x = export tax (currently, T_x=.01*PFOB).

ICAFE estimates that the average cost to the exporter is $1.65/100 lbs, while the average return to the exporter is limited by law to a maximum of 2.5 percent. Although tax rates are proportional to price levels and the law has changed many times in the period analyzed, it is reasonable to assume that at the time the exporter buys coffee from the miller he knows which export tax rate will be applied, therefore this element does not add to the conditional variance of PFOB. Another source of variation is the average cost to the exporter, but this element is not expected to add significantly to the variance. Presumably at the time the coffee is purchased the exporter has a good idea of what costs he will bear. The return to the exporter, although limited by law, is clearly a stochastic variable. However, since the return is small relative to the total value of the product and is limited by law, its variance is not expected to affect significantly the variance of the precio rieles.

The optimal hedge ratio obtained from the bivariate model was 0.76. The estimate of the conditional variance-covariance matrix for the basis and futures price system of equations is shown in Table 12. The interpretation is that for each unit of coffee bought from the miller at t (sold internationally at t), the exporter will sell (buy) 0.76 units of futures for delivery at T or at a posterior date close to T. Then at time T the exporter will "lift" the hedge.

TABLE 12. CONDITIONAL SECOND MOMENT MATRIX AND OPTIMAL HEDGE RATIO (OHR) 1/

	$\hat{u}$	$\hat{v}$
$\hat{u}$	58.3449	-17.9154
$\hat{v}$	-17.9154	75.1315

OHR: $(\hat{u}'\hat{v}/\hat{v}'\hat{v}) + 1 = 0.7615$

1/ $\hat{u}$ denotes the vector of residuals from the basis equation, $\hat{v}$ denotes the vector of residuals from the futures price equation.

The presence of autocorrelation in the futures price changes suggests that some degree of market bias could be present. If the exporter has an expectation of the market bias at any point in time he can use equation (4.9) or (4.17) in order to get estimates of the hedge rules. In order to test whether a consistent market bias was present in the data, the bias defined in (4.9) by f_t-μ_f was computed for the expectation of f one, two and four periods in the future, i.e. up to two months ahead. Thus, forecasts for f_t corresponding to f_{t+1}, f_{t+2}, and f_{t+4} were generated from the model and compared against f_t over the out of sample horizon (last two years). Then each of the biases was regressed on a constant and a trend variable. In the presence of a consistent market bias the coefficients associated with the constant or the trend are expected to be different from zero. In each of the regressions neither the constant nor the trend coefficients were statistically different from zero. Furthermore the F-statistics associated with the three models were insignificant. This evidence supports the market unbiasedness assumption. The results are summarized in Table 13. Similar results were obtained from regressing each bias series on only a constant, in which case the coefficient associated with that constant is the mean of the series.

TABLE 13. OUT OF SAMPLE BIAS TESTS.					
SERIES	MEAN	VAR	COEFF	T-STAT 1/	F-STAT 1/
BIAS: 1 PERIOD AHEAD	-.39	C	-3.75	-.38	
$(f_t - \hat{f}_{t+1})$		TREND	.009155	0.34	.12
BIAS: 2 PERIODS AHEAD	-.84	C	-4.69	-.33	
$(f_t - \hat{f}_{t+2})$		TREND	.0105	0.27	.07
BIAS: 4 PERIODS AHEAD	-.92	C	-4.14	-.18	
$(f_t - \hat{f}_{t+4})$		TREND	.00881	0.44	.02
1/ All the t and F-statistics are insignificant.					

D. PERFORMANCE EVALUATION

Two types of performance analysis were carried out. Ex post performance evaluation consisted of comparing per unit portfolio profits and their unconditional variance against the no hedge option. Ex ante performance evaluation consisted of measuring the portfolio's conditional variance reduction compared to the no hedge option. Both procedures are explained in detail as follows.

The portfolio of futures and cash positions for the exporter who is long in the cash market and short in the futures market generates a per unit profit (ignoring storage costs) given by

$$y_t = \Delta p_t - h_{t-1}\Delta f_t \qquad (5.5)$$

Where h_{t-1} is the optimal hedge ratio (4.10). An estimate of the unconditional variance of the portfolio's per unit profit is given by

$$var(y_t) = (\frac{1}{n})y'y - [(\frac{1}{n})\iota'y]^2 \tag{5.6}$$

Where: n = number of observations in the time horizon;
ι = vector of ones.

Under the no hedge option, per unit profits are given by Δp_t and an estimate of the variance of per unit profits is

$$var(\Delta p_t) = (\frac{1}{n})\Delta p'\Delta p - [(\frac{1}{n})\iota'\Delta p]^2 \tag{5.7}$$

For the ex post analysis, per unit profit increases and percent variance reductions were calculated for different in sample and out of sample time horizons. Table 14 presents these results of the hedge rule for the case of the exporter who is long in the cash market and short in the futures market. The period from January 1985 to December 1986 was chosen to evaluate performance within the sample period. Four different time horizons were chosen to test the out of sample performance of the optimal hedge ratio, the first is the semester from 4/30/88 to 10/15/88, the second one is the year from 4/30/88 to 4/15/89, the third one is the year from 4/30/89 to 4/15/90, and the fourth comprises the two years from 4/15/88 to 4/30/90. As expected the hedge rule performs better within the sample in terms of variance reduction. The out of sample results seem to indicate that the optimal hedge ratio improves the level of income for the exporter who is routinely long in the cash market and decreases the level of variance significantly. The real problem with this approach is that the performance results are very susceptible of the evaluation period used. If the hedge rules are used in a time of general price declines (rises), then the portfolio with hedging will perform better (worse) than the no hedge alternative for the agent who routinely takes short positions in futures. The results in the profit levels reported in Table 14 were expected since prices were declining for most of the horizons analyzed. The out of sample period contains the effects of the break up of the ICA in July 1989 and the subsequent price declines.

TABLE 14. EX-POST PERFORMANCE EVALUATION OF THE OHR WITH RESPECT TO THE NO HEDGE OPTION.

PERIOD	INCREASE IN PER UNIT PROFIT 1/	PROFIT VARIANCE REDUCTION
IN SAMPLE: 1.15.85- 12.31.86	248%	57.5%
OUT OF SAMPLE 1: 4.30.88-10.15.88	415%	2.8%
OUT OF SAMPLE 2: 4.30.88-4.15.89	27%	18.9%
OUT OF SAMPLE 3: 4.30.89-4.15.90	327%	6.8%
OUT OF SAMPLE 4: 4.30.88-4.15.90	145%	14.5%

1/ The increase in per unit profit apply to the case of the exporter who is routinely long in the spot market and hedges by selling futures.

A better method to evaluate the performance of the hedge rules consists of computing the percentage reduction in the conditional variance of the portfolio per unit profits compared to the no hedge outcome over a period of time. Again, per unit profits for the hedging alternative are given by (5.5). The conditional variance of per unit profits is:

Where $\mho_{t-1}$ is the information set available to traders at t-1.

$$var(y_t|\Omega_{t-1}) = \\ var(\Delta p_t|\Omega_{t-1}) + h_{t-1}^2 var(\Delta f_t|\Omega_{t-1}) - 2h_{t-1}cov(\Delta p_t, \Delta f_t|\Omega_{t-1}) \tag{5.8}$$

From the system of equations (4.31) estimates of the conditional variances and covariances can be obtained as follows:

$$cov(p_t, f_t|\Omega_{t-1}) = (\frac{1}{n})(\hat{v}'\hat{v} + \hat{u}'\hat{v}) \tag{5.9}$$

$$var(f_t|\Omega_{t-1}) = (\frac{1}{n})(\hat{v}'\hat{v}) \tag{5.10}$$

$$var(p_t|\Omega_{t-1}) = (\frac{1}{n})(\hat{u}'\hat{u} + \hat{v}'\hat{v} + 2\hat{u}'\hat{v}) \tag{5.11}$$

The conditional variance of per unit profits was calculated for each date in the sample and out of sample time horizons under the optimal hedge rule and the no hedge alternatives. At any point in time, the decision maker has information of the complete past history of the conditioning variables. The hedge ratio was evaluated by computing the percentage reduction obtained in the conditional variance of the portfolio profits, compared to what this conditional variance would have been under no hedging. Percentage variance reductions at each date were then averaged over the sample to give a summary measure of hedging performance. The time horizons are similar to those used in the ex post analysis.

Table 15 shows the results of the ex ante analysis. As expected the hedge ratio performs very well over the in sample horizon. For the out of sample period the optimal hedge ratio reduces the conditional variance of per unit profits by more than 40 percent as compared to the no hedge option. The results suggest that the application of the hedging rule could contribute to reduce significantly the conditional variance of an exporter's profits.

TABLE 15. EX-ANTE PERFORMANCE EVALUATION OF THE OHR WITH RESPECT TO THE NO HEDGE OPTION.

PERIOD	CONDITIONAL VARIANCE REDUCTION IN PER UNIT PROFITS
IN SAMPLE: 1.15.85-12.31.86	40.8%
OUT OF SAMPLE 1: 4.30.88-10.15.88	44.3%
OUT OF SAMPLE 2: 4.30.88-4.15.89	43.9%
OUT OF SAMPLE 3: 4.30.89-4.15.90	42.3%
OUT OF SAMPLE 4: 4.30.88-4.15.90	43.1%

CHAPTER VI.

SUMMARY AND CONCLUSIONS

The position of coffee as generator of one fifth of all foreign currency earned by Costa Rica and its broad production base make risk management in this commodity a concern not only to those directly involved in the industry but also to policy makers. The break up of the International Coffee Agreement has increased the need to transfer price risks internationally, a task that could be at least partially achieved by the use of contingent claims markets like futures and options.

This study described the main risks stemming from short term price fluctuations that coffee farmers, millers and exporters face and developed and estimated optimal hedge rules for coffee exporters. The Costa Rican coffee marketing system is sui generis, it distributes price risks in a way that affects farmers, millers, and exporters differently.

Farmers bear most of the risk of adverse price fluctuations, although they seem to be protected from the risk of very low short term price levels through an implicit contract with the government. The government has shown a pattern of changing laws in order to favor coffee farmers and subsidize them in various ways in times of very low prices like those following the break up of the ICA in 1989. Acting independently, the main variable farmers can manipulate to manage price risks is the choice of miller. The fact that cherry coffee needs to be delivered within 24 hours of harvest limits the number of potential buyers for a farmer's crop. The greater the competition among millers for throughput the greater the likelihood that farmers will receive higher initial advances. This type of apparent competition is more prevalent in the central highlands (where 90 percent of the mills are located) than in the more retired rural areas.

Millers face limited price risk since the final price is settled at the end of the crop year and the initial advances are almost always less than the final pooled price. The mills can effectively adjust the cost of their main input, unprocessed coffee, according to the price they are able to obtain from their processed coffee. This also creates an implicit market for borrowing coffee from farmers at no charge.

The potential for different alternatives to manage risks involving cooperation between farmers and millers or between millers and exporters was discussed. For instance, it was argued that the payment of higher initial advances to the farmer, together with the purchase of put options to cover the risk of a pooled price lower than the initial payment, seemed consistent with the objectives of a miller who wants to become more competitive, as long as the alternative was beneficial in the farmers' eyes.

The empirical part of the study focused on exporters. An optimal hedging rule for exporters who want to hedge a long or a short position in the cash market with futures contracts was derived and estimated. This optimal hedge ratio of 0.76 means that an exporter who is a unit of coffee long (short) in the cash market should sell (purchase) 0.76 units of coffee futures in order to minimize the variance of profits.

The optimal hedge ratio under the assumption of market unbiasedness was defined as the ratio of the covariance between futures and cash (precio rieles) prices to the variance of futures prices. Since both variance and covariance are clearly conditional upon all relevant information available to traders, explicit processes for the price basis and the futures price were modelled. The two equation system was estimated via maximum likelihood due to the nonlinearities introduced as a result of moving average terms. The explicit modelling of the price basis for Costa Rican coffee is in itself a valuable input for traders' decisions.

In the price basis model the individual structural variables did not seem to contribute significantly to the predictive power of the model. Only three seasonal components possess significant t-statistics (α=.05). On the other hand the moving average term for t-1 proved highly significant. The fact that the structural variables did not pass t-tests does not mean they have no individual effect on the price basis. The fact that the basis is defined for the "average Costa Rican coffee" exported may contribute to hide some of the explanatory power of structural variables. Costa Rica produces eight main types of coffee that are priced differently. Lower quality Costa Rican coffees have more substitutes than the higher quality types. The basis for the different types might behave differently.

The performance evaluation of the hedging rule suggests that the implementation of the optimal hedge ratio could contribute to a significant reduction of the conditional variance of the profits as compared with the no hedge option. Hedging would have also resulted in a reduced unconditional variance of profits in the out of sample period as compared with the no hedge alternative.

The assumption of a constant optimal hedge ratio could be relaxed thus allowing for the explicit modelling of the variance. Future research using GARCH models would be an interesting exercise in this sense. In addition, the modelling of optimal positions for mills and exporters involving options contracts is another area where future research with potential for application can be carried out.

APPENDIX

INTRODUCTION TO THE GLOBAL COFFEE ECONOMY

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The use of Coffee as a beverage was initiated by the Arabs in the 15th century. Latin American countries became important producers in the 19th century and Brazil has remained the world largest producer since 1840. Today Latin America produces 65% of the world coffee compared with 23% from Africa and 11% from Asia. Brazil and Colombia provide respectively 27% and 14% of the world supply. By comparison, Costa Rica's share of the market is approximately 2.5%.

Coffea arabica, *C.robusta L.* and *Coffea liberica* are economically the most important species of the genus. *C.arabica* provides 76% of the world's commercial coffee, compared to 23% from *C.robusta*.

The fact that the commodity is almost exclusively produced by developing countries and then exported to developed economies, especially the United States and Western Europe, is a distinguishing feature of the global coffee market, and one that pervades its institutional arrangements. For example, the International Coffee Agreement (ICA), that collapsed in July 1990, was a consumer-supported cartel in which the developed consuming countries acknowledged that price stabilization was a desirable goal.

In most producing countries national or quasi-governmental coffee agencies provide services to producers. Emphasis is usually given to provision of technical assistance, credit, price stabilization, marketing and research.[10] In Costa Rica, the ICAFE is the agency that plays that role.

Many countries have supported the establishment and management of coffee growers' cooperatives. Through these cooperatives inputs and credit are facilitated, although they often lack enough resources. In some countries cooperatives are also responsible for the processing and marketing of the bean. In Costa Rica, coffee growers' cooperatives are associated in a Federation (FEDECOOP) that has become the main exporter in the country.

The supply of coffee has been growing at a faster rate than demand. In the United States per capita consumption has been declining since 1963. In years of high prices, producers apparently improve plantations whereas during low price years they keep on producing coffee (de Graaff). Through this general response to world market prices, there has

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[10] These marketing authorities can be divided in three categories (Unctad, 1984):

1. the "Marketing Board" type, prevalent in English speaking coffee producing countries (e.g. Kenya, Nigeria, India), which usually have a monopoly on the purchase of the entire crop;
2. the "Caisse de Stabilisation" type found in many Francophone coffee-producing countries (e.g. Côte d'Ivoire, Cameroon, Madagascar), which usually does not take possession of the crop;
3. the quasi governmental coffee producer's associations and "Institutes" common in Latin America (e.g. Mexico, Brazil until 1990, Colombia), which usually guarantee minimum prices for growers.

been a tendency towards continuous stockpiling. This situation, however, has been interrupted by climatic disasters (Brazil) and political disturbances in some major production countries (e.g. Angola).

Supply price elasticities for different countries have been estimated by Akiyama (1982) and Singh (1977). When analyzing supply response to world prices it should be remembered that these price signals are transformed by the marketing authorities. The price elasticity of supply in the short run is low due to the perennial nature of the trees. The long term elasticities, however, are much higher. Akiyama has measured high long term elasticities of supply for the major producers Brazil, Colombia and Indonesia. In the generally lower elasticities obtained by Singh, the impact of the extremely high prices of 1977-1979 could not be fully incorporated. The results are shown in Table A1.

TABLE A1. PRICE ELASTICITIES OF SUPPLY.

COUNTRY	SHORT TERM		LONG TERM		
	1/	2/	3/	4/	5/
Brazil	.093	.20	1.10	.44	.66
Colombia	.0673	.03	.96	.18	.40
Central America		.03		.14	.77
El Salvador	.207		.56		
Guatemala	.110		.50		
Africa		.12		.44	1.87
Côte d'Ivoire	.55		.73		
Asia		.10		.43	3.01
Indonesia	.285		1.05		
Rest of the world	.0771		.38		
World Total	.12		.739		

SOURCES:
1/ Akiyama, 1982. Short run elasticities refer to production response to prices one year lagged, except for Brazil where the lag is two years.
2/ Singh, 1977. One year lag.
3/ Akiyama, 1982. Long run elasticities refer to the effect of a 1% price change on production after ten to thirteen years.
4/ Singh, 1977. Seven year lag.
5/ Sing, 1977. Full adaptation.

As mentioned above, there are two main types of coffee, arabicas and robustas. Arabicas are generally preferred by consumers because of their milder flavor. Arabicas also have a lower content of caffeine. Arabica coffees are divided into washed arabicas and unwashed arabicas. Washed arabicas, are further classified as "Colombian milds" and "other milds". Costa Rican coffee belongs to the latter. Within each category there are subtypes. Arabicas are more differentiated than robustas.

The processing of green beans takes place primarily in the consuming countries. Blending, roasting and grinding practices differ across markets. Firms try to keep the perceived final taste as constant as possible, in order to build brand image and consumer loyalty.

The four commercial types of coffee, namely, robustas, unwashed arabicas, Colombian milds and other milds are partially substitutes and partially complements. The taste of a coffee bean blend is determined by "blending types" and "fillers". A mild blend can consist of the Brazilian Santos 4 type together with a blending type of Other Milds. Robusta and more bitter tasting Brazils (Hards) cannot be blended in a high quality blend because they would destroy the mild flavor of the coffee blend. Large quality differences exist within each type.

Over the last three decades the coffee processing industry in the consuming countries has become more concentrated. In all of the major consuming countries the four-firm sales concentration ratio (CR4) for roasted coffee is over 60% (UNCTAD, 1984).

REFERENCES

REFERENCES

Anderson, Ronald W. and Jean-Pierre Danthine. "Hedger Diversity in Futures Markets." Econ. J. 93(1983):370-389.

Akiyama, Takamasa. "Analysis of the World Coffee Market." Commodity Papers. No. 8. Wahsington, D.C.: The World Bank, 1982.

Arrow, Kenneth J. Essays in the Theory of Risk Bearing. Amsterdam: North-Holland, 1970.

Baillie, Richard T. and Robert J. Myers. "Modeling Commodity Price Distribution and Estimating the Optimal Futures Hedge." Working Paper. No. 201. Center for the Study of Futures Markets. Columbia University, 1989.

Berck, Peter. "Portfolio Theory and the Demand for Futures: The case of California Cotton." Amer. J. Agr. Econ. 63(1981):466-474.

Bollerslev, Tim. "Generalized Autoregressive Conditional Heterskedasticity." Journal of Econometrics. 31(1986):307-327.

Bornemisza Paschka, Paul. "Evolución de la Distribución del Ingreso en el Sistema Cafetero Costarricense desde 1974 hasta 1984." Unpublished Lic. Thesis. Escuela de Econ. Agr. Univ. de Costa Rica, 1986.

Cecchetti, Stephen, Robert Cumby and Stephen Figlewski. "Estimation of Optimal Futures Hedge." Rev. of Economics and Statistics. 70(1988):623-630.

de Graaff, J. The Economics of Coffee. Wageningen: Pudoc, 1986.

Engle, Robert F. "Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation." Econometrica. 50(1982):987-1007.

Facio, Rodrigo A. Estudio sobre la Economía Costarricense. San José: Surco, 1942.

Ferris, John N. "The Essence of Forward Pricing of Crops and Livestock." Staff Paper. Dept. of Agr. Econ. Michigan State University, 1987.

Graf, T.F. "Hedging -how effective is it?" J. Farm Econ. 35(1953):398-413.

Hanson, Steven D. "Price level risk management in the presence of commodity options: Income distribution, optimal market positions, and institutional value." Unpublished Ph.D. dissertation. Iowa State University, 1988.

Harvey, Andrew C. The Econometric Analysis of Time Series. Cambridge: MIT, 1990.

Huang, Chi-fu and Robert H. Litzenberger. Foundations for Financial Economics. New York: North-Holland, 1988.

ICAFE. Informe sobre la Actividad Cafetalera de Costa Rica 1989 . San José: Instituto del Café.

ICAFE. Informe sobre la Actividad Cafetalera de Costa Rica 1990. San José: Instituto del Café.

Jaramillo, Felipe. "Costa Rica: Coffee Sector Report." Washington, D.C.: The World Bank, Dec. 1989.

Jiménez Castro Alvaro. "La Experiencia de Costa Rica dentro de la Situación Cafetera Internacional." Unpublished, undated.

Johnson, Leland L. "The Theory of Hedging and Speculation in Commodity Futures." Rev. Econ. Studies. 27(1960):139-151.

Knight, Frank H. Risk, Uncertainty and Profit. Boston: Houghton Mifflin, 1933.

Levy H. and H. M. Markowitz. "Approximating Expected Utility by a Function of Mean and Variance." Amer. Econ. Rev. 69(1979):308-317.

Machina, Mark J. "Expected Utility analysis without the independence axiom." Econometrica. 50(1982):277-323.

Marshall, John F. Futures and Option Contracting, Theory and Practice. Cincinnati: South-Western, 1989.

Meyer, Jack. "Two Moment Decision Models and Expected Utility Maximization." Amer. Econ. Rev. 77(1987):421-430.

Mora, Laura, Henry Ledezma and Katya Cubero. "Análisis Crítico-Jurídico del proceso cafetalero en Costa Rica." Unpublished Lic. thesis. Facultad de Derecho. Univ. de Costa Rica, 1988.

Myers, Robert J. "Managing Price Risks in the Coffee Sector of Costa Rica." The World Bank, Dec. 1989.

Myers, Robert J. and Stanley R. Thompson. "Generalized Optimal Hedge Ratio Estimation." Amer. J. Agr. Econ. 71(1989):857-868.

Pieterse, M.Th.A. and H.J. Silvis. The World Coffee Market and the International Coffee Agreement. Wageningen: Pudoc, 1988.

Porter, R.B. "An Empirical Comparison of Stochastic Dominance and Mean-Variance Portfolio Choice Criteria." J. Financial and Quant. Anal. 8(1973):587-608.

Pratt, John W. "Risk aversion in the small and in the large." Econometrica. 32(1964):122-136.

Restaurant Hospitality. 71(1987):172.

Robison, Lindon J. and Peter J. Barry. The Competitive Firm's Response to Risk. New York: Macmillan, 1987.

Rodríguez, Guiselle C. "Análisis Parcial del Subsector Cafetalero con Enfasis en Crédito y Comercialización." Unpublished Lic. thesis. Esc. Econ. Agr. Univ. de Costa Rica, 1980.

Rolfo, Jacques. "Optimal Hedging under Price and Quantity Uncertainty: The case of the Cocoa Producer." J. Polit. Econ. 88(1980):100-116.

Sáenz Maroto, Alberto. Historia Agrícola de Costa Rica. San José: UCR, 1970.

Samuelson, Paul A. "The Fundamental Approximation Theorem of Portfolio Analysis in Terms of Means, Variances and Higher Moments." Rev. Econ. Stud. 37(1970):537-542.

Savage, L. J. Foundations of Statistics. New York: Dover, 1972.

Singh, S. and J. de Vries. "Coffee, Tea and Cocoa. Market Prospects and Development Lending." Staff Occasional Papers. No. 22. Washington, D.C.: The World Bank, 1977.

Stein, Jerome L. "The Simultaneous Determination of Spot and Futures Prices." Amer. Econ. Rev. 51(1961):1012-1025.

Stein, Jerome L. "The Opportunity Locus in a Hedging Decision: A Correction." Amer. Econ. Rev. 54(1964):762-763.

Stone, Samuel. La Dinastía de los Conquistadores. San José: EDUCA, 1975.

Tobin, James. "Liquidity Preference as Behavior Toward Risk." Rev. Econ. Stud. 37(1958):65-86.

Tsiang, J. "The Rationale of the Mean-Standard Deviation Analysis, Skewness Preference, and the Demand for Money." Amer. Econ. Rev. 62(1972):354-371.

UNCTAD. "The Processing and Marketing of Coffee: Areas for International Cooperation." Studies in the Processing, Marketing and Distribution of Commodities. New York: United Nations, 1984.

Von Neumann, John and Oskar Morgenstern. The Theory of Games and Economic Behavior. Princeton: Princeton Univ. Press, 1947.

Ward, Ronald W. and Lehman B. Fletcher. "From Hedging to Pure Speculation." Amer. J. Agr. Econ. 53(1971):71-78.

Williams, Jeffrey. The Economic Function of Futures Markets. London: Cambridge, 1986.

Working, Holbrook. "Futures Trading and Hedging." Amer. Econ. Rev. 43(1953a):314-343.

Working, Holbrook. "Hedging Reconsidered." J. Farm Econ. 35(1953b):544-561.

Working, Holbrook. "New Concepts Concerning Futures Markets and Prices." Amer. Econ. Rev. 52(1962):431-459.

Yamey, Basil S. "Hedging in an Organized Produce Exchange." Manchester School. 19(1951):305-319.

Yamey, Basil. "Hedging, Risk and Profits: notes on motives for hedging on futures markets." In Futures Markets: Their Establishment and Performance. Edited by Barry A. Goss. New York: NY Univ. Press, 1986.