8501159

Milonas, Nikolaos T.

LIQUIDITY, PRICE VARIABILITY, AND STORAGE ASYMMETRY: A STUDY OF THE BEHAVIOR OF PRICES IN FUTURES MARKETS

*City University of New York* PH.D. 1984

University Microfilms International 300 N. Zeeb Road, Ann Arbor, MI 48106

PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark __√__.

1. Glossy photographs or pages _____
2. Colored illustrations, paper or print _____
3. Photographs with dark background _____
4. Illustrations are poor copy _____
5. Pages with black marks, not original copy __√__
6. Print shows through as there is text on both sides of page _____
7. Indistinct, broken or small print on several pages __√__
8. Print exceeds margin requirements _____
9. Tightly bound copy with print lost in spine _____
10. Computer printout pages with indistinct print _____
11. Page(s) __________ lacking when material received, and not available from school or author.
12. Page(s) __________ seem to be missing in numbering only as text follows.
13. Two pages numbered __________. Text follows.
14. Curling and wrinkled pages _____
15. Other ______________________________________________

# LIQUIDITY, PRICE VARIABILITY, AND STORAGE ASYMMETRY: A STUDY OF THE BEHAVIOR OF PRICES IN FUTURES MARKETS

by

Nikolaos T. Milonas

A dissertation submitted to the Graduate Faculty in Business in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1984

This manuscript has been read and accepted for the Graduate Faculty in Business in satisfaction of the dissertation requirement for the degree of Doctor of Philosophy.

28 June 1984
date

Chairman of Examining Committee

19 July 1984
date

Executive Officer

Steven Lustgarten

George Papaioannou

Joel Rentzler

Kishore Tandon

Stavros Thomadakis

Supervisory Committee

The City University of New York

## ABSTRACT

LIQUIDITY, PRICE VARIABILITY, AND STORAGE ASYMMETRY:
A STUDY OF THE BEHAVIOR OF PRICES IN FUTURES MARKETS

by

Nikolaos T. Milonas

Adviser: Professor Ashok Vora

The hypothesis that price variability increases as time to maturity nears provides the rationale for the so-called "maturity effect", with important implications on futures price behavior. Essay I derives the theoretical basis for this effect in line with Samuelson's (1965) arguments and investigates various non-stationary sources in spot and futures prices in three major futures markets: agricultural, financial and metals. In addition, it explores the hypothesis that near and distant contracts from maturity exhibit different price variability.

The results in Essay I support the following statements: (1) Cyclical movement of prices is the essence in commodity markets. The "month effect" is well documented in the com-

modities examined. (2) The non-stationary nature of the spot price generating process makes variances across years change randomly. Clearly, there is evidence of the "year effect". (3) There is virtually no "contract month effect" with financial futures, but there is with agricultural and metal futures. (4) There is strong evidence that Samuelson's hypothesis of the "maturity effect" cannot be rejected. (5) The behavior of price variability of far-maturing contracts is commodity-dependent; we reject the hypothesis that near and far-maturing contracts behave similarly, for a given commodity.

Essay II of the study develops a common methodology with which commodities from different markets could be compared. Such comparison rests on a distinct source of illiquidity that is associated with the physical nature of the commodities traded. The impossibility of bringing a future crop into consumption today, renders a liquidity premium on nearer contracts over far-maturing contracts. Hirshleifer (1972) presents theoretically this issue of illiquidity and the problem of physical storage with some empirical implications. Since the issue of storage is not crucial for financial futures and precious metals, we do not expect liquidity premium described above in this kind of futures markets. Furthermore, the study of the different pattern of price behavior and different response to new information in futures markets will reveal the degree of "storage asymmetry" in each market.

to my parents

Drosia and Theodoros,

for their unmatched efforts

and personal sacrifices.

being with them is the

most joyful part of my life.

## ACKNOWLEDGEMENT

Many might agree that the most idiosyncratic experience in a dissertation is the writing of acknowledgements. In a few lines I should bring justice to all people who directly helped in the genesis of this dissertation. An even more difficult task is to refer to a good number of individuals who contributed to my education, influenced my thinking, and thus indirectly charted the river of my thought which brought this thesis as the first harvest. In this delicate process of expressing my appreciation, I stand alone in a fortunate moment of truth where present meets past and future with the timeless feeling of always being a student of yet unknown subjects.

My greatest appreciation goes to Ashok Vora, chairman of my dissertation committee, for his undefatigable process of directing this thesis. I would always be indebted for his inumerable hours of suggesting, reading, and encouraging my research. A fine and responsible scholar, he taught me the paradigm of the "true" academician. I am also grateful to the members of my committee, Steve Lustgarten, George Papaioannou, Joel Rentzler, Kishore Tandon and Stavros Thomadakis for their valuable comments and suggestions. I thank Stavros Thomadakis and Gabriel Hawawini for teaching me the theory of finance in the most demanding and creative way and in a friendly and collaborative atmosphere. Jack Francis read earlier drafts of the thesis and provided useful comments. I also received encouraging and helpful comments on earlier drafts presented at the Finance Workshops of Baruch College, University of Massachusetts-Amherst, Syracuse University and University of Pittsburgh.

In no way can I fail to acknowledge the help of two colleagues, roommates, and best friends of mine: Nickolaos Travlos and Theoharry Grammatikos. Their continuous encouragement, enthusiasm, and comments were valuable and will not be forgotten. Best wishes for Nick and Harry in their academic careers. Special thanks are due to Fahrettin Okcabol and the other doctoral students in finance for providing a supportive environment by compounding my optimism and discounting my pessimism. The touching emotional support of my fiancee Maria Kappatos was very important in creating an excellent atmosphere of work. In addition to performing the tedious work of collecting data, she was always understanding, patient, and ready to make sacrifices.

To all my teachers, a list too long to mention here, and in particular at Graduate Industrial School of Thessaloniki who planted in me the seeds of the theory of economics and cultivated the idea of graduate studies abroad, I am most grateful. Finally and importantly, the financial assistance via a Dissertation Grant from the Center for the Study of

Futures Markets, Graduate School of Business, Columbia University is gratefully acknowledged. CSFM has also provided the price data.

CONTENTS

-- ESSAY II: PRELIMINARY INVESTIGATION INTO THE STORAGE ASYMMETRY

Chapter page

## LIST OF TABLES

## LIST OF FIGURES

# ESSAY I: PRICE VARIABILITY AND LIQUIDITY IN FUTURES MARKETS

# Chapter 1

## INTRODUCTION TO ESSAY I

Recent developments in futures markets have led market participants to accept new futures contracts as an alternative tool in investment strategies. This growth of the futures markets today, is a good indication of the useful role these new contracts are playing in allocating risk among a large number of individuals.

From the second half of the 19th century, when they first appeared in an organized form, futures markets served the interests of many distinct groups of people (e.g. farmers, commercial firms, merchandisers, processors of commodities) who wanted to hedge against adverse changes in prices of agricultural goods. Speculators were among these groups of people who had no particular interest in commodities but were taking opposite positions in anticipation of gains from price changes.

Commodity price instability is essential for a successful market to exist. Over the last ten years we have seen the initiation of futures trading in a variety of goods ranging from metals (gold) to financial instruments such as Treasury securities (bills, bonds and notes), commercial paper, foreign currencies and stock indexes. Moreover, the use of futures markets has expanded with the introduction of options on contracts such as gold futures and Treasury bonds futures.

The success of the new financial futures markets is attributed to the same factors that rendered success to agricultural commodities. On one hand, recent increases in interest rate volatility created the need for hedging against adverse changes in interest rates for a variety of fund-managing institutions (banks, pension funds, insurance companies, mutual funds, money funds, corporations, etc.). On the other hand, the possibility of gains from interest rate changes attracted a large number of speculators.

The study of futures markets differs in many respects from the study of spot markets, such as the stock or bond markets. In a stock market there is a similar contract (stock) for all participating firms but underlying firms differ from one another. In contrast, in futures markets there are different contracts for different commodities and in addition for the same commodity there are contracts that differ in time to maturity. However, the underlying commodity for delivery is homogeneous for a set of contracts irrespective of maturity. This characteristic forces futures and spot prices to bear a direct and strong relationship to each other.

Research in futures markets is particularly concerned with the relationship between spot and futures prices and among various futures prices observed simultaneously. According to Working (1948, 1949) the spread in futures prices reflects the carrying charges (costs of storage, interest, and insurance). Among other analysts, Brennan (1958) hypothesized another factor in the spread, the so called risk premium. This is theoretically valid in the context of the liquidity theory of Hicks (1946). In an empirical study, Dusak (1973) finds no such premium to exist in the commodities markets. But others (Bodie and Rosansky (1980)) find a presence of risk premia for the 23 commodities examined.

Among the studies that deal with the "maturity effect" is Samuelson's seminal paper in 1965. He offers a theoretical basis for increasing price variability as contracts approach maturity. Recent empirical evidence by Castelino (1981), Castelino and Francis (1982) and Anderson (1982) strongly support Samuelson's argument. Samuelson's hypothesis has intuitive appeal since he argues that contracts far from maturity react weakly to new information because there is ample time for the uncertainty to resolve before maturity. Conversely, a contract near to maturity reacts strongly to new information since at maturity the futures price must equal the spot price. However, in this context Samuelson's hypothesis is in sharp contrast to Working's. Working (1942, 1948, 1949) argues that intertemporal spreads in futures prices result from current levels of inventories and not from events anticipated in later periods. Therefore, the impact of new information will be impounded equally in all spot and futures contracts irrespective of the time to maturity.

The behavior of price variability is also linked with trading activity. Telser and Higinbotham (1977) and Telser (1981) argue that the standard deviation of market clearing prices is inversely related to the volume of trade. This result can be attributed to the market information which increases with the number of market participants. Cox (1976) substantiates this argument by reporting that an increase in the number of persons with interest in a contract tends to create a liquid market. Illiquid markets are present in the first few months of the opening of a new contract (due to low open interest). Research has suggested that price variability is higher for securities with thin markets than with liquid ones (Cohen et.al. (1976), Cohen et.al. (1978)).

The objective of this study is to investigate the sources and patterns of price variability in various futures markets. It aims to explain price variability from the opening of a contract until its maturity, in three basic futures markets: agricultural, financial and metals. The study, which is based on Samuelson's argument, provides evidence on the following issues:

(1) Non-stationary shocks in spot prices. Random shocks on the demand or supply in the product markets, affect differently the year-to-year variability of spot and futures pric-

es. These year-to-year differences in the price variability produce a non-stationary factor known as "calendar year effect", or simply "year effect". Similar shocks within a year due to seasonality of mainly the supply are captured in the form of different monthly price variability. This source of seasonality is known as the "calendar month effect", or "month effect" for simplicity.

(2) The "contract month effect" in futures prices. In futures prices there is another source of non-staticnarity in addition to the two mentioned above. This random shock which we call "contract month effect", is associated with the fact that futures contracts mature in different calendar months.

(3) "The maturity effect". The hypothesis of the increasing price variability as the futures contract nears maturity, is statistically tested after the non-stationarity in prices is controlled.

(4) Price variability in distant months. We finally test whether distant contracts exhibit higher variability than suggested by the "maturity effect" hypothesis. This hypothesis rests on findings in the stock markets that thinly traded securities exhibit higher variability than liquid securities. In futures markets liquidity can be measured with open interest or volume of trade. The relatively low levels of open interest during the first few months of the opening of a contract, suggests the presence cf illiquid markets.

This might be associated with higher variability than implicit in the maturity effect hypothesis.

The organization of Essay I is as follows: In chapter 2 we review the literature and the major issues in futures markets with implications on futures price variability. Next, in chapter 3 we present the model as the basis for the "maturity effect" and discuss its properties and limitations. Chapter 4 describes the data used in this study and presents some statistical considerations. In chapter 5 we provide empirical evidence on the existence of the non-stationary shocks in spot prices. The use of descriptive statistics and a parametric test as well as the methodology of normalizing futures variances are presented in chapter 6. The evidence on the "contract month" effect and the "maturity effect" hypothesis are also presented in chapter 6. The issue of the price variability in thin markets is the subject of chapter 7. Chapters 8 and 9 present evidence on the relationship of volume and open interest with time to maturity and of the thinness-related price variability hypothesis. Chapter 10 concludes Essay I with some implications of these results on futures markets.

# Chapter 2

## REVIEW OF THE LITERATURE

A futures contract is a promise to deliver a specified quantity of a given commodity, on a specific future date. Every day such contracts are traded on futures exchanges. We can observe, at a specific moment in time, for every traded commodity a cash price quotation (for immediate delivery) and a series of futures price quotations. Demand for and supply of a contract determine the price level of that futures contract. However, what affects demand for and supply of futures contracts and how information about future events is transmitted into futures prices are two closely related issues which have generated a debate with three major positions.

(1) The first position was taken by Working who expressed the traditional view of factors that affect the demand for and supply of agricultural commodities. Holbrock Working (1942, 1948, 1949), a pioneer in futures markets research, has repeatedly argued that the constellation of futures prices is solely determined by the existing levels of inventories and not by expectations regarding future events (e.g. crop yields, income, consumption shifts). The fact that the price of one contract is greater than the price of another,

is attributed to the cost of carrying that commodity between the two delivery dates. Since he precluded expectations on future events from being incorporated in far-maturing contracts, he was reluctant to view futures prices as forecasts of future events to occur before and up to maturity. In this way all futures and cash prices respond equally upon the new information. To state Working's argument differently, the whole spectrum of prices does not exhibit any differential reaction to the new information. In Tomek and Gray's (1970) terminology, "prices of futures six months from maturity, one month from maturity and cash prices are all "forecasts" or "nonforecasts" in approximately the same degree. ...of course, unforeseen developments occur between futures expiration dates. The new but unpredictable information may indeed change expectations, but this is reflected in the entire constellation of prices".[1]

A rejection of Working's conclusion both on theoretical and empirical grounds was advocated by Weymar (1968). He noticed that Working is right only if the time interval between various futures prices is not long enough (two to three months) to allow for change in expectations of inventory levels. However, in his empirical tests he used cocoa as a case study and his findings may very well have revealed some special characteristics of this commodity rather than disputing Working's hypothesis.

-------------------

[1] Tomek and Gray (1970), page 139.

Tomek and Gray (1970) tried to refine Working's concept of the price of storage. They view the price of the distant futures as a forecast of the forthcoming spot price. This clearly is not inconsistent with Working's hypothesis and is quite true in these kinds of futures contracts in which there are no continuous inventories (e.g. potatoes). They tested whether the cash price at harvest time is closely related to the futures price quoted in spring. They found that in inventory-hedging markets (corn, soybeans) the springtime price is a good estimate of the postharvest price and near and distant futures contracts exhibit a high positive correlation. However, in a non-continuous inventory market (Maine potatoes) "the expected price for the next crop year is not related to current stocks", a result which opposes Working's hypothesis. In fact in the non-continuous inventory markets, prices of distant futures are not as variable as cash prices. Although only three commodities are tested (with 17 observations for each) they do throw some light on what we may expect in the behavior of futures prices across commodities of the same kind: (wheat-corn-soybeans-oats), (gold-silver-copper), (live cattle-live hogs-pork bellies), (Treasury securities), as well as across futures markets such as agricultural, metals, and financial.

(2) The second approach was more recently introduced by Samuelson as a promising explanation of futures price behavior. In his 1965 paper, "Proof that Properly Anticipated

Prices Fluctuate Randomly", Samuelson advanced, on theoretical grounds, the intuitive idea that futures contracts near to maturity exhibit greater volatility than futures contracts away from maturity. Indeed, on an intuitive basis, futures contracts far from maturity represent greater uncertainty to be resolved and therefore react weakly on a given information. The opposite is true with contracts close to maturity. Since at maturity, the price of an expiring contract must equal the prevailing spot price, nearer contracts tend to respond strongly to new information so that the price of an expiring futures contract will converge to the spot price.

Starting from a general spot price formation process where next period's spot price is not known but follows at best a probability distribution, Samuelson deducts his main Axiom of Mathematically Expected Price Formation where a futures price quoted today represents a competitive bid for the spot price expected to prevail at contract maturity. Such a model postulates that futures prices on an average will exhibit neither an upward nor a downward bias anywhere and therefore their sequence will be a fair game (or martingale). However, the sequence of futures prices exhibits increased variability during the life of a contract. Such systematic behavior of futures prices induced by the "maturity effect" has important implications on risk-return characteristics. Since riskiness is monotonically increasing towards maturity, the implied return of a futures contract should also increase to compensate risk-averse market participants. Such a requirement imposes certain restrictions on futures behavior similar in spirit with the Keynes-Houthakker-Cootner "normal backwardation" hypothesis. Samuelson, in a more general version of his theorem, provides thecretical support on this disputed doctrine.

Samuelson's argument has important implications for the way spot and futures prices of contracts with different maturities react to the arrival of new information. Whether the information concerns current inventcry conditicns or expectations on the future level of inventories, contracts close to maturity will tend to react more than contracts far away from maturity. In other words, the entire constellation of prices will systematically react to the advent of new information. One can then examine the strength of such reaction of each contract, holding maturity constant. Such an investigation will enrich our understanding of the process by which new information is incorporated intc spot and futures prices.

In an attempt to measure speculators' forecasting ability, Houthakker (1957) examined their skill in choosing near futures as opposed to distant ones. While his results are not clear-cut, they are indicative of the factors influencing near contracts (magnitude and ownership of deliverable stocks at the various terminals) and distant contracts (crop prospects, government policy, outlook of the economy). His results have clear implications. Since the factors that affect futures prices of near and distant contracts are different, these contracts are expected tc behave differently. Naturally, variability patterns is one aspect of behavior this study is set to investigate.

More recently, direct empirical tests of Samuelson's hypothesis provide additional evidence on the "maturity effect". Rutledge (1976) shows that Samuelson's result that the variability decreases with time to maturity, is not a general case. An alternative specification of the spot price generating process can also result in increasing variability with time to maturity.[2] Using four commodities (silver, cocoa, wheat and soybean meal), he tested the null hypothesis that futures price variability is independent of the time to maturity. Absolute value of logarithmic price changes were used as a proxy of price variability. A three-way contingency table grouping daily data by spot price variability, futures price variability and time tc maturity was applied to calculate goodness of fit based on Kendall and Stuart test statistics. The "maturity effect" hypothesis was rejected for wheat and soybean oil, but not for sil-

---

[2] Indeed, Samuelson (1976) in his reply to Rutledge shows that for autoregressive stationary processes of higher order, futures price variability may temporarily reverse its direction with time to maturity. However, with sufficient distance from maturity, futures price variability will be smaller compared with the variability of a contract close to maturity.

ver and cocoa.

Miller (1979) studied the maturity effect on June and December live beef cattle contracts during the 1964-1972 period. While she used the logarithmic price changes as a proxy for variance -as Rutledge did- she calculated the .28-.72 interfractile range as an additional measure. Employing the standard correlation test between price variability and time left to maturity, she accepted Samuelson's hypothesis of the maturity effect. However, these results cannot be considered general since only one commodity is tested.

Castelino (1981) in a recent study of five agricultural commodities (wheat, corn, soybeans, soybean meal and soybean oil) and one metal (copper) gives strong support to Samuelson's hypothesis. Monthly variances based on daily logarithmic price changes are adjusted to take into consideration the non-stationarity of the spot price generating process and the associated effects in the futures markets (calendar year and calendar month effect).[3] Based on 12 years of data (1960-1971), he rejected the null hypothesis that futures price variability is homogeneous across the different times to maturity, for all tested commodities.

Castelino and Francis (1982) also provided evidence of the "maturity effect", an underlying component of basis risk. Based on Samuelson's original result, they tested the

---

[3] Failure of Rutledge (1976) and Miller (1979) to recognize these effects in their analysis contributed to the biasedness of their results.

hypothesis that the volatility of changes in the basis declines as maturity approaches. For all commodities tested (wheat, soybeans, soybean meal and soybean oil) the variability of change in the basis declines uniformly as maturity nears, evidence which indirectly supports Samuelson's basic hypothesis.

(3) The third approach simultaneously determines equilibrium prices in the spot and futures markets and is more general. Within such a framework, Anderson and Danthine (1980) and Stein (1979) derive the testable hypothesis that the variability of futures prices is systematically higher during those periods in which the resolution of uncertainty is high. Within this context, Samuelson's hypothesis is a rather special case in which the resolution of uncertainty is systematically greater as the contract nears maturity. In the same context, Working's hypothesis could equally fit at least for the agricultural commodities where the supply and demand-induced uncertainty follow strong seasonal patterns. Critical weather conditions are constantly affecting expected inventory levels during the summer months. Shocks from the demand side are also greater during those months since demand fluctuations depend upon the prices of other substitutes whose inventory levels are equally volatile in that period.

Since both Samuelson's and Working's views of the behavior of futures prices can be interpreted within the so called "state variable hypothesis", we believe this hypothesis is more general and provides an appropriate explanation of the mechanism of price determination. This suggests that seasonality and time to maturity each affect futures prices alone or jointly and should not be ignored from any study of futures markets.

Anderson (1982) using various statistical techniques provided support for the maturity effect, but recognized seasonal patterns in futures prices as more important determinants of the volatility. A non-parametric generalized rank test showed strong seasonal patterns in agricultural commodities (wheat, corn, oats, soybeans and soybean oil) and live cattle and no seasonality in the case of silver and cocoa. In a parametric test, he regressed the log of monthly variances of daily price changes against the time to maturity, seasonality and a calendar year variable (in a qualitative form). Again seasonality is present in all the markets examined. The maturity effect is significant in 6 cut of the 9 commodities, a finding that supports the notion that increasing price variability as maturity approaches, seems to be a general property in futures markets. In summary, Anderson's study provides support of the "state variable hypothesis" in which Samuelson is right as a special case and where seasonal patterns in all commodities are more significant.

However, in Anderson's paper there is no consideration of the "contract month" effect. If variability of futures prices is affected by the month of maturity, non-adjustment for the "contract month effect" might introduce serious bias, especially in the agricultural commodities.[4] Another constraint of Anderson's methodology is that it cannot "quantify" the "maturity effect" or examine its behavior as maturity nears. Neither can it investigate the linearity or non-linearity of the "maturity effect" hypothesis, a task we undertake in a later chapter.

---

[4] Evidence on this issue is provided in Chapter 6.

## Chapter 3

## THEORETICAL MODEL

A rigorous investigation of the "maturity effect" requires an assumption about the spot price generating process. We assume that for a commodity there is a constant price level P determined by the equilibrium forces of the demand and supply. This "deterministic" price level remains rather stable over a given time. However, as the current and future expected demand and supply conditions are randomly changing, they make current spot and futures prices change in a random fashion. Hence, we can view prices as constantly "hovering" around the deterministic price P and occasionally shift away due to a non-deterministic random shock in the market, $\tilde{S}$. The interaction of the deterministic (P) and the non-deterministic ($\tilde{S}$) components is additive and results in the spot price $\tilde{P}(t)$ at time t:

$$\tilde{P}(t) = P + \tilde{S}(t)$$

Once we isolate S(t) in today's price, we can use it as our basic error component. Following Samuelson (1965) and Rutledge (1976), we model the generation process of the non-deterministic component of spot prices $\tilde{S}$ as an autoregressive linear equation:

$$\tilde{S}(t+1) = aS(t) + \tilde{u}(t+1) \quad (1)$$

where $\tilde{S}(t+1)$ is the uncertain non-deterministic component of spot prices as viewed at present time t. $S(t)$ is the realized non-deterministic component at time t, "a" is a positive damping factor smaller than unity and $\tilde{u}(t+1)$ are independent Gaussian variates with mean and intertemporal covariances zero and a constant variance $s^2$:

$E(\tilde{u}(t+1))=0$, $E(\tilde{u}(t+1)^2)=s^2$, $E(\tilde{u}(t)\tilde{u}(r))=0$, where $t \neq r$.

Also:

$$\tilde{S}(t+2)=a\tilde{S}(t+1)+\tilde{u}(t+2)=a(aS(t)+\tilde{u}(t+1))+\tilde{u}(t+2) =$$
$$=a^2S(t)+a\tilde{u}(t+1)+\tilde{u}(t+2)$$

Subsequently, substituting for $\tilde{S}(t+3)$, $\tilde{S}(t+4)$,..., etc., we can carry this process up to the time of maturity (T):

$$\tilde{S}(T) = a^{(T-t)} S(t) + a^{(T-t-1)} \tilde{u}(t+1) +...+ \tilde{u}(T)$$

Taking the expectations of the last equation, we can derive the expected non-deterministic component of spot prices and its variance as of time t:

$$E_t(\tilde{S}(T)) = a^{(T-t)} S(t) \qquad (2)$$

$$Var_t(\tilde{S}(T)) = (1-a^{2(T-t)}) s^2/(1-a^2) \qquad (3)$$

As a way of linking futures prices to spot prices, we adopt Samuelson's axiom of mathematically expected price formation which expresses current futures prices as the expected spot prices at maturity. However, for us it is only necessary to link the non-deterministic components of spot and futures prices. In this way, $F(t,T)$ is the non-deterministic component of futures prices observed at time t for a contract that matures in time T.

$$F(t,T) = E_t(\tilde{S}(T)) = a^{(T-t)} S(t) \qquad (4)$$

Similarly:

$$\tilde{F}(t+1,T) = a^{(T-t-1)}\tilde{S}(t+1) = a^{(T-t-1)}(aS(t)+\tilde{u}(t+1)) =$$

$$a^{(T-t)}S(t) + a^{(T-t-1)}\tilde{u}(t+1) \qquad (5)$$

If we define $\widetilde{DF}(t,T) = \tilde{F}(t+1,T)-F(t,T)$, as the uncertain change in the futures price between time t and t+1, substituting for $\tilde{F}(t+1,T)$ and $F(t,T)$ from (4) and (5) we have:

$$\widetilde{DF}(t,T) = a^{(T-t)}S(t) + a^{(T-t-1)}\tilde{u}(t+1) - a^{(T-t)}S(t) =$$

$$a^{(T-t-1)}\tilde{u}(t+1)$$

$\widetilde{DF}(t,T)$ is a fair game (or martingale) in the sense of having unbiased price changes, zero expectation,[5] and variance:

$$var(\widetilde{DF}(t,T)) = a^{2(T-t-1)}s^2 \qquad (6)$$

Taking the natural logarithms in equation (6) we derive the following linear equation:

$$\ln\{var(\widetilde{DF}(t,T))\} = \ln(s^2) + 2(T-t-1)\ln(a) \qquad (7)$$

Equation (7) is our basic formula which depicts the variability of futures prices as a linear function of the time to maturity. The following considerations underly the properties of the model:

(1) The "maturity effect" is well manifested if we differentiate (7) with respect to time to maturity, T-t:

$$\partial\ln\{var(\widetilde{DF}(t,T))\}/\partial(T-t) = 2\cdot\ln(a) < 0 \qquad (8)$$

---

[5] The existence of any risk premia is explicity ignored from this discussion by accepting the axiom in (4). If they were to be included, the expected value would be a function of a constant adjustment factor $\lambda$ and would still be a fair game. In such a case one can still show the maturity effect. If this risk adjustment factor is time dependent, it may still be possible to show the maturity effect. For an inclusion of a constant risk adjustment factor in (4), see Castelino (1981).

Since $0<a<1$, equation (8) states that as the time to maturity decreases, futures price variability - expressed as the differences in logarithmic prices - will increase monotonically. Therefore, the null hypothesis of the maturity effect H(0), can be stated explicitly as follows: there is no relationship between time to maturity and price variability. The alternative hypothesis H(1), calls for an inverse relationship between time to maturity and price variability.

(2) At maturity ($t=T-1$), equation (7) produces an anticipated result: $\ln(\mathrm{var}(\widetilde{DF}(t,T)) = \ln(s^2) = \ln(\text{spot variance})$, i.e., at maturity, a contract is as volatile as the underlying spot commodity.[6] $\ln(s^2)$ serves as the upper limit of the variability of futures prices. The lower limit is at the initiation time of a contract, $t=0$:

$$\ln\{\mathrm{var}(\widetilde{DF}(t,T))\} = \ln(s^2) + 2(T-1)\ln(a)$$

(3) The damping factor "a" of the autoregressive process assumed in (1) is present in (7) and affects futures price variability. By differentiating (7) with respect to "a" we get:

$$\partial \ln\{\mathrm{var}(\widetilde{DF}(t,T))\}/\partial a = 2(T-t-1)/a > 0 \qquad (9)$$

i.e., higher damping factors affect positively the futures price volatility. For a given commodity, a higher "a" would mean that a higher portion of any given shock will be embedded in the spot price. Different commodities will have different "a", i.e., spot prices of different commodities will

---

[6] Indeed, equation (3) agrees with this result. If we substitute t with T-1 we get: $\mathrm{var}_{T-1}(\tilde{S}(T))=s^2$

tend to revert to their mean with different strength. By necessity "a" should capture characteristics uniquely identified with each commodity, such as storability, substitutability, elasticities of demand and supply, etc. In light of equation (7), it is interesting to know that "a" can be estimated with conventional estimation techniques. Since "a" is assumed to be less than 1, there is no possibility that the non-deterministic component of spot prices could skyrocket indefinitely.[7]

(4) With the pure expectations hypothesis manifested in equation (4) we have introduced a channel through which information on future events is impounded in futures prices, through the expectation of the future spot price. However, someone could argue that in equation (5) we have abandoned this mechanism since the futures price next period only depends on the spot price prevailing in that period. Nonetheless, what is included in (5) is the damping factor "a" which captures this transmission process of information to the whole constellation of futures prices. In this sense, "a" is bound to reflect the individual characteristics of the particular commodity as well as the general patterns of information arrival into this product market. Hence, commodities with "a" very close to unity would indicate fast transmission of the impact of any given shock on all prices of the underlying commodity. That would be the case of ma-

---

[7] If $a=1$, the variance of futures price changes is constant and the maturity effect disappears.

ture markets where traders can accurately assess the price impact on all the futures prices of supply or demand-induced random events. Therefore, an implicit estimation of "a" could play a rcle of measuring the maturity of a given futures market.

Despite its appropriateness, certain limitations of equation (7) should not be overlooked:

(1) As it was mentioned earlier, the monotonicity of the inverse relationship between volatility and time to maturity can reverse if a higher order autoregressive scheme is used. However, even in such a case, all the present results will again be obtained as long as the coefficients of the lagged variables are smaller than unity.

(2) The damping factor "a" is assumed to be less than 1. The validity of this assumption is jeopardized if there are trends of non-stationarity in cash prices. In this case "a" would be greater than 1. Empirical analysis is left to test the appropriateness of this assumption.

(3) The variance of the autoregressive errors ($s^2$) is assumed constant. If random shocks in cash prices do not have a constant variance the assumption would be violated.

In the next chapter we describe our sample and discuss the major statistical considerations.

# Chapter 4

# DATA AND STATISTICAL CONSIDERATIONS

## 4.1 DATA DESCRIPTION

Some 230,000 daily price observations (available from the Center for the Study of Futures Markets), are the subject of our empirical analysis. The selected commodities, the respective period under investigation, number of delivery months, maximum time (in months) between initiation and maturity of a contract and the number of observations for each commodity are presented in Table 1.

In constructing our sample, an attempt is made to select the most representative commodities from the major futures markets. Thus, we choose three categories: agriculturals, financial and metals. This selection serves another purpose also: it helps to investigate the maturity effect in (a) commodities examined by other researchers (agriculturals, copper and silver) and (b) commodities on which no evidence is available (financials and gold).

The time period for each category of commodities is different: 11 years for the agriculturals, 8 years for metals and for financials ranging from 5.5 years for Treasury bonds and 7 years for Treasury bills to more then 7 years for

TABLE 1

Data Description

| Commodity | Time Period | Number of Delivery months | Highest maturity time (in mon.) | Number of obs. |
|---|---|---|---|---|
| | A. AGRICULTURAL | | | |
| 1. Wheat | Jan 1972-Jan 1983 | 5 | 14 | 17,588 |
| 2. Corn | Jan 1972-Jan 1983 | 5 | 15 | 18,020 |
| 3. Soybeans | Jan 1972-Jan 1983 | 7 | 15 | 23,200 |
| 4. Soybean Meal | Jan 1972-Jan 1983 | 8 | 15 | 26,290 |
| 5. Soybean Oil | Jan 1972-Jan 1983 | 8 | 15 | 26,600 |
| | B. FINANCIAL | | | |
| 6. G.N.M.A. CDR | Oct 1975-Jan 1983 | 4 | 35 | 19,620 |
| 7. Treasury bills (91 Day) | Jan 1976-Jan 1983 | 4 | 23 | 14,736 |
| 8. Treasury bonds | Aug 1977-Jan 1983 | 4 | 35 | 15,928 |
| | C. METALS | | | |
| 9. Copper | Jan 1975-Jan 1983 | 12 | 22 | 23,200 |
| 10.Gold | Jan 1975-Jan 1983 | 12 | 22 | 22,532 |
| 11.Silver | Jan 1975-Jan 1983 | 12 | 22 | 22,622 |

G.N.M.A.[8]

The number of daily price observations (which include spot prices as well) is a function of the number of delivery (contract) months available,[9] time to maturity at initiation and number of years included. So, while the soybean complex

[8] All three financial futures prices begin at the time the first contract was initiated.

[9] Thereafter, "delivery month" or "contract month" will be used interchangeably to denote the specified month on which the futures contract calls for delivery of the underlying commodity.

is selected for the same period as wheat and corn, we have more observations with the soybean complex since trading is permitted for greater number of delivery months (7 for soybeans and 8 for soymeal and soyoil, compared to only 5 for corn and wheat). For all agricultural commodities the maximum number of months to maturity is 14 or 15. Financial futures contracts are delivered 4 times within a year. However, G.N.M.A. and Treasury bonds can be initiated 35 months before maturity. Treasury bills can be initiated up to 23 months before maturity, while for metals the number is 22. Note that all metals have a delivery every calendar month.[10]

## 4.2 STATISTICAL CONSIDERATIONS-THE MATURITY EFFECT HYPOTHESIS

With our main result in equation (8), we can construct the null hypothesis as follows:

> H(0): There is no relationship between time to maturity and futures price variability.
>
> H(1): There is an inverse relationship between time to maturity and variability of futures price changes.

This hypothesis can be tested by using the following OLS regression model:

$$\ln(Y) = c + bX + e \qquad (11)$$

---

[10] However, there are only six specific delivery months in which you can initiate a contract up to 22 months in advance. In the other six months delivery is permitted either because they are current months, or they are the next two calendar months.

where, Y is measuring the variability of futures prices, "c" is a constant which according to (7) estimates the logarithm of the variance of spot price. As such, it is expected to be positive and significantly different than zero. "b" is the coefficient estimate of the time-to-maturity variable (X). By virtue of (7), "b" estimates the quantity 2·ln(a) from which "a" can be estimated implicitly. Furthermore, "b" should be negative and significantly different from zero if there is a maturity effect in futures markets. Finally, "e" is the regression error with a zero mean, constant variance, and no autocorrelation.[11]

Measuring the variability of futures prices (Y), is a choice with many alternatives for the researcher: variance of price changes, residual variance, coefficient of variation, interfractile ranges, etc. The estimation time can be daily, weekly, or monthly.[12]

---

[11] It should be noted that Y, X and e, are time series-cross sectional vectors that extend over the entire sample period of each commodity for all possible delivery months.

[12] Parkinson (1980), Garman and Klass (1980) and Beckers (1983), demonstrate a daily estimate of the variance based on the high, low and closing prices. Assuming that the logarithm of stock prices follows a random walk with the true variance as a diffusion constant, Parkinson (1980) derived the following estimate of the variance of returns (claimed to be 5.4 times more efficient than the conventional estimate of variance):

$$\hat{s}^2 = (H-L)^2 / 4\ln 2$$

Garman and Klass (1980) assuming that the logarithm of stock prices follows a Brownian motion with zero drift, presented an estimate 7.4 times better than the conventional. Their estimate utilizes the closing prices as an additional source of information, as well as the joint effects between high, low and closing quantities.

In our empirical analysis we estimate the variability of price changes by calculating the classical estimator of variance, for its simplicity of use and its freedom from obvious sources of error or bias. The recent studies of Castelino (1981) and Anderson (1982) also use the variance of price changes, so our results can be compared.

For each contract maturing in month T, the logarithmic price changes are calculated as follows:[13]

$$DF(t,T) = \ln\{F(t+1,k,T)/F(t,k,T)\} \qquad (12)$$

where, t denotes the day in which the futures closing price F(t,k,T) is observed and k denotes the calendar month. Then we can calculate the average ADF(k,T) of the distribution of price changes for contract T in month k:

---

The main disadvantage of these methods is that (1) assume transactions occuring continuously and (2) stock prices follow the same path during the periods on which stock exchanges are closed. These two strong assumptions might introduce bias to the estimators either predictable (finite transaction volume, bid-ask spread differential non-stationary volatility), or unpredictable. It seems that lack of continuous trading will bias the estimators downwards since the observed "high" and "low" prices will understate and overstate respectively, the unobserved "true prices". A third problem that biases the estimators further is associated with their use in estimating daily variances of futures price changes. Since in these markets daily price limits are always imposed, daily estimates of variances will intensify the problem of downward biased estimators. The main advantage however, is that these estimators utilize additional information that the close-to-close conventional estimation techniques do not and as such they may contribute more to estimator efficiency.

[13] Price changes in (12) can also be considered as daily returns for an investor with zero capital investment (0% margin requirements).

$$ADF(k,T) = \sum_{t=1}^{N(k)} DF(t,k,T)/N(k)$$

The respective variance VDF(k,T) of these price changes is given by:

$$VDF(k,T) = \sum_{t=1}^{N(k)} \{DF(t,k,T) - ADF(k,T)\}^2/(N(k)-1) \quad (13)$$

where, N(k) is the number of observations in month k.[14]

In equation (11) we use logarithms for two main reasons: (1) The theoretical derivation in (7) expresses price changes in a logarithmic form so direct use of logarithms is well-justified. (2) The use of logarithmic price changes prevents at least one source of non-stationarity from unpredictably affecting futures price variability. This source is associated with the price level of the commodity. As prices move in one direction, their dispersion most likely moves in the same direction introducing unwanted biases. Use of logs minimizes these biases.

To capture the maturity effect in the variability of futures prices we should select a short enough period. The distribution of price changes will follow a stationary process within this period, even though it may be non-stationary from period to period. One month seems a good estima-

---

[14] The maximum number of trading days within any calendar month is 23. Months with fewer than 15 observations were excluded from the study.

tion period that conforms to these assumptions on the distribution of price changes. However, some bias might be introduced if the distribution of price changes is somewhat non-stationary within the estimation period.

Another important reason for calculating variances over monthly periods is to dilute the effect of the daily price limits present in futures markets. It is believed that a long enough period such as one month will permit trading to reach a market-clearing price. The existence of a market clearing price is prevented occasionally by daily price limitations.[15]

There are other sources of biases which are also of much importance. Two such biases present in the variability of spot prices, known as the "year effect" and the "month effect", are presented in the next chapter.

---

[15] Daily price limitations are bound to introduce downward biases if statistical techniques that allow the estimation of daily price variability are applied in futures markets. See footnote 12.

# Chapter 5

# NON-STATIONARY SHOCKS IN SPOT PRICES

## 5.1 EVIDENCE ON THE CALENDAR YEAR EFFECT

Inventory levels in agricultural commodities are very volatile from year to year. This is due to the worldwide weather conditions which affect the commodity supply and unpredictable political events that affect their demand. The year-to-year instability in inventory levels imposes different volatility in spot and futures prices. Similar situation exists for financial futures where Federal Reserve policies and the government fiscal policies influence strongly the volatility of interest rates from year-to-year. Year-to-year shocks affect the volatility of precious metals (gold and silver) as well, through the level of interest rates, the exchange value of the dollar, expected inflation, political instability, etc. Copper, as an industrial metal, is sensitive to interest rate changes and relates its volatility to the status of the economy rather than any other particular factor.

In Table 2 the year effect is presented for all commodities except Treasury bonds. While the year effect underlies both spot and futures prices we study it only in the spot prices because: (1) we want to avoid any confounding due to the "contract month effect" as well as the "maturity effect" present in the futures prices and (2) the futures prices are not suitable for studying the non-stationary behavior of the commodity since they are associated with different crops.

Average of the spot variances calculated over monthly periods are presented for each year of the available data.[16] The total number of observations involved is also included. The commodities within each of the three selected groups tend to behave similarly, showing significantly different volatilities from year-to-year. Agriculturals exhibit high volatilities in the years of relatively small supplies (1973-1974) and President Carter's grain embargo to the Soviet Union (1979, 1980). G.N.M.A and T-bills peaked in volatility in the two most expensive years to borrow, 1979 and 1980. Precious metals peaked in 1980, the year with turbulent political events. In addition, they experienced higher variability after 1979 when indeed expectations on inflation were also very high. Overall, silver shows a higher level of variability relatively to gold. Copper had its highest volatility during 1977, then decreased smoothly (possibly due to the low economic activity) until a jump in 1980 and an increase in 1982.

---

[16] Note that the variance of spot price changes was calculated similarly to the variance of futures price changes, equation (13).

TABLE 2

The Year Effect in Spot Prices

Average Spot Variances

| Year | Corn | Wheat | Soybeans | Soymeal | Soyoil |
|---|---|---|---|---|---|
| 1972 | .000136 | .000214 | .000126 | .000244 | .000314 |
| 1973 | .000739 | .001213 | .001993 | .002436 | .002393 |
| 1974 | .000715 | * | .000903 | .002333 | * |
| 1975 | .000393 | * | .000487 | .000658 | * |
| 1976 | .000261 | * | .000459 | .000509 | * |
| 1977 | .000187 | .000424 | .000567 | .000790 | .002782 |
| 1978 | .000106 | .000391 | .000438 | .002246 | .001256 |
| 1979 | .000167 | .000526 | .000320 | .000330 | .000221 |
| 1980 | .000466 | .000416 | .000405 | .001175 | .000615 |
| 1981 | .000163 | .000561 | .000206 | .000618 | .000394 |
| 1982 | .000179 | .000265 | .000129 | .000119 | .000162 |
| OBS | 132 | 80 | 132 | 132 | 82 |
| DF | 10/121 | 7/72 | 10/121 | 10/121 | 7/74 |
| F-VALUE | 7.06 | 2.29 | 8.33 | 8.99 | 5.06 |
| PR>F | .0001 | .0362 | .0001 | .0001 | .0001 |
| H-VALUE | 50.06 | 15.59 | 53.04 | 60.06 | 28.69 |
| PR>CHI-SQ | .0001 | .0291 | .0001 | .0001 | .0002 |

| Year | G.N.M.A. | T-bills | Copper | Gold | Silver |
|---|---|---|---|---|---|
| 1975 | * | * | * | * | .000283 |
| 1976 | * | * | * | * | .000266 |
| 1977 | .000003 | .000001 | .006953 | .000081 | .000090 |
| 1978 | .000054 | .000006 | .001107 | .000210 | .000140 |
| 1979 | .000131 | .000013 | .000315 | .000314 | .000745 |
| 1980 | .000113 | .000059 | .000791 | .001024 | .004190 |
| 1981 | .000159 | * | .000222 | .000366 | .000865 |
| 1982 | .000092 | .000006 | .001244 | .000715 | .000844 |
| OBS | 61 | 41 | 62 | 61 | 93 |
| DF | 5/55 | 4/36 | 5/56 | 5/55 | 7/85 |
| F-VALUE | 12.43 | 9.32 | 6.05 | 6.32 | 24.32 |
| PR>F | .0001 | .0001 | .0002 | .0001 | .0001 |
| H-VALUE | 22.21 | 19.23 | 22.17 | 21.57 | 63.08 |
| PR>CHI-SQ | .0005 | .0007 | .0005 | .0006 | .0001 |

* Spot prices were not available

To test the significance of the year-to-year differences in the volatility of spot prices, we run ANOVA tests (with randomized sample sizes of unbalanced data).[17] An ANOVA test for a one-way classification for n years, has the following null and alternative hypothesis:

> H(0): m(1)=m(2)=.....=m(n), i.e., the n population means are equal.
>
> H(1): At least one of the n population means differs from the rest.

We calculate $s^2(b)$ as a measure of the variability among the n sample means and $s^2(w)$ as a measure of the variability within the n populations. The null hypothesis of equality of the n population means is rejected if $F=s^2(b)/s^2(w)$ exceeds the tabulated value of F for a given significance level and degrees of freedom for numerator n-1 and N-n for denominator, where N is the total number of observations (OBS). Degrees of freedom (DF), F-value and the significance probability (PR>F) are all included in Table 2. The results are very convincing for all the commodities. At the .01% level of significance we reject the null hypothesis that the average monthly spot variances are equal in all years of data.[18]

---

[17] In all the ANOVA and the non-parametric tests that follow in the text we took the logarithm of the variance of spot or futures relative price changes, simply because the use of logarithms eliminates additional sources of non-stationarity such as the changing level of prices. See also earlier discussion.

[18] The only exception is wheat where significance is at 3.62%.

The use of the one-way analysis of variance rests on the assumptions that the sampled populations are normally distributed with equal variances. As long as these assumptions hold, the parametric test of ANOVA is very powerful. When either of these assumptions is not met we need an alternative test with weaker assumptions. Non-parametric tests offer such an alternative by not requiring any specific form of the population distributions. The only requirement is for the samples to be independent and for the populations to be infinite. The most widely used non-parametric test is the Kruskal-Wallis one way analysis of variance by ranks, which makes use of ranks rather than the original observations. This ranking process of our observations measures the data by scores on an ordinal scale, a procedure which makes the median score as the only appropriate descriptor of the variance of price changes. Hence, if we have monthly estimated variances for n years, we test the null hypothesis that the median scores are equal for the n populations:

> H(0): M(1)=M(2)=.....=M(n), i.e., the n population medians are equal.
>
> H(1): At least two of the population medians differ from each other.

The Kruskal-Wallis test statistic H is then calculated using the basic form of ordinary one-way analysis of variance. A large H-value tends to dispute the null hypothesis that the samples are drawn from identically distributed populations. If there are more than three groups and more than five observations in each group, the asymptotic sampling distribution of H is the CHI-SQUARE distribution with n-1 degrees of freedom and this is usually accurate enough for most practical purposes.[19]

The H statistic of the Kruskal-Wallis non-parametric test is included in Table 2, as well as its significance probability (PR>CHI-SQ) using the Chi-square approximation. The "year-effect" is again present at .01% level of significance (2.91% in the case of wheat). Two other non-parametric test were also calculated: Brown-Mood (n-sample median test) and n-sample Van der Waerden test. The results were similar to Kruskal-Wallis tests and hence are not presented.

## 5.2 EVIDENCE ON THE CALENDAR MONTH EFFECT

The second important source of non-stationarity in spot prices is the fact that in certain calendar months futures prices are more volatile than in others. This is due to the arrival pattern of information regarding futures contracts. It is only natural that information on the crop size of agricultural commodities accumulates and becomes of much importance during the summer and early fall months of the harvest season. The same may be true for financials and metals if some information on financial variables is repeatedly revealed during certain months.

---

[19] For a description of the Kruskal-Wallis test and other non-parametric tests, see J.D. Gibbons (1976); and J.V. Bradley (1968).

What the "month-effect" really means is the following: observing a December wheat contract in March or in June, is not only different because of the different time to maturity involved but it is also different since it is observed in months that exhibit different volatility. It also means that a September contract observed in March, or a December contract observed in June is not the same thing, despite the fact that the time-to-maturity is 6 months in both cases.

In Table 3 we test for the "month effect". Average variances of spot prices for each calendar month seems to be different for each of the commodities as is clearly seen in Figures 1-3. The heightened volatility of spot prices during the summer and fall months is quite clear in the agricultural commodities. Wheat has the highest variability in June (the month of harvest), with significant variability in the surrounding months but lowest during the fall and winter months. Similarly the soybean complex (beans-meal-oil) reaches its highest variability during the summer months and the lowest during the late fall and early winter months. With the harvest of corn reaching a peak in September and October, price variability becomes very high in these months. For the two financials examined, Treasury bills show higher price variability in the first six months (January through June) and 4-5 times smaller in the second six months (July through December). For GNMA the pattern is repeatedly reversed throughout the months, although the vari-

TABLE 3

The Month Effect in Spot Prices

Average Spot Variances

| Calendar Month | Corn | Wheat | Soybeans | Soymeal | Soyoil |
|---|---|---|---|---|---|
| Jan | .000250 | .000431 | .000786 | .001014 | .000294 |
| Feb | .000299 | .000547 | .000253 | .001110 | .000416 |
| Mar | .000204 | .000280 | .000278 | .000520 | .000322 |
| Apr | .000164 | .000419 | .000301 | .001356 | .000281 |
| May | .000231 | .000381 | .000335 | .000379 | .000342 |
| Jun | .000317 | .000962 | .000613 | .001948 | .001673 |
| Jul | .000381 | .000306 | .001468 | .001879 | .002639 |
| Aug | .000390 | .000445 | .000740 | .001320 | .000609 |
| Sep | .000427 | .000804 | .000695 | .000862 | .000290 |
| Oct | .000541 | .000216 | .000438 | .000755 | .000369 |
| Nov | .000333 | .000359 | .000407 | .000710 | .001651 |
| Dec | .000274 | .000303 | .000267 | .000646 | .000295 |
| OBS | 132 | 80 | 132 | 132 | 82 |
| DF | 11/120 | 11/68 | 11/120 | 11/120 | 11/70 |
| F-VALUE | 2.27 | 0.59 | 1.29 | 0.59 | 0.65 |
| PR>F | .0151 | .8322 | .2386 | .8344 | .7798 |
| H-VALUE | 20.15 | 5.58 | 12.51 | 5.83 | 5.15 |
| PR>CHI-SQ | .0433 | .9001 | .3264 | .8843 | .9237 |

| Calendar Month | G.N.M.A. | T-bills | Copper | Gold | Silver |
|---|---|---|---|---|---|
| Jan | .000098 | .000030 | .002130 | .001593 | .001733 |
| Feb | .000147 | .000019 | .000505 | .000436 | .000600 |
| Mar | .000102 | .000018 | .002796 | .000266 | .002894 |
| Apr | .000113 | .000029 | .000295 | .000415 | .000472 |
| May | .000073 | .000032 | .000263 | .000130 | .000662 |
| Jun | .000052 | .000024 | .000299 | .000243 | .000571 |
| Jul | .000049 | .000005 | .000285 | .000321 | .000362 |
| Aug | .000158 | .000007 | .000505 | .000382 | .000515 |
| Sep | .000072 | .000004 | .000433 | .000519 | .001376 |
| Oct | .000175 | .000004 | .000292 | .000372 | .000563 |
| Nov | .000088 | .000003 | .004522 | .000411 | .000657 |
| Dec | .000097 | .000008 | .000545 | .000266 | .000613 |
| OBS | 61 | 41 | 63 | 62 | 93 |
| DF | 11/49 | 11/29 | 11/51 | 11/50 | 11/81 |
| F-VALUE | 0.46 | 0.93 | 0.70 | 1.04 | 0.25 |
| PR>F | .9196 | .5240 | .7368 | .4274 | .9922 |
| H-VALUE | 8.10 | 10.03 | 6.32 | 9.44 | 2.59 |
| PR>CHI-SQ | .7047 | .5280 | .8509 | .5809 | .9951 |

Figure 1

# The Month Effect In Spot Prices: Agricultural Commodities

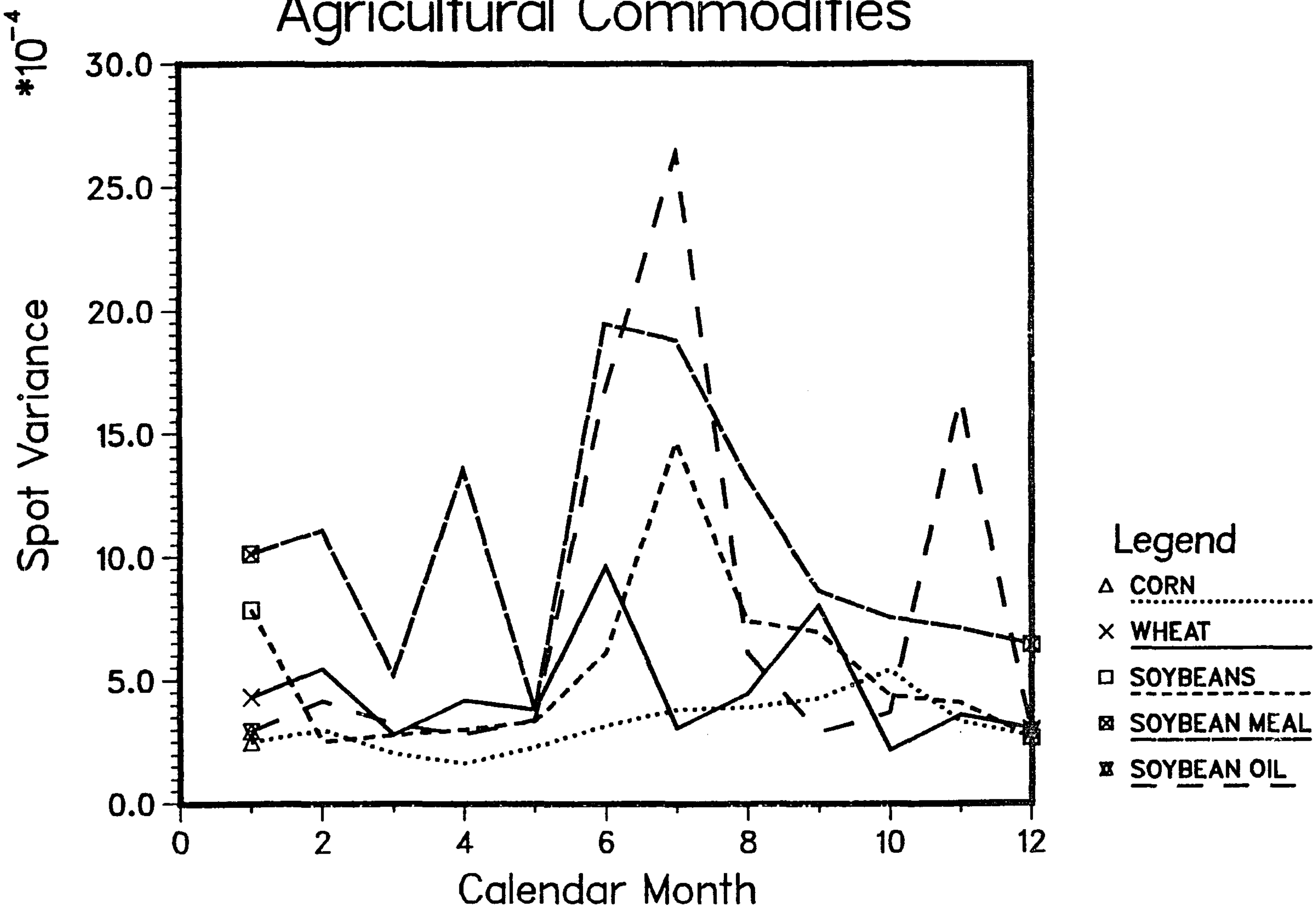


Figure 2

# The Month Effect In Spot Prices: Financials

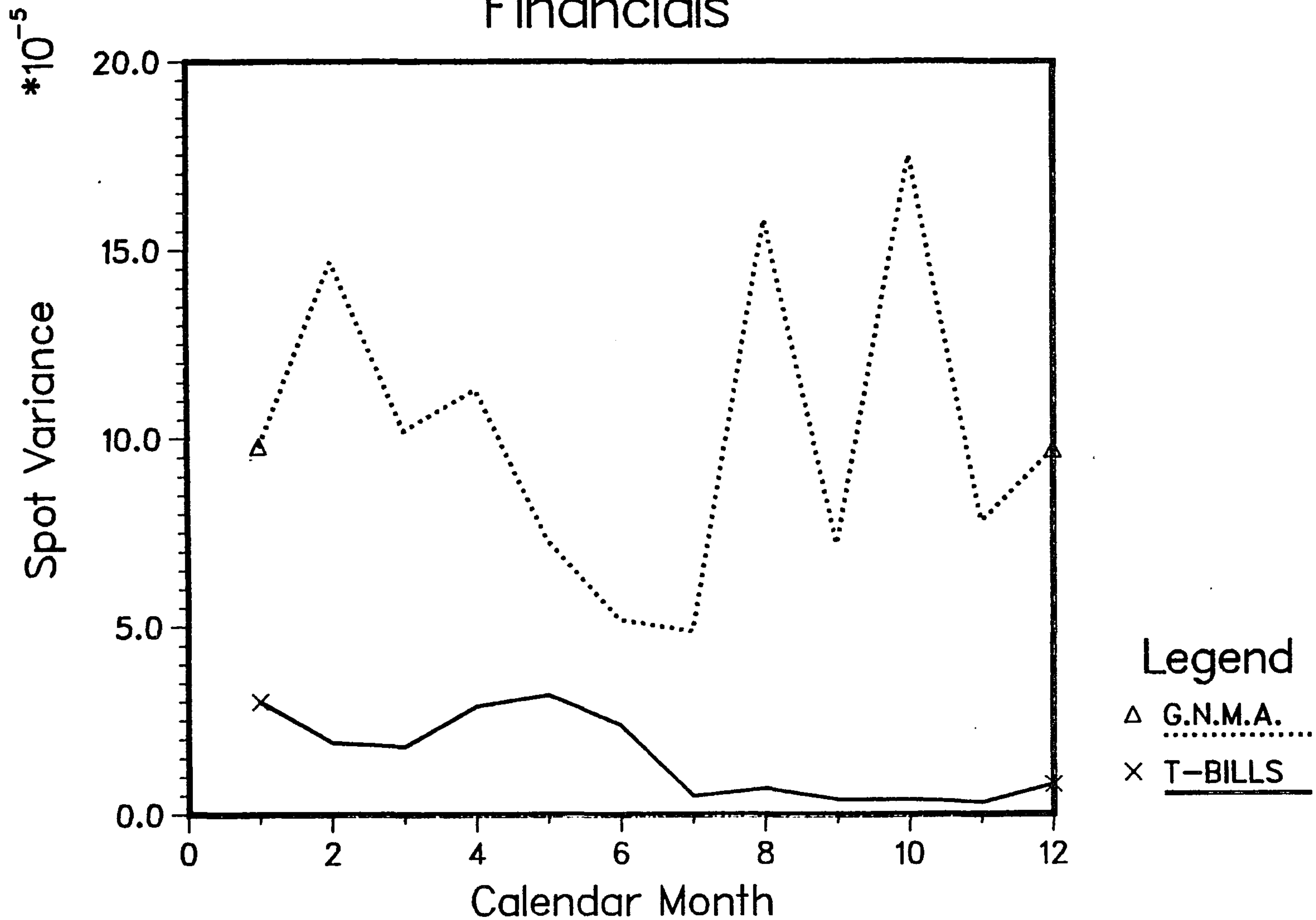
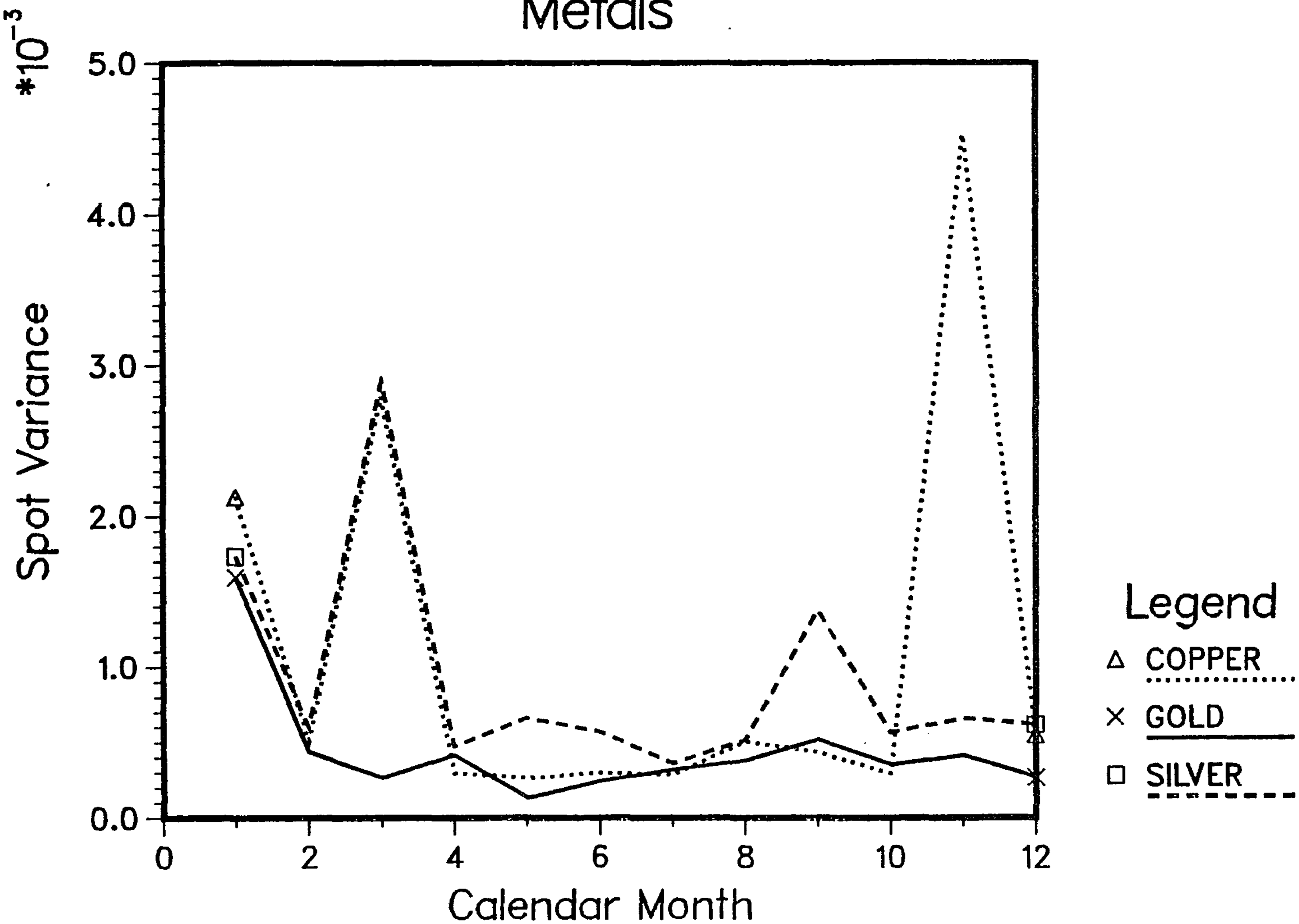


Figure 3

# The Month Effect In Spot Prices: Metals



ability in May, June, July and September is on the average almost as half as the variability in the others. The results seem to indicate that GNMA is more volatile through the year than Treasury bills. This might be attributed to the fact that the GNMA underlying instrument has a longer maturity than the 91-day Treasury bill. It may also be because the market for GNMA contracts is affected by other factors (e.g. housing demands, etc.), in addition to those which affect the Treasury bill rates. For all the metals it is clear that seasonality through the "month-effect" is significant, although the exact reasons is rather difficult to pinpoint.

To manifest the "month effect" statistically, we use the ANOVA tests as described before. However, now we classify the logarithms of spot variances according to the calendar month they are observed in. As it is indicated by the marginal significance level (PR>F) in Table 3, we cannot reject the null hypothesis of the equality in the variances in all commodities. Even with Kruskal-Wallis tests we cannot reject the null hypothesis. This statistical result contrasts sharply with our earlier discussion about the differences in variability across calendar months. The explanation for this paradox, however, seems to be very simple: because the "year effect" is very significant (as it is evident from Table 2) in the variability of spot prices, it dominates the "month effect" and hides the latter when using conventional techniques to test differences. If an attempt is made to control for the year effect, it is believed that the "month effect" would significantly be revealed.[20]

The results on Tables 2 and 3 have important implications on future research in futures markets: calculating a simple logarithmic price change between two trading days as in equation (12) is not sufficient to control for the calendar year or month the observation is taken from. There are additional steps to be taken in constructing price series free of non-stationary effects. The evidence shows that both the calendar year and month are important sources of non-stationarity in spot prices. Hence these effects need to be neutralized before we assess the variability due to maturity effect. A methodology for controlling these effects and evidence on the "contract month" effect and "maturity effect", is presented in the next chapter.

---

[20] In Appendix A we attempted an ANOVA test on geometrically normalized spot variances as follows: From the monthly spot variances we found the geometric average for each calendar year and use it to standardize all monthly spot variances for that year. We then run an ANOVA test as described earlier. According to the F-test, only three commodities (corn, soybeans and gold) show significant "month effect". For the rest, this method of standardization is still ineffective.

## Chapter 6

## EMPIRICAL RESULTS IN FUTURES PRICES

### 6.1 A METHODOLOGY OF NORMALIZING MONTHLY VARIANCES

In order to increase the degrees of freedom in our statistical tests, we not only must mix observations from different calendar months and years, but also observations from different contract months. In so doing, however, we should recognize the various biases we introduce in our tests.

In any given year Y, within any given calendar month t, for a single commodity, trading is possible in C(t) contracts. The variability of each futures contract maturing in month T(j) (where j=1,2,...,C(t)) is subject to a uniquely defined information set:

$$I^{T(j)}(Y, t, T(j))$$

where T(j)-t equals the time (in months) left for contract T(j) to mature. Since our objective is to study the maturity effect we must "normalize" the information set in such a way as to make the futures price dependent upon only the time to maturity.

If $V_{tj}$ denotes the variance of futures price changes in calendar month t of a contract maturing in T(j)-t months, the average futures variance in month t, $A(v_t)$, is defined as the geometric average of the individual variances $V_{tj}$ observed in month t:

$$A(v_t) = \left(\prod_{j=1}^{C(t)} V_{tj}\right)^{1/C(t)} \qquad (14)$$

where, C(t) is the number of contracts open for trading in calendar month t. The use of the geometric average in (14) -as it is also argued in Castelino (1981)- is justified by our derivation in (6).[21] Then, the normalized monthly variance is defined as:

$$N(V_{tj}) = V_{tj}/A(v_t) \qquad (16)$$

This averaging procedure makes the normalized variance independent of the month and year in which it was estimated.

Having normalized the monthly futures variances through (14) and (16) we can now test for the possible non-stationarity due to the contract months. It is hoped that the normalization procedure would alleviate this problem but it is possible that a strong "contract month" effect may still exist in the normalized variances.[22]

---

[21] It can be proved that the geometric average variance of C(t) contracts in month t, is the (implicit) variance of a contract with maturity equal to the arithmetic maturity of the C(t) contracts.

Suppose that n=C(t) contracts are traded in month t with maturities, T(1), T(2), T(3),..., T(n). From equation (6), we can substitute for the variance of price changes in equation (14):

$$A(v_t) = \{a^{2(T(1)-t-1)}s^2 a^{2(T(2)-t-1)}s^2 \ldots \ldots a^{2(T(n)-t-1)}s^2\}^{1/n} =$$
$$= \{a^{2n(T(1)+T(2)+\cdots+T(n)-n(t-1))}s^{2n}\}^{1/n} =$$
$$= a^{2(\bar{T}-t-1)}s^2 \qquad (15)$$

where, $\bar{T}=\{T(1)+T(2)+T(3)+\ldots+T(n)\}/n$. Equation (14) shows that $A(v_t)$ is the same as the variance of a contract with maturity equal to the average maturity of the contract months traded in month t.

[22] Note that we cannot test the "contract month" effect on

## 6.2 EVIDENCE ON THE CONTRACT MONTH EFFECT

In Table 4 we present evidence of the contract month effect for the 11 futures markets. The normalized variances are averaged by the contract month. Therefore, Table 4 refers to arithmetic averages of geometrically normalized variances. The results show that for the agriculturals (except corn) the May or July contracts have the highest volatility. Both May (for wheat) and July (for the soybean complex) contracts call for delivery of the "old crop". Since it is possible for the agricultural commodities to experience uncertainty before the "new crop" arrives, the "harvest effect" seems to impose greater variability in the maturing contracts. Another factor which might add to the higher variability is the phenomenon of squeezes in the delivery month (which often is a technical problem) where the outstanding futures contracts call for delivery of amounts greater than the existing supplies. Squeezes appear usually before the new crop arrives and as such affect positively the variability of contracts maturing during these months. Both phenomena of inverted markets (shortages and squeezes) are serious for agricultural commodities but less so for metals and financial futures.[23] The December contract month

---

non-normalized monthly futures variances. The reason is that non-normalized futures variances are unpredictably biased by the "year" and "month" effects. Only after controlling for these effects through the normalization process we can test for the "contract month" effect.

[23] The problem of inverted markets created by shortages in current supplies, is discussed in Essay II of this study.

has the highest variability for corn, GNMA (excluding November), and T-bills. For T-bonds and gold, the most volatile contract is for March and for copper and silver it is the October contract.

To test the significance of mean differences of normalized variances across contract months, we run ANOVA tests. As shown in Table 4 the mean of normalized variances is not different among the various contracts in the three financial futures. Therefore, for these futures we cannot reject the null hypothesis that there is no contract month effect, e.g., a financial contract maturing in March appears to have the same variability as a contract maturing in December.

For agriculturals and metals however, the situation is reversed. We reject the null hypothesis for corn, wheat, soybeans, copper and silver at .2% level of significance and for soybean meal, soybean oil, and gold at 10% level of significance. It seems that for agriculturals and metals, trading in a particular contract month implies accepting price variability that is specific to that contract month.

The Kruskal-Wallis test results are also in the same direction as the ANOVA test results. However at 10%, gold, soymeal and soyoil join the three financials in insignificance to reject the null hypothesis of "no contract month effect". Therefore, it is safe to conclude that there is strong evidence that the contract month is responsible for some portion of the variability of futures prices for only

TABLE 4

The Contract Month Effect

Average Normalized Futures Variances

| Contract Month | Corn | Wheat | Soybeans | Soymeal | Soyoil |
|---|---|---|---|---|---|
| Jan | - | - | 1.0060 | 1.0240 | 1.0041 |
| Mar | 1.0362 | 1.0268 | 1.0208 | 1.0244 | 1.0344 |
| May | 0.9956 | 1.0730 | 1.0280 | 1.0733 | 1.0305 |
| Jul | 0.9516 | 0.9991 | 1.0516 | 1.0637 | 1.0613 |
| Aug | - | - | 1.0431 | 1.0412 | 1.0259 |
| Sep | 0.9955 | 0.9763 | 1.0046 | 0.9926 | 1.0081 |
| Oct | - | - | - | 0.9830 | 0.9893 |
| Nov | - | - | 0.9655 | - | - |
| Dec | 1.0654 | 1.0104 | - | 1.0193 | 1.0133 |
| OBS | 682 | 659 | 906 | 1042 | 1066 |
| DF | 4/677 | 4/654 | 6/899 | 8/1034 | 8/1057 |
| F-VALUE | 13.29 | 4.29 | 3.46 | 1.79 | 1.69 |
| PR>F | .0001 | .0020 | .0022 | .0748 | .0962 |
| H-VALUE | 57.16 | 13.88 | 12.12 | 11.43 | 11.69 |
| PR>CHI-SQ | .0001 | .0077 | .0593 | .1785 | .1657 |

| Contract Month | GNMA | T-bonds | T-bills | Copper | Gold | Silver |
|---|---|---|---|---|---|---|
| Jan | - | - | - | 0.9888 | 1.0087 | 1.0184 |
| Feb | - | - | - | 1.1568 | 0.9998 | 1.0710 |
| Mar | 1.0056 | 1.0137 | 1.0380 | 0.9871 | 1.0540 | 0.9909 |
| Apr | - | - | - | 1.1291 | 1.0033 | 1.0468 |
| May | - | - | - | 0.9902 | 1.0095 | 1.0232 |
| Jun | 1.0045 | 1.0108 | 1.0445 | 1.1659 | 1.0016 | 1.0760 |
| Jul | - | - | - | 0.9934 | 1.0181 | 0.9889 |
| Aug | - | - | - | 1.1563 | 0.9919 | 1.0433 |
| Sep | 1.0076 | 1.0049 | 1.0579 | 1.0000 | 1.0377 | 0.9898 |
| Oct | - | - | - | 1.1670 | 0.9983 | 1.0873 |
| Nov | 1.0409* | - | - | 1.0992 | 1.0455 | 1.0718 |
| Dec | 1.0082 | 1.0023 | 1.0608 | 1.0015 | 1.0030 | 1.0008 |
| OBS | 808 | 661 | 604 | 908 | 892 | 880 |
| DF | 4/803 | 3/657 | 3/600 | 11/896 | 11/880 | 11/868 |
| F-VALUE | 0.06 | 0.27 | 0.07 | 10.11 | 1.70 | 2.82 |
| PR>F | .9923 | .8470 | .9703 | .0001 | .0694 | .0013 |
| H-VALUE | 0.27 | 0.50 | 0.47 | 103.62 | 15.86 | 70.15 |
| PR>CHI-SQ | .9918 | .9187 | .9245 | .0001 | .1463 | .0001 |

* November currently is not one of the delivery months for GNMA. It was only available for trading for very short periods of time.

corn, wheat, soybeans, copper and silver. But, there is no contract month effect for the financials and a weak or no effect on gold, soymeal and soyoil.

## 6.3 EVIDENCE ON THE MATURITY EFFECT

Samuelson's hypothesis of the "maturity effect" is tested in Tables 5 and 6 and is depicted graphically in Figures 4-6. Table 5 shows the average normalized variances for each month to maturity for all commodities. The maturity effect, as a general phenomenon, is evident across commodities. As time to maturity nears, on the average, the variability of futures markets is constantly increasing. However, the almost strict relationship of the increasing variability with time to maturity is true only with wheat, soybeans, and to a lesser degree T-bonds and gold. This might be attributed to a mispecification of the spot price generating process, as has been suggested by Samuelson (1976). A spot price generating process that includes higher order terms can result in temporary decreases in a generally increasing pattern of price variability.

To test whether the means of the logarithms of normalized variances are significantly different among the different months to maturity, we run ANOVA tests. At .01% level of significance (.37% for corn) we reject the null hypothesis that the means are equal, for all 11 commodities tested. We also reject the null hypothesis at .01% level of signifi-

TABLE 5

The Maturity Effect

Average Normalized Variances $N(V_{tj})$ by Months to Maturity

| Months to Maturity | GNMA | T-bonds | T-bills | Copper | Gold | Silver |
|---|---|---|---|---|---|---|
| 1 | 1.0581 | 1.1618 | 1.0978 | 1.1585 | 1.0254 | 1.1224 |
| 2 | 1.0937 | 1.1525 | 1.1873 | 1.1332 | 1.0313 | 1.0608 |
| 3 | 1.0905 | 1.1650 | 1.2539 | 1.1005 | 1.0245 | 1.0470 |
| 4 | 1.0561 | 1.1429 | 1.2087 | 1.0945 | 1.0460 | 1.0411 |
| 5 | 1.0838 | 1.1251 | 1.1967 | 1.0794 | 1.0306 | 1.0380 |
| 6 | 1.0389 | 1.1493 | 1.2171 | 1.0470 | 1.0340 | 1.0200 |
| 7 | 1.0376 | 1.1209 | 1.2178 | 1.0300 | 1.0152 | 0.9990 |
| 8 | 1.0532 | 1.0914 | 1.1185 | 1.0184 | 1.0265 | 1.0101 |
| 9 | 1.0179 | 1.0760 | 1.0696 | 0.9868 | 0.9978 | 0.9824 |
| 10 | 1.0263 | 1.0567 | 1.1104 | 0.9747 | 1.0074 | 0.9795 |
| 11 | 1.0280 | 1.0601 | 1.1097 | 0.9410 | 1.0001 | 0.9654 |
| 12 | 1.0056 | 1.0538 | 1.0707 | 0.9874 | 0.9857 | 0.9800 |
| 13 | 1.0078 | 1.0130 | 1.0288 | 0.9359 | 0.9825 | 0.9789 |
| 14 | 0.9864 | 1.0151 | 1.0732 | 0.9346 | 0.9869 | 0.9593 |
| 15 | 1.0068 | 1.0024 | 0.9222 | 0.9121 | 0.9739 | 0.9420 |
| 16 | 0.9674 | 0.9745 | 0.9813 | 0.8909 | 0.9670 | 0.9750 |
| 17 | 1.0052 | 0.9886 | 0.9894 | 0.8751 | 0.9659 | 0.9524 |
| 18 | 0.9865 | 0.9652 | 0.8714 | 0.9025 | 0.9418 | 0.9089 |
| 19 | 0.9795 | 0.9666 | 0.9095 | 0.8442 | 0.9488 | 0.9352 |
| 20 | 0.9857 | 0.9677 | 0.8121 | 0.8419 | 0.9395 | 0.9220 |
| 21 | 0.9884 | 0.9425 | 0.8214 | 0.8506 | 0.9419 | 0.9318 |
| 22 | 0.9718 | 0.9528 | 0.7951 | 0.8446 | 0.9277 | 1.0060 |
| 23 | 0.9653 | 0.9398 | 0.8337 | - | - | - |
| 24 | 0.9839 | 0.9122 | - | - | - | - |
| 25 | 0.9807 | 0.9098 | - | - | - | - |
| 26 | 0.9346 | 0.9240 | - | - | - | - |
| 27 | 0.9417 | 0.9050 | - | - | - | - |
| 28 | 0.9554 | 0.8989 | - | - | - | - |
| 29 | 0.9375 | 0.8950 | - | - | - | - |
| 30 | 0.9801 | 0.9124 | - | - | - | - |
| 31 | 0.9844 | 0.8831 | - | - | - | - |
| 32 | 0.9413 | 0.9024 | - | - | - | - |
| 33 | 0.9763 | 0.8435 | - | - | - | - |
| 34 | 0.9157 | 0.7962 | - | - | - | - |
| 35 | 0.9785 | 0.8203 | - | - | - | - |
| OBS | 808 | 661 | 604 | 908 | 892 | 880 |
| DF | 34/773 | 34/626 | 22/581 | 21/886 | 21/870 | 21/858 |
| F-VALUE | 3.52 | 21.94 | 6.12 | 58.89 | 10.73 | 10.33 |
| PR>F | .0001 | .0001 | .0001 | .0001 | .0001 | .0001 |
| H-VALUE | 124.30 | 401.01 | 167.84 | 603.92 | 211.14 | 448.00 |
| PR>CHI-SQ | .0001 | .0001 | .0001 | .0001 | .0001 | .0001 |

Table 5 (continued)

| Months to Maturity | Corn | Wheat | Soybeans | Soymeal | Soyoil |
|---|---|---|---|---|---|
| 1 | 1.0185 | 1.1871 | 1.1449 | 1.2555 | 1.1254 |
| 2 | 0.9989 | 1.1730 | 1.1209 | 1.2025 | 1.1477 |
| 3 | 1.0091 | 1.0826 | 1.1130 | 1.1471 | 1.1156 |
| 4 | 1.0119 | 1.0571 | 1.1118 | 1.1276 | 1.1016 |
| 5 | 1.0151 | 1.0319 | 1.0675 | 1.0418 | 1.0900 |
| 6 | 1.0268 | 1.0176 | 1.0277 | 1.0130 | 1.0438 |
| 7 | 1.0250 | 0.9846 | 0.9893 | 0.9740 | 1.0167 |
| 8 | 0.9949 | 0.9632 | 0.9515 | 0.9246 | 0.9804 |
| 9 | 1.0357 | 0.9714 | 0.9416 | 0.9023 | 0.9546 |
| 10 | 1.0092 | 0.9321 | 0.9232 | 0.9214 | 0.9145 |
| 11 | 0.9873 | 0.9368 | 0.9056 | 0.8782 | 0.9037 |
| 12 | 1.0670 | 0.9218 | 0.8701 | 0.8911 | 0.8525 |
| 13 | 0.9581 | 0.8915 | 0.8635 | 0.8978 | 0.8402 |
| 14 | 0.8708 | 0.7932 | 0.9212 | 0.9744 | 0.9075 |
| 15 | 1.0886 | - | 0.9165 | 1.1148 | 0.7574 |
| OBS | 682 | 659 | 906 | 1042 | 1066 |
| DF | 14/667 | 13/645 | 14/891 | 14/1027 | 14/1051 |
| F-VALUE | 2.34 | 14.24 | 19.69 | 25.81 | 23.66 |
| PR>F | .0037 | .0001 | .0001 | .0001 | .0001 |
| H-VALUE | 29.82 | 136.30 | 282.54 | 310.87 | 291.40 |
| PR>CHI-SQ | .0081 | .0001 | .0001 | .0001 | .0001 |

cance (.81% for corn), by applying the Kruskal-Wallis non-parametric test.

Table 6 exhibits the results from the linear regressions of equation (11) for all 11 commodities. For all commodities, except corn, the null hypothesis of no strictly linear relationship between time to maturity and futures price variability is rejected at the .01% level of significance by means of the F-test. The $R^2$ in general is high in all cases (except corn) and is over .5 in the case of T-bonds and copper. In the other commodities it varies between .181 to .245 and only for GNMA and T-bills is as low as about .12.

Figure 4

# The Maturity Effect: Agricultural Commodities

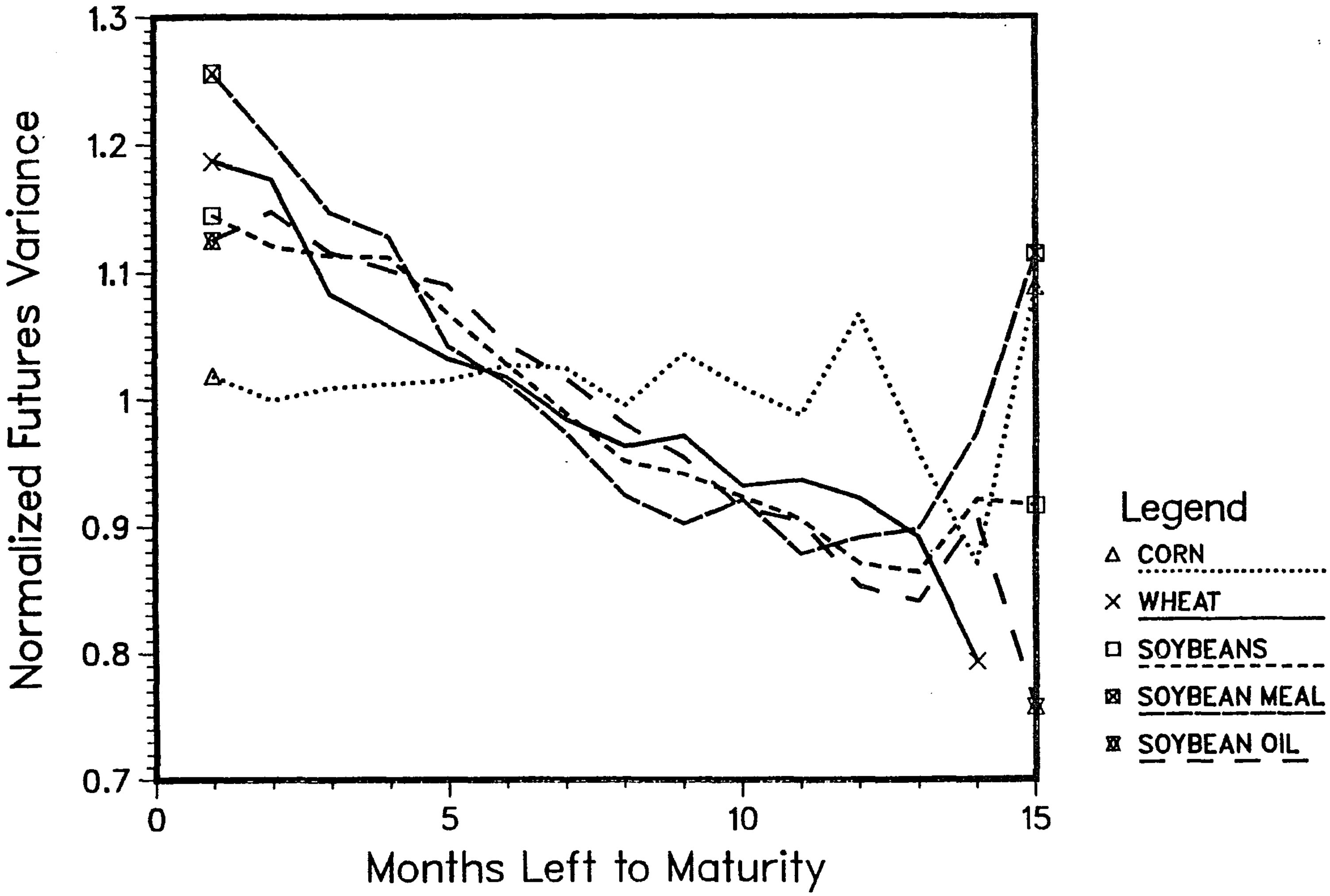


Figure 5
The Maturity Effect:
Financials

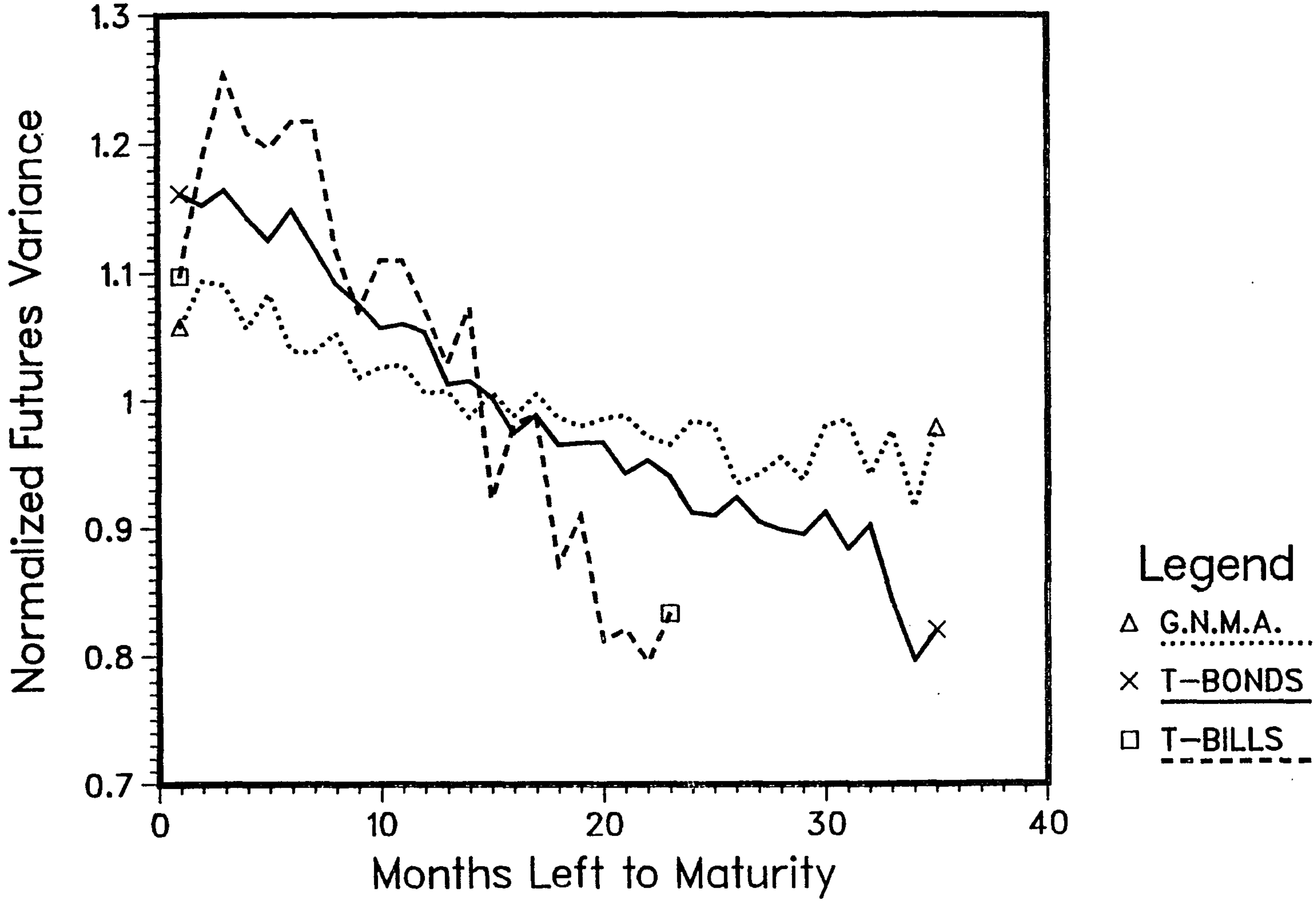
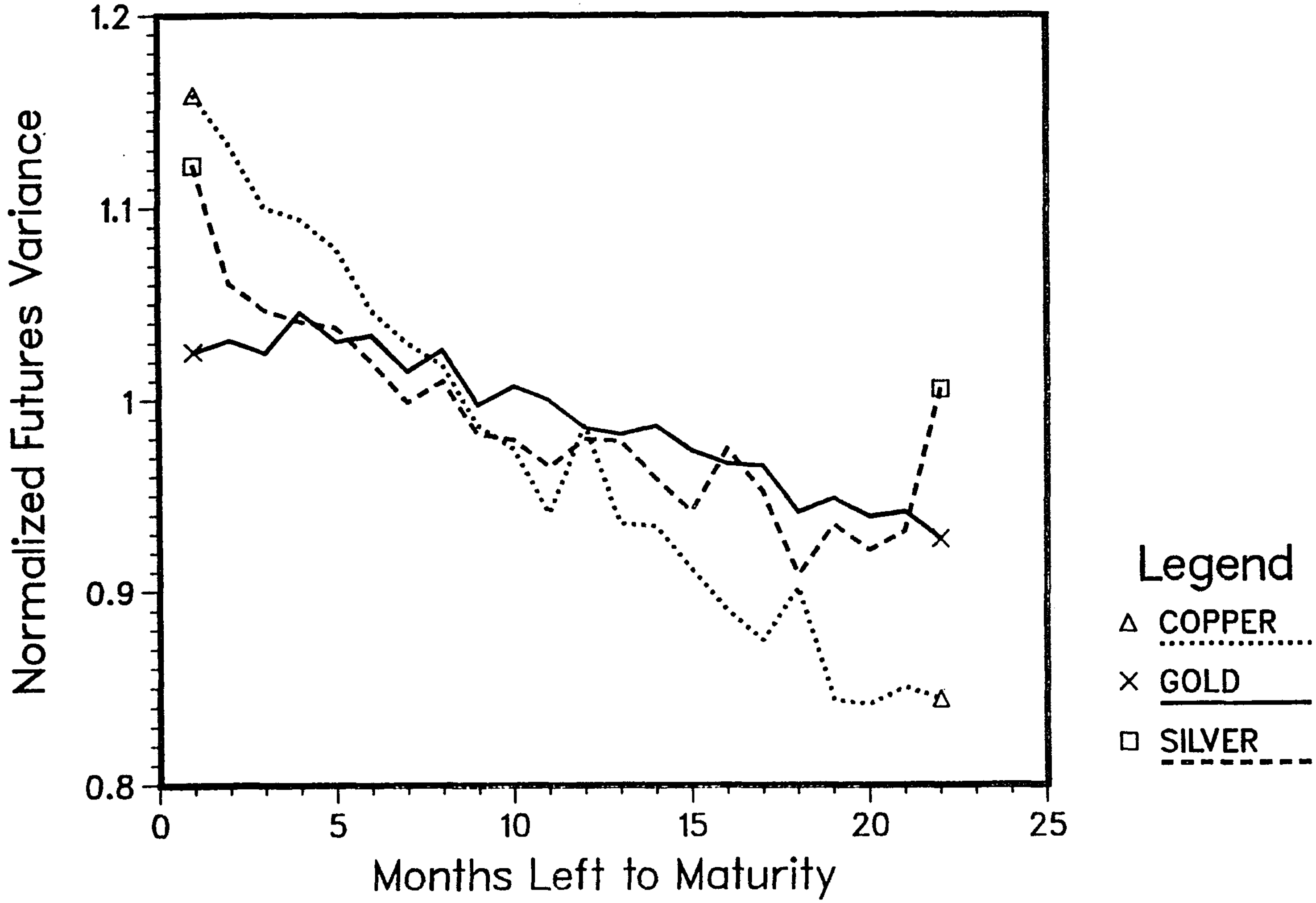


Figure 6

# The Maturity Effect: Metals



For the commodities examined it seems that time to maturity explains a significant portion of the variation in futures price changes. Only in the case of corn the time to maturity fails to explain any significant portion of the futures price variability. There may be other factors not included in our regression that account for the unexplained variability in corn.

The regression coefficients and their sign are in strict conformity with Samuelson's hypothesis. In all cases the intercept is positive and significantly different than zero at .01% level of significance, as suggested by their t-statistics. Exception is only for corn where the intercept is not significantly different than zero. The theoretical derivation in (7) suggests that the intercept in our linear regression is the logarithm of the spot variance. Therefore, we can solve for the normalized spot variance, which appears in Table 6 under $s^2$, as follows:

$$s^2 = \exp(c)$$

In all cases the implicitly estimated normalized spot variance is greater than 1. It reaches its highest value with soybean meal suggesting that the variability of the spot price of this commodity when compared to the variability of its futures prices, is higher than all the other commodities examined.

The slope of the linear regression is negative for all commodities and significantly different from zero at the

TABLE 6

Linear Regression Results: Maturity Effect

Regression Model: $\ln(N(V_{tj})) = c + b(T(j)-t) + e$

| Commod. | DF | c | b | $s^2$ | "a" | F-ratio | Pr>F | $R^2$ |
|---|---|---|---|---|---|---|---|---|
| Corn | 680 | .0105 | -.0015 | 1.0106 | .9993 | 1.11 | .2918 | .002 |
| | | ( 0.94) | ( -1.05) | | | | | |
| Wheat | 657 | .1503 | -.0226 | 1.1622 | .9888 | 176.11 | .0001 | .211 |
| | | (11.66) | (-13.27) | | | | | |
| Soybeans | 904 | .1609 | -.0250 | 1.1746 | .9876 | 262.73 | .0001 | .225 |
| | | (14.25) | (-16.21) | | | | | |
| Soymeal | 1040 | .2117 | -.0330 | 1.2358 | .9836 | 337.67 | .0001 | .245 |
| | | (16.16) | (-18.38) | | | | | |
| Soyoil | 1064 | .1757 | -.0267 | 1.1921 | .9867 | 300.13 | .0001 | .220 |
| | | (15.19) | (-17.32) | | | | | |
| GNMA | 806 | .0644 | -.0041 | 1.0665 | .9979 | 101.79 | .0001 | .112 |
| | | ( 8.68) | (-10.09) | | | | | |
| T-bonds | 659 | .1573 | -.0096 | 1.1703 | .9952 | 730.61 | .0001 | .526 |
| | | (23.44) | (-27.03) | | | | | |
| T-bills | 602 | .1951 | -.0170 | 1.2154 | .9915 | 83.60 | .0001 | .122 |
| | | ( 7.96) | ( -9.14) | | | | | |
| Copper | 906 | .1452 | -.0159 | 1.1563 | .9921 | 1203.99 | .0001 | .571 |
| | | (28.44) | (-34.70) | | | | | |
| Gold | 890 | .0446 | -.0049 | 1.0456 | .9976 | 196.67 | .0001 | .181 |
| | | (11.48) | (-14.02) | | | | | |
| Silver | 878 | .0742 | -.0082 | 1.0770 | .9959 | 197.27 | .0001 | .184 |
| | | (11.49) | (-14.05) | | | | | |

't' statistics are in parentheses.
"a" is the implicitly calculated autoregressive coefficient of the spot price generating process in equation (7).
'$s^2$' is the implicit normalized variance of spot price changes derived from (7).

.01% level of significance (except for corn where it is negative but insignificant). The negative slopes reveal once more the existence of the maturity effect. Using the slope coefficient we can implicitly estimate the autoregressive coefficient of the spot generating process. From equation (7) it follows that:

$$a = \exp(b/2)$$

The results appear under "a" and prove the appropriateness of the spot generating process in (1). For all commodities (except corn), "a" is significantly less than unity, with the smallest value .9836 for soybean meal.

In general, the results are in line with Castelino (1981). His evidence is poor for corn as in our case. For the other agricultural commodities he reports similar results with higher "a" in all cases. Since the methodology used is similar, these differences can be attributed to the different non-overlapping periods. He covered the period 1960-1971 while the present study covers the period 1972-1982. Another major difference is that in the earlier period contracts were offered for trading only up to 11 months before maturity. After 1977, contracts opened for trading more than 11 months before maturity and we are able to include them in our study. Similar lack of evidence for the "maturity effect" on corn is reported by Anderson(1982), who also fails to find any "maturity effect" in silver and Kansas City wheat. This evidence in conjuction with the fact that "a" for corn is not significantly different from unity, hints on the explanation that corn is a very mature market where participants for over a century, are trading a commodity which is minimally affected by international events. The domestic production dominates the world markets and in this sense only domestic events affect corn prices. This characteristic plus the heavy volume of trading in corn help traders make better assessments of prices, which are evidently reflected on the high value of "a". This evidence further suggests that the non-deterministic component of corn prices tends to follow a zero-drift random walk.

All the tests in this section conclude that the inverse relationship between time to maturity and futures price variability is a general phenomenon in all the markets examined: agriculturals, financials and metals. Furthermore, the strong evidence we established on the "maturity effect", sets the foundations to investigate another question: Do distant contracts with relatively thin markets (low open interest and volume), exhibit price variability that cannot be explained by the maturity effect alone? The discussion of thin markets, its impact on the price variability and the associated empirical evidence are studied in the next three chapters.

# Chapter 7

# PRICE VARIABILITY AND RELATED WORK IN THIN MARKETS

## 7.1 RELATED WORK IN THIN MARKETS

Trading exchanges offer the place or the communication devices or both through which investors exchange titles of ownership (stock and bond markets), or agree to contracts for future delivery of a commodity with specified quality and quantity. What drives investors to buy or sell is the new information upon which prior expectations are revised. We can therefore perceive trading in the exchanges as the process through which previous or immediate information is evaluated and impounded in the prices of securities. The number of investors attracted to a particular security in a particular exchange varies. Some exchanges attract a very large number of market participants, others do not. Some securities are very popular among investors while others attract only a few. Common reasons for such phenomena of preference are: size of the market, liquidity of the market, investors' tastes, price stability, riskiness, etc.

Among the reasons mentioned, liquidity of the market for the security plays a very decisive role on whether an investor enters the market or not. If a security is held by a small number of people and/or traded in inactive markets the investor cannot easily liquidate his position. When he does, he incurs high transactions costs and a possible loss (gain) in the market value induced by adverse (favorite) changes in prices during the time he is searching for a buyer or a seller.

Garbade (1982), defines a market as thin if two conditions are met: (1) there are few buyers and sellers at any given time and (2) the frequency of transactions is low. The implications of these two conditions on price behavior is the absence of price resilience in the market, or the presence of thinness. According to Stigler (1964), "resilience is the ability to absorb market bid or ask orders without appreciable fluctuation in price". There are active and thin exchanges both in spot and futures markets. But even on the same exchange there is a different degree of liquidity and thinness. For instance, on the Chicago Board of Trade (the oldest futures exchange with the largest trading volume) Treasury Bond futures is by far the most active market followed by corn and soybeans, while silver (5000 oz.) and plywood are very inactive markets. This existence of thin markets is not the result of the absence of facilities or communication devices. It results from the small number of participants in these markets who trade infrequently in a regime of high transactions costs.

Open interest can be implemented as a proxy fot the number of market participants in the work of Cox (1976). Cox observed the presence of additional market participants (speculators) when futures trading is permitted. Speculators are able to acquire information, evaluate it and transmit it to the market by means of taking short or long positions.[24] In addition, Cox argued that since a futures market has a lower transaction costs, it makes possible the trading among market participants with heterogeneous expectations. This is due to the fact that the cost of communicating and searching for a potential trader is small in a centralized and impersonal setting.

It is obvious that Cox's arguments rest on the assumption that information is costly to acquire and costly to transmit. If information was costless futures trading would not contribute to price stabilization. Furthermore, if prices do not exhibit substantial variability there is no need for futures markets, since information need not be acquired. Therefore, the best candidates for futures trading are commodities that exhibit substantial price variability which in

---

[24] Not all speculators are well informed. Some are uninformed and enter the market just because they are lured towards the chance of earning high profits. In fact both Houthakker (1957) and Rockwell (1967) shed light on this issue by empirically finding that large speculators are well-informed (have good forecasting ability) and make substantial profits, while small speculators are rather uninformed and suffer considerable losses. Both studies use the number of open commitments of the large and small speculators as well as futures prices to estimate the profits and losses of these trading groups.

turn invites the generation and transmission of new information.

Using weekly spot prices, Cox found that with futures markets traders acquire more information about factors that affect the demand for and supply of the commodity. This newly generated information attracts a larger number of people with an interest in the commodity which in turn makes the market liquid. In liquid markets the cost of executing a transaction is much less than the "execution costs" in a thin market.[25] Carrying Cox's findings one step further we realize that for each specific contract the degree of liquidity varies depending on the number of traders with outstanding commitments, i.e., open interest. In general, volume of open interest is monotonically increasing with the elapsed time from initiation until it reaches a peak and then starts declining.[26] Therefore, we can use the open interest as a good proxy for liquidity.[27] The market for this contract in the first few months from initiation will be thin or illiquid, then a prolonged period of a liquid market, and in the last one or two months, again an illiquid market.

---

[25] Both Working (1970) and Telser and Higinbotham (1977) support this statement.

[26] Empirical evidence presented in a later section shows the behavior of volume with time to maturity resembles the behavior of open interest.

[27] Gray (1960) also uses open interest as a measure of thinness in futures markets.

Such an analysis sets to examine the differential futures price variability during the periods of liquidity and illiquidity. The linkage between open interest and volume and the variability of prices is supported by Telser and Higinbotham (1977). They found evidence of an inverse relationship between price variability and volume of trade and reaffirm Cox's argument that futures trading increases the liquidity of the market.

In their theory the standard deviation of the market clearing prices is used to measure the liquidity of the market. They show that the dispersion of the market clearing prices, decreases due to increased futures trading. The standard deviation approaches zero as the volume of transactions increases per unit of time. A sample of 51 commodities, divided equally into active, less active and dormant groups, generates results quite consistent with their arguments. In a sample of 25 commodities (17 active and 8 inactive) they observed that the simple correlation between open interest and volume of trade is .933. Their results are good indicators of the relationship of trading activity with price behavior. However, they used average volume and open interest for a given commodity. Such data cannot provide evidence on how this relationship holds for individual contracts. In a strict sense, their theory cannot be used to test the behavior of price variability because it disregards the observed relationship between time to maturity and volume of open interest. They considered the standard deviation of the market clearing prices as a proxy for liquidity. However, (as mentioned above) volume of trade is also an indicator of the liquidity in the market. Defining the standard deviation as a function of the volume of trade in their equation (6), they do not make this formula explicit in terms of liquidity. Therefore, we cannot use their results to imply a relationship between price variability and liquidity.

Studies in the stock markets (Cohen et.al. (1976), Cohen et.al. (1978) and Papaioannou (1982)) assess the possible effect of thinness (illiquidity) on the variability of returns. The evidence suggests that the thinner the market for a security the higher the price and return variability it exhibits. Copeland (1976, 1977), and Epps (1975) presented theoretical models where they found that the total number of shareholders, the percent of traders who view new information optimistically, the number of shares outstanding, transactions costs and the rate of message arrival per unit time affect trading activity. A reduction in trading activity will increase the bid-ask spreads and consequently increase the volatility of such spreads. In futures markets trading does not involve market makers (i.e, specialists) but is conducted in an open outcry of available bids and offers.[28] When trading activity is low speculators who initi-

---

[28] This means that at times of high trading activity it is likely that same contracts may simultaneously be bid or

ate and offset positions in the course of one day's trading session (scalpers, day traders) are unwilling to enter the market. This is because of the higher risk that they may not be able to offset their position timely without a loss or without ensuring an appropriate profit in the absence of a liquid market. Unwillingness among these traders to take positions in the markets is bound to introduce lower bids and higher asked prices than it would in a liquid market. Therefore, the spread in bid and asked prices is widened in futures markets as in the stock markets, when trading is reduced. Furthermore, the volatility of the spread will increase if transactions are slow and order imbalances do not stabilize temporary price changes. Another way to establish higher variability in thin markets is through Stigler's (1964) contention: lower trading activity increase market uncertainty about fair prices and thus buy and sell orders are quoted at prices that deviate from the equilibrium fair prices.

Futures contracts exhibit a unique characteristic that is not present in the spot markets. Since each contract has a finite span of life, the number of participants for each contract exhibits systematic relationship with the passage of time. It increases slowly, reaches a peak gradually and declines quickly to zero at maturity. At the time a contract opens for trading the open interest is zero since no

---

offered at different prices in different parts of the trading pit.

one has undertaken any promise of delivery as of that time. However, as time unfolds trading on this contract advances and the number of contracts increases monotonically until it reaches a peak 2-3 months before maturity. Then, open interest starts declining very fast until all positions are closed at maturity. A typical case of the open interest-time to maturity relationship is depicted in Figure 7, which can also be expressed as:

$$OI = f(T-t) \quad (18)$$

where, current time is denoted with t, CI is the open interest, T is the maturity date and T-t is the time to maturity.

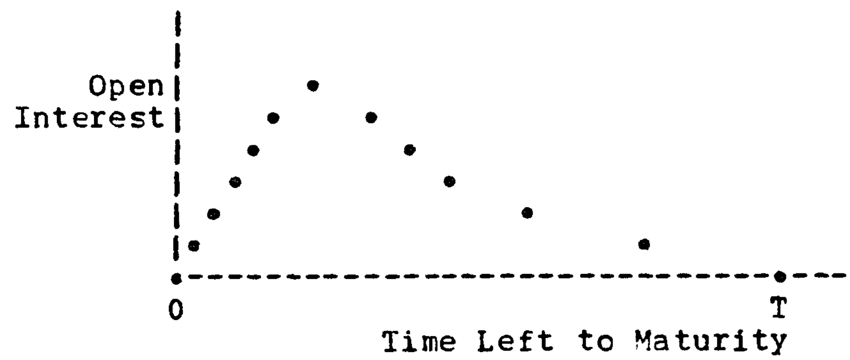



Figure 7: The Relationship between Open Interest and Time to Maturity

If the open interest is sufficiently capturing the trading activity in futures markets, we can write price variability as a function of open interest:

$$s = g(OI) \quad (19)$$

where, $$ds/dOI < 0 \qquad (20)$$

In equation (18), the derivative with respect to time to maturity for the distant months is negative:

$$dOI/d(T-t) < 0 \qquad (21)$$

Substituting for OI from (18) in (19), we can express price variability s, as a function (h) of open interest and time to maturity:

$$s = g(f(T-t)) = h(CI, T-t) \qquad (22)$$

Differentiating (22) with respect to time to maturity and using the signs of the derivatives in (20) and (21) we get:

$$ds/d(T-t) = (\partial s/\partial OI)\,(\partial OI/\partial (T-t)) > 0 \qquad (23)$$

Based on the previous discussion, equation (23) should be true during the distant months in which open interest is low. The positive systematic relationship between price variability and time to maturity, as evidenced in (23), is contrary to Samuelson's maturity effect hypothesis. Since we have already established strong evidence on the latter, the question arises whether in the months with low open interest, futures price variability is greater than predicted by Samuelson's hypothesis. A variability in excess of the amount predicted by the time to maturity would be due to thinness. In the next section we discuss the methodology to test this issue.

## 7.2 EXCESS VARIABILITY IN THE ILLIQUID MONTHS HYPOTHESIS

This hypothesis is derived from equations (22) and (23) and can be stated as follows:

> H(0): There is no difference in the variability between liquid and illiquid months, after the maturity effect is neutralized.
>
> H(1): Price variability during the liquid months is different than the price variability in the illiquid months, ceteris paribus.

To test for this hypothesis we need quantifiable measures for price variability and liquidity. Since we can use the variance of price changes as calculated earlier, we focus our attention on the measure of liquidity.

Copeland (1979), in a study of stock markets used two measures to estimate the liquidity in the market: (1) changes in the proportional share volume of trading and (2) changes in transactions costs as a percent of value traded. Cornell (1981) studied the relationship between liquidity and price variability using volume partly as a measure of liquidity in the futures markets. Telser and Higinbotham (1977) use both open interest and volume of trading to measure liquidity in the market. In our study we can select either open interest or volume, as a surrogate for liquidity in the market because we are only interested in dividing the trading period of a futures contract into liquid and illiquid parts. Since we measure price variability over monthly estimation intervals, we need a proxy for liquidity that captures the monthly movements of public interest in trading. We believe that monthly averages of open interest or volume can reveal changes in the level of liquidity. This measure of liquidity is calculated as follows:

For each of the 11 commodities we obtain daily open interest for each contract, which we average in monthly intervals and record the corresponding time to maturity.[29] Monthly averages are taken as a simple average of open interest on the first and the last trading day of the month.[30] Then we take the grand average of all averages across contracts (for a commodity) segmented according to the time to maturity. Plotting open interest against the time to maturity, as in Figure 7, should reveal the "cut-off" month (if any) between liquid and illiquid months. Since the maturity effect imposes a negative monotonic relationship between variability and time to maturity, we can plot this relationship for the liquid months (as in Figure 8) and then extend it to the illiquid months. If the calculated variability (denoted with x) lies consistently above the implied variability (denoted with dots) our alternative hypothesis will be accepted.

---

[29] Open interest and volume data were obtained from the Statistical Annuals which are published by the futures exchanges on which the various commodities are traded.

[30] Figlewski (1981) constructed in the same way an open interest variable as a measure of futures markets activity. Hill and Schneeweis (1982) refer to the liquid contracts as those with high open interest.

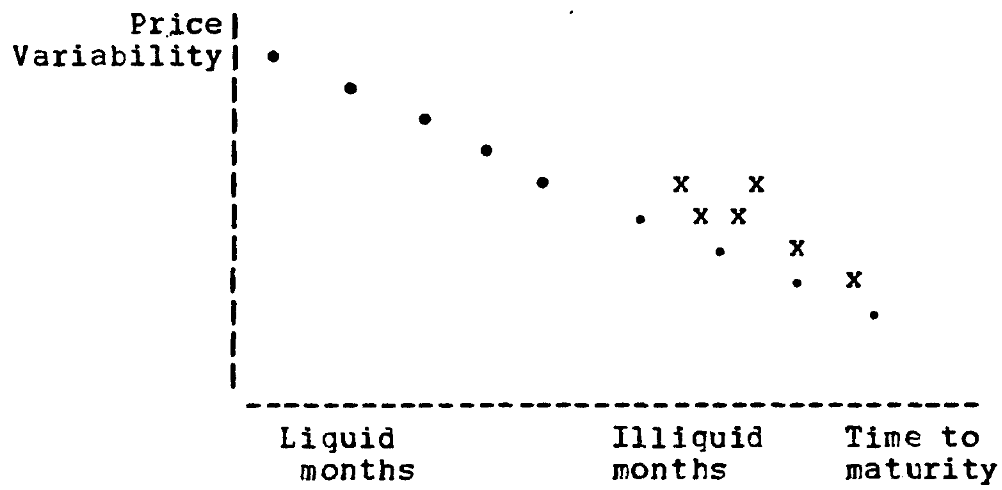



Figure 8: Price Variability during the Liquid and Illiquid Months

The evidence on the relationship of time to maturity with volume and open interest is presented in the next chapter.

## Chapter 8

# THE RELATIONSHIP OF TIME TO MATURITY WITH VOLUME AND OPEN INTEREST

The calculations of the monthly average volume is slightly different from the calculation of the average open interest. The difference is that monthly averages of volume are based on all trading days in a month. If the first-last trading day average volume was used, significant biases would have been introduced. This is because the daily volume within a month has a rather random behavior with no specific trends. Therefore, an average based on first-last trading day volume seems innapropriate. However, this problem is not present when calculating average open interest, because within any month open interest exhibits a monotonic behavior (increasing or decreasing), in general. Hence, first-last trading day open interest can sufficiently estimate monthly average open interest.

Another important issue in calculating monthly averages of open interest and volume is the observed seasonality in the variance of price expressed as "month", "year", or "contract month" effects. If open interest and/or volume are sensitive to the same sources of seasonality that the variance of price changes is, then it matters what averaging procedure we use. Using two years of data we try to isolate these effects by averaging across different calendar years, calendar months and contract months, holding constant only the time to maturity. In this way any form of seasonality will not bias the relationship of liquidity measures to the time to maturity.

In Table 7 we present the average open interest in a given month away from maturity. The results are for the years 1980-1981 for all commodities. Overall, the results reveal the interesting behavior of open interest as contract nears maturity: it increases rapidly during the first 3-4 months from initiation and then slowly, until it reaches the maximum value 2-3 months before maturity. This relationship is captured dramatically in each of Figures 9 through 12.

The level of open interest differs across futures markets, with corn having the highest open interest and silver the smallest. It is no surprise that corn enjoys such a large number of open commitments. Corn is the biggest single crop in the U.S. and as such it affects a relatively large number of market participants-farmers, commercial users and animal feeders. On an average, it takes the open interest of wheat (second largest crop) together with that of soybean complex (beans, meal and oil) to match corn's open interest. Among the three metals, gold has the highest open interest followed by copper and far below by silver. T-bonds, following corn, soybeans and wheat, have the highest open interest among the financials with G.N.M.A. and T-

TABLE 7

Average Open Interest by Month to Maturity: 1980-81

| | CORN | | | WHEAT | | | SOYBEANS | | | SOYMEALS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MTM | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) |
| 0 | 33,402 | 9 | -.81 | 8,169 | 6 | -.88 | 23,955 | 13 | -.79 | 2,669 | 16 | -.77 |
| 1 | 174,973 | 49 | -.44 | 66,527 | 53 | -.42 | 112,811 | 63 | -.37 | 11,677 | 70 | -.30 |
| 2 | 314,309 | 88 | -.11 | 114,870 | 91 | -.09 | 178,347 | 100 | .18 | 16,713 | 100 | .22 |
| 3 | 354,377 | 100 | .10 | 126,327 | 100 | .13 | 150,765 | 84 | .12 | 13,703 | 82 | .32 |
| 4 | 323,091 | 91 | .31 | 112,001 | 89 | .28 | 134,824 | 76 | .23 | 10,388 | 62 | .37 |
| 5 | 246,887 | 70 | .23 | 87,788 | 69 | .38 | 109,733 | 76 | .21 | 7,566 | 45 | .31 |
| 6 | 200,339 | 57 | .22 | 63,620 | 50 | .17 | 91,044 | 51 | .20 | 5,796 | 35 | .40 |
| 7 | 163,930 | 46 | .26 | 54,510 | 43 | .52 | 75,958 | 43 | .25 | 4,145 | 25 | .40 |
| 8 | 130,164 | 37 | .35 | 35,755 | 28 | .40 | 60,789 | 34 | .28 | 2,969 | 18 | .45 |
| 9 | 96,308 | 27 | .44 | 25,492 | 20 | .63 | 47,313 | 27 | .38 | 2,047 | 12 | .51 |
| 10 | 66,683 | 19 | .49 | 15,684 | 12 | .52 | 34,162 | 19 | .53 | 1,360 | 8 | .59 |
| 11 | 44,749 | 13 | .55 | 10,312 | 8 | .78 | 22,295 | 13 | .59 | 854 | 5 | .87 |
| 12 | 28,821 | 8 | .70 | 5,794 | 5 | 1.05 | 14,058 | 8 | 1.17 | 456 | 3 | 1.22 |
| 13 | 16,941 | 6 | 1.88 | 2,830 | 2 | 2.42 | 6,492 | 4 | 1.68 | 205 | 1 | 3.77 |
| 14 | 5,877 | 2 | 1.19 | 827 | 1 | 2.88 | 2,421 | 1 | 11.29 | 43 | 0 | 3.78 |
| 15 | 2,683 | 1 | - | 213 | 0 | - | 197 | 0 | - | 9 | 0 | - |

| | SOYOIL | | | COPPER | | | GOLD | | | SILVER | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MTM | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) |
| 0 | 3,249 | 17 | -.77 | 876 | 5 | -.90 | 2,571 | 8 | -.86 | 808 | 9 | -.63 |
| 1 | 14,022 | 71 | -.29 | 8,538 | 50 | -.48 | 17,928 | 58 | -.42 | 4,632 | 54 | -.46 |
| 2 | 19,666 | 100 | .25 | 16,344 | 96 | -.04 | 31,110 | 100 | .15 | 8,588 | 100 | .11 |
| 3 | 15,754 | 80 | .46 | 17,031 | 100 | .29 | 27,140 | 87 | .24 | 7,754 | 90 | .14 |
| 4 | 10,789 | 55 | .40 | 13,162 | 77 | .43 | 21,893 | 70 | .08 | 6,827 | 79 | .37 |
| 5 | 7,733 | 39 | .26 | 9,187 | 54 | .29 | 20,185 | 65 | .07 | 4,987 | 58 | -.01 |
| 6 | 6,203 | 32 | .30 | 7,116 | 42 | .30 | 18,953 | 61 | -.03 | 5,038 | 59 | .27 |
| 7 | 4,753 | 24 | .30 | 5,492 | 32 | .29 | 19,550 | 63 | -.00 | 3,979 | 46 | .02 |
| 8 | 3,645 | 19 | .40 | 4,251 | 25 | .34 | 19,562 | 63 | -.03 | 3,884 | 45 | .19 |
| 9 | 2,605 | 13 | .47 | 3,173 | 19 | .27 | 20,234 | 65 | -.02 | 3,254 | 38 | -.18 |
| 10 | 1,777 | 9 | .18 | 2,496 | 15 | .17 | 20,645 | 66 | -.03 | 3,949 | 46 | .02 |
| 11 | 1,510 | 8 | 1.46 | 2,125 | 12 | .35 | 21,203 | 68 | .03 | 3,888 | 45 | .18 |
| 12 | 615 | 3 | .75 | 1,576 | 9 | .19 | 20,634 | 66 | -.02 | 3,300 | 38 | .47 |
| 13 | 352 | 2 | 1.50 | 1,328 | 8 | .07 | 21,029 | 68 | .06 | 2,252 | 26 | .17 |
| 14 | 141 | 1 | .74 | 1,238 | 7 | .41 | 19,825 | 64 | .58 | 1,918 | 22 | .57 |
| 15 | 81 | 0 | - | 880 | 5 | .19 | 18,740 | 60 | .13 | 1,223 | 14 | .11 |
| 16 | | | | 742 | 4 | .60 | 16,604 | 53 | .10 | 1,106 | 13 | .46 |
| 17 | | | | 465 | 3 | .26 | 15,094 | 49 | .22 | 757 | 9 | .08 |
| 18 | | | | 369 | 2 | .63 | 12,367 | 40 | .33 | 703 | 8 | .53 |
| 19 | | | | 226 | 1 | .35 | 9,277 | 30 | .96 | 458 | 5 | .36 |
| 20 | | | | 168 | 1 | .79 | 4,724 | 15 | .64 | 338 | 4 | .94 |
| 21 | | | | 94 | 1 | 2.90 | 2,879 | 9 | 1.61 | 174 | 3 | 1.64 |
| 22 | | | | 24 | 0 | - | 1,105 | 4 | - | 66 | 1 | - |

Table 7 (continued)

| | G.N.M.A. | | | T-BONDS | | | T-BILLS | | |
|---|---|---|---|---|---|---|---|---|---|
| MTM | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) |
| 0 | 1,284 | 10 | -.80 | 6,829 | 17 | -.69 | 4,270 | 30 | -.52 |
| 1 | 6,560 | 53 | -.38 | 22,377 | 54 | -.32 | 8,889 | 64 | -.36 |
| 2 | 10,665 | 86 | -.14 | 33,122 | 81 | -.25 | 13,995 | 100 | .00 |
| 3 | 12,467 | 100 | .11 | 41,088 | 100 | .29 | 13,940 | 100 | .29 |
| 4 | 11,276 | 90 | .02 | 31,810 | 77 | .47 | 10,822 | 77 | .27 |
| 5 | 11,068 | 89 | .18 | 21,601 | 53 | -.03 | 8,546 | 61 | .30 |
| 6 | 9,370 | 75 | .04 | 22,289 | 54 | .15 | 6,590 | 47 | .24 |
| 7 | 9,044 | 73 | -.01 | 19,334 | 47 | .12 | 5,336 | 38 | .08 |
| 8 | 9,178 | 74 | .07 | 17,303 | 42 | -.03 | 4,918 | 35 | .27 |
| 9 | 8,559 | 69 | -.01 | 17,816 | 43 | .05 | 3,865 | 28 | .32 |
| 10 | 8,683 | 70 | -.01 | 16,931 | 41 | .04 | 2,935 | 21 | .20 |
| 11 | 8,758 | 70 | .02 | 16,322 | 40 | -.08 | 2,439 | 17 | .29 |
| 12 | 8,590 | 69 | -.03 | 17,649 | 43 | .02 | 1,896 | 14 | .24 |
| 13 | 8,896 | 71 | -.05 | 17,311 | 42 | .01 | 1,534 | 11 | .01 |
| 14 | 9,341 | 75 | -.04 | 17,077 | 42 | -.02 | 1,512 | 11 | .16 |
| 15 | 9,744 | 78 | -.01 | 17,417 | 42 | .02 | 1,299 | 9 | .19 |
| 16 | 9,878 | 79 | -.03 | 17,028 | 41 | .02 | 1,095 | 8 | .23 |
| 17 | 10,170 | 82 | .02 | 16,687 | 41 | .00 | 887 | 6 | .24 |
| 18 | 9,992 | 80 | .03 | 16,563 | 40 | .07 | 716 | 5 | .23 |
| 19 | 9,667 | 78 | .02 | 15,458 | 38 | .01 | 580 | 4 | .37 |
| 20 | 9,518 | 76 | .04 | 15,379 | 37 | -.02 | 424 | 3 | .58 |
| 21 | 9,172 | 74 | .07 | 15,670 | 38 | .06 | 269 | 2 | .88 |
| 22 | 8,578 | 69 | .07 | 14,716 | 36 | .07 | 143 | 1 | 1.80 |
| 23 | 8,023 | 64 | .16 | 13,790 | 34 | .07 | 51 | 0 | - |
| 24 | 6,939 | 56 | .11 | 12,844 | 31 | .06 | | | |
| 25 | 6,244 | 50 | .06 | 12,087 | 29 | .04 | | | |
| 26 | 5,899 | 47 | .18 | 11,672 | 28 | .07 | | | |
| 27 | 4,982 | 40 | .19 | 10,919 | 27 | .18 | | | |
| 28 | 4,202 | 34 | .13 | 9,272 | 23 | .20 | | | |
| 29 | 3,705 | 30 | .34 | 7,751 | 19 | .28 | | | |
| 30 | 2,771 | 22 | .18 | 6,032 | 15 | .59 | | | |
| 31 | 2,353 | 19 | .30 | 3,791 | 9 | -.09 | | | |
| 32 | 1,812 | 15 | .41 | 4,172 | 10 | .60 | | | |
| 33 | 1,285 | 10 | -.34 | 2,607 | 6 | -.47 | | | |
| 34 | 1,936 | 16 | 1.12 | 4,948 | 12 | .40 | | | |
| 35 | 1,729 | 14 | - | 3,530 | 9 | - | | | |

'MTM' stands for months to maturity.
The monthly average open interest is in column (1).
Column (2) is the percentage proportion of each average open interest relative to the highest average open interest for that commodity.
Column (3) shows the rate of increase or decrease of the average open interest for a given month to maturity, over the previous month to maturity.

Figure 9

# Open Interest and Time to Maturity: Grains

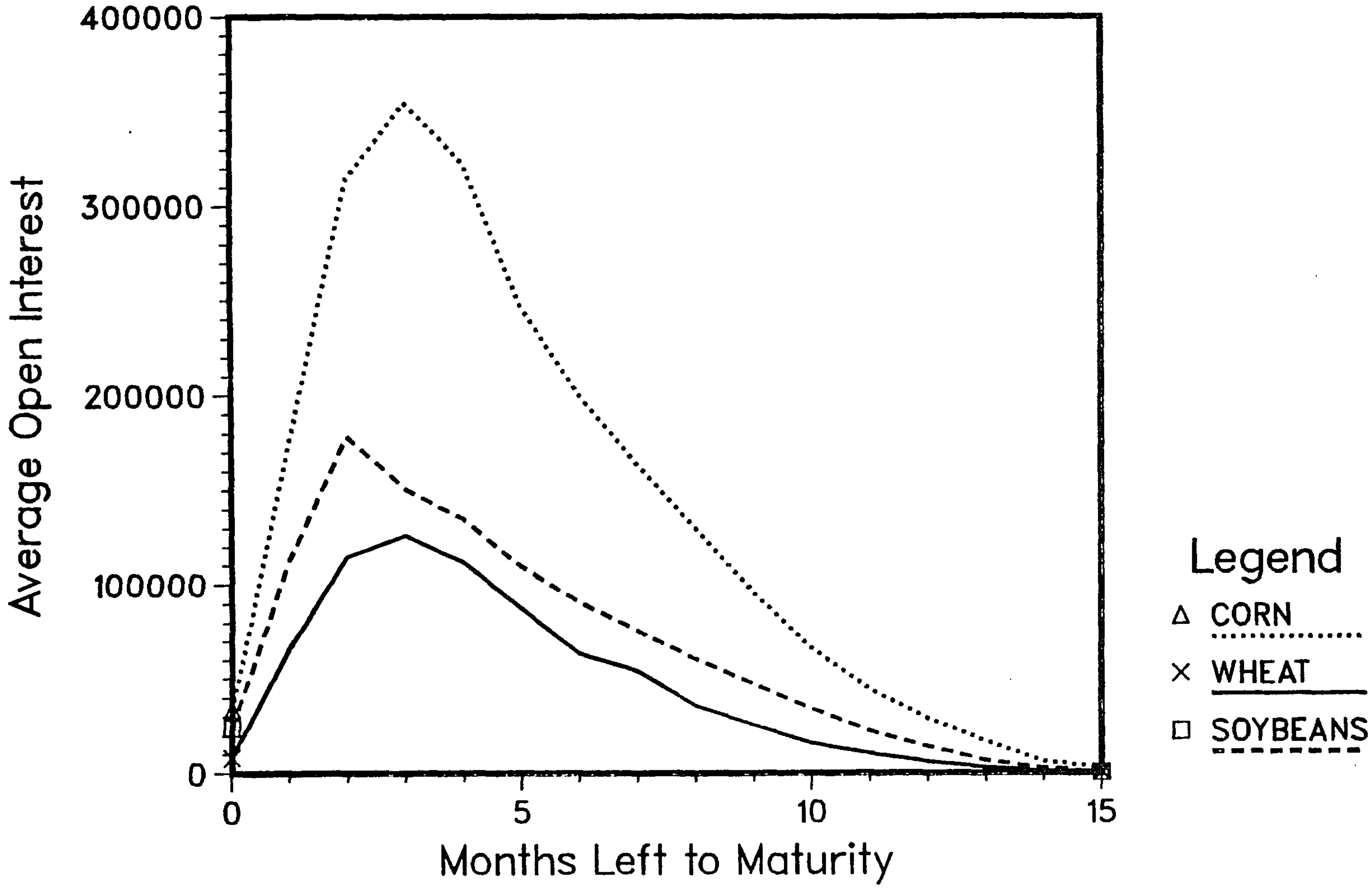


Figure 10

# Open Interest and Time to Maturity: Soybean Meal and Oil

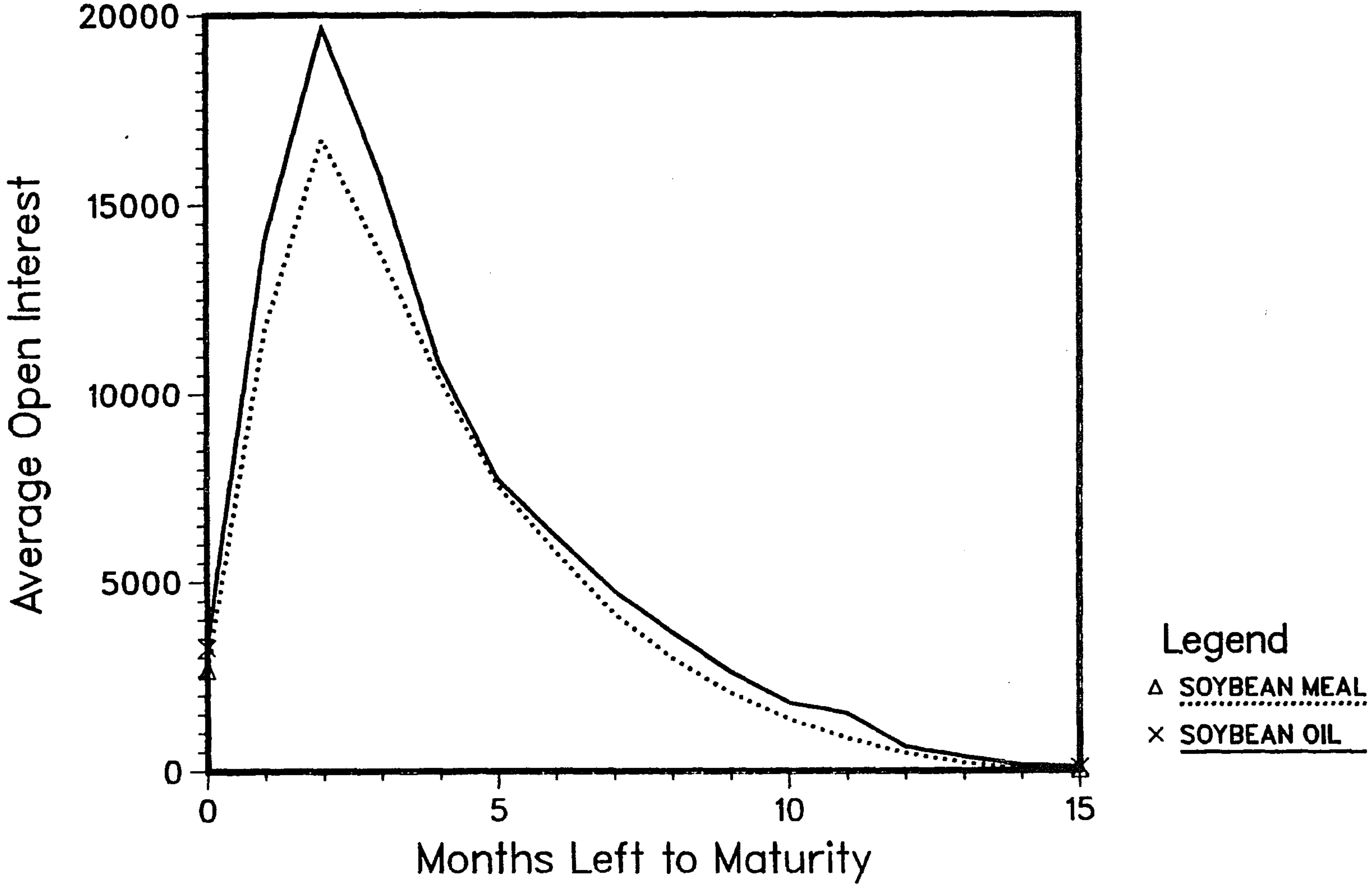


Figure 11

# Open Interest and Time to Maturity: Financials

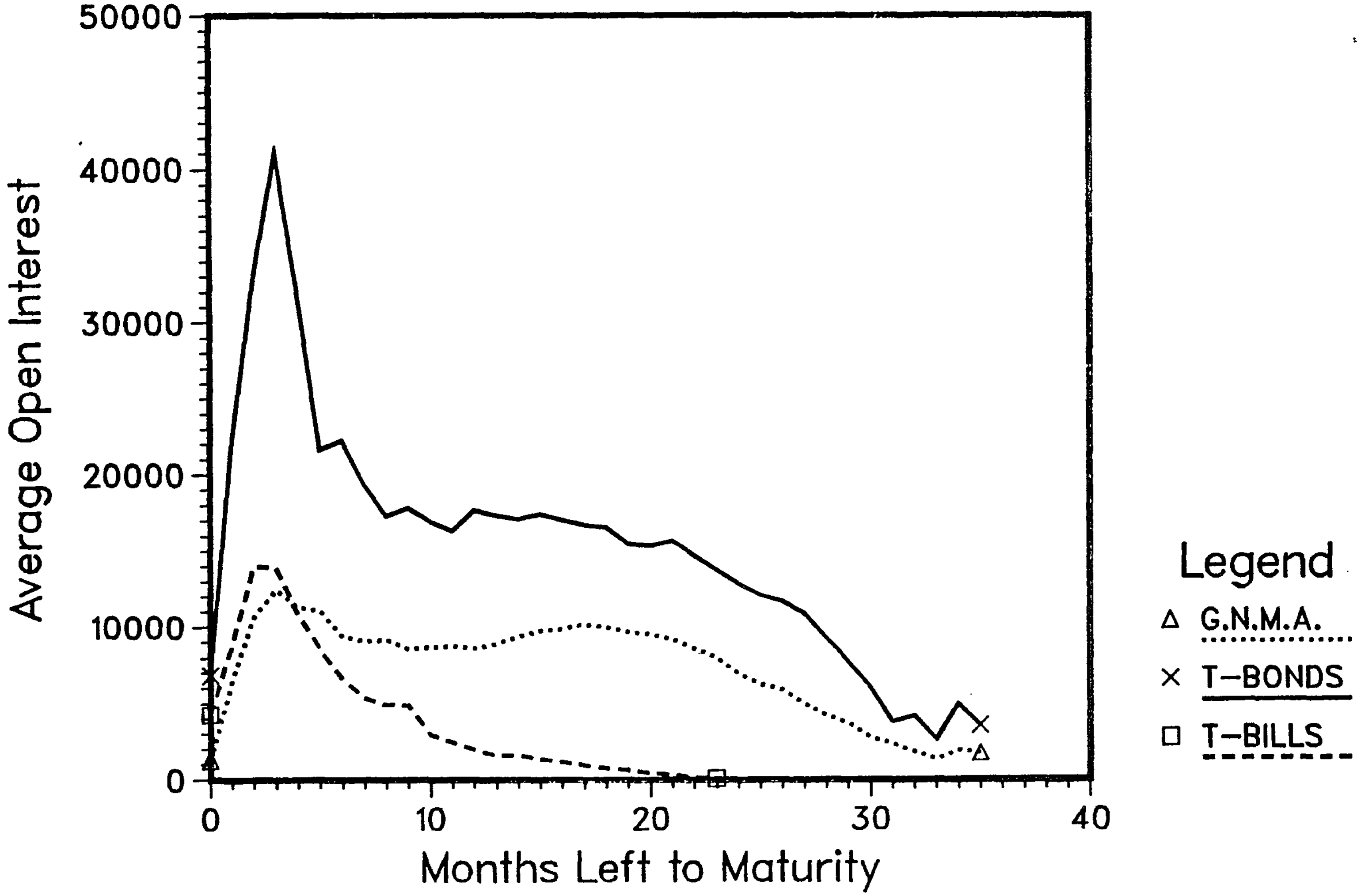
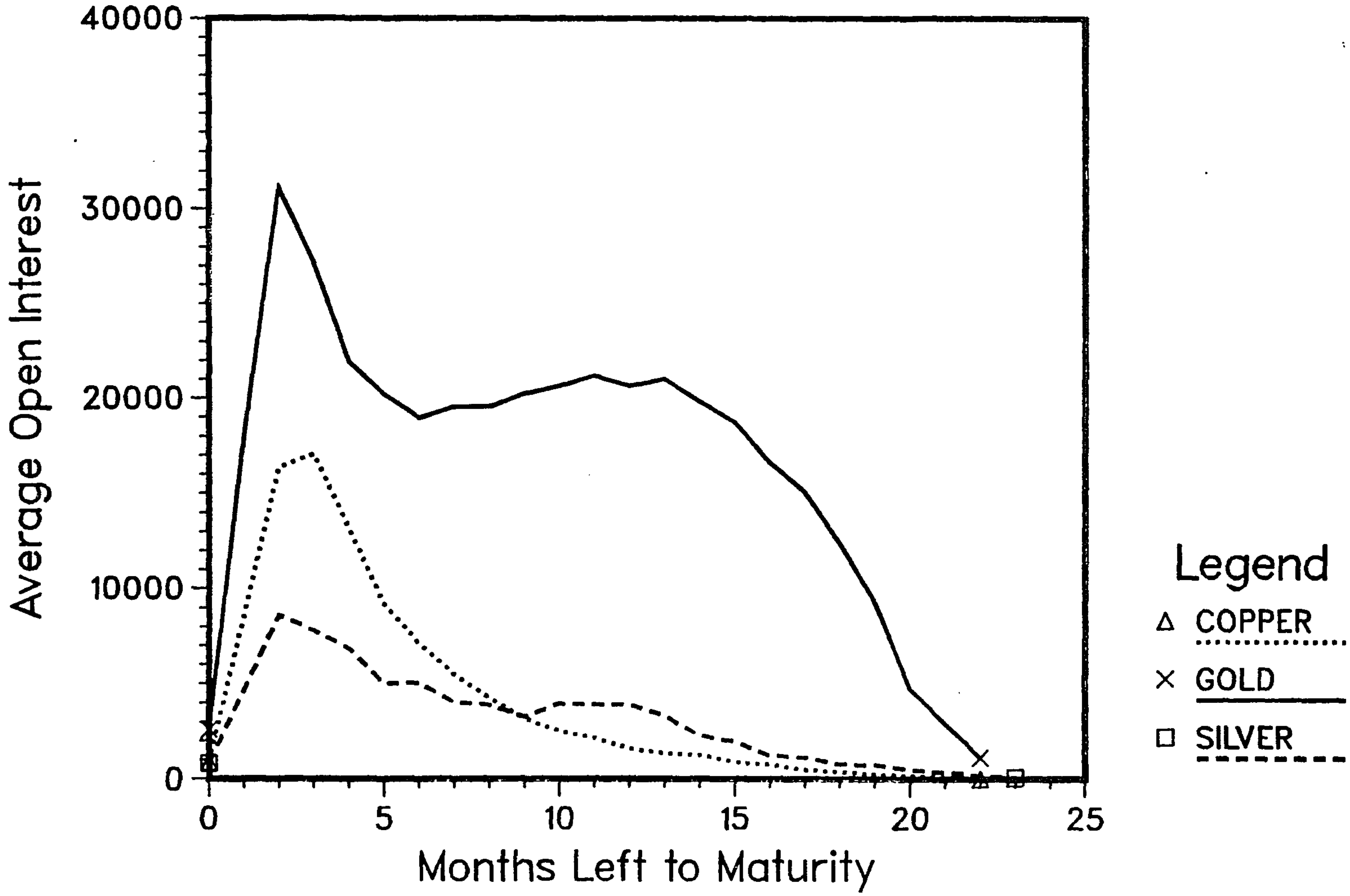


Figure 12

# Open Interest and Time to Maturity: Metals



bills in lower but similar ranking. Among the 11 commodities examined, only the 5 agriculturals, copper, silver, T-bonds and T-bills exhibit a strict gradual increase with a decrease in time to maturity. G.N.M.A. and especially gold, seem to attain most of the open interest in the first 5-8 months from initiation and retain it at the same level until 4-5 months before maturity. This behavior of open interest can easily be seen in the percentage of each average open interest relative to the highest average open interest for that commodity (column (2)) and in the relative change of average open interest between two consecutive months to maturity (column (3)). Column (2) reveals that 50% of the average highest open interest is reached within 4-6 months before the delivery month, while the peak (100%) occurs in the 2nd or 3rd month before maturity. Exception to the former conclusion is the behavior of gold and G.N.M.A. where half of the open interest is reached 16 months (gold) and 25 months (G.N.M.A.) before maturity.

Column (3) shows dramatic rates of increases during the first 3-4 months from initiation, then relative smooth rates of increases until the 50% open interest level is reached. Beyond this point, large rates of increase are observed so that the peak is reached within 2-3 months. Afterwards, traders start closing their positions and the open interest declines abruptly to small levels of 5%-30% of the highest observed open interest. This proportion is higher with financials (G.N.M.A.=10%, T-bonds=17%, T-bills=30%) and the soybean complex (beans=13%, meal=16%, oil=17%). Such behavior might signify a higher proportion of contracts delivered with these futures markets, or different risk of exposure during the month of delivery.

One disadvantage in measuring liquidity as number of open commitments, is that it does not capture the trading that involves offseting positions within a day. Day traders (mostly commodity exchange members) initiate positions during the course of a trading session and they rarely carry them overnight. Scalpers (professional traders and exchange members) fall in this category of traders. They trade in minimum fluctuations a large number of contracts taking small profits or losses. Their presence in futures markets adds to the level of speculative liquidity and it is captured in the reported volume of transactions. Our results on the average volume per month are shown in Table 8 and Figures 13-16.

In all 11 commodities the results indicate a strong relationship of average volume with time to maturity. Volume increases significantly during the first few months from contract initiation, then slowly increases to reach a peak in 1-3 months before maturity and drop to very low levels thereafter. The two most heavily traded commodities are corn and soybeans followed by wheat, T-bonds and gold. The rankings based on volume are the same as those with the open

TABLE 8

Average Volume by Month to Maturity: 1980-81

| | CORN | | | WHEAT | | | SOYBEANS | | | SOYMEALS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MTM | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) |
| 0 | 18,415 | 20 | -.76 | 5,910 | 12 | -.80 | 22,072 | 23 | -.69 | 1,926 | 38 | -.62 |
| 1 | 75,217 | 81 | -.19 | 29,435 | 59 | -.37 | 71,827 | 76 | -.24 | 5,037 | 100 | .18 |
| 2 | 93,152 | 100 | .04 | 46,779 | 94 | -.06 | 94,059 | 100 | .37 | 4,264 | 85 | .44 |
| 3 | 89,227 | 96 | .16 | 49,573 | 100 | .33 | 68,617 | 73 | .45 | 2,947 | 59 | .73 |
| 4 | 76,899 | 83 | .35 | 37,413 | 75 | .26 | 47,276 | 50 | .80 | 1,703 | 34 | .36 |
| 5 | 57,107 | 61 | .51 | 29,712 | 60 | .77 | 26,299 | 28 | .52 | 1,256 | 25 | .65 |
| 6 | 37,733 | 41 | .17 | 16,774 | 34 | .61 | 17,273 | 18 | .34 | 763 | 15 | .56 |
| 7 | 32,200 | 35 | .27 | 10,412 | 21 | .64 | 12,880 | 14 | .41 | 489 | 10 | .48 |
| 8 | 25,279 | 27 | .61 | 6,332 | 13 | .63 | 9,152 | 10 | .31 | 331 | 7 | .55 |
| 9 | 15,693 | 17 | .64 | 3,896 | 8 | .62 | 6,999 | 7 | .42 | 214 | 4 | .34 |
| 10 | 9,538 | 10 | .25 | 2,407 | 5 | .54 | 4,923 | 5 | .30 | 160 | 3 | .82 |
| 11 | 7,646 | 8 | .62 | 1,566 | 3 | 1.01 | 3,798 | 4 | .55 | 88 | 2 | .54 |
| 12 | 4,716 | 5 | .79 | 781 | 2 | 1.02 | 2,443 | 3 | .85 | 57 | 1 | .36 |
| 13 | 2,641 | 3 | .88 | 387 | 1 | .34 | 1,322 | 1 | .72 | 42 | 1 | 1.63 |
| 14 | 1,406 | 2 | .15 | 288 | 1 | 2.31 | 768 | 1 | 27.44 | 16 | 0 | .33 |
| 15 | 1,223 | 1 | - | 87 | 0 | - | 27 | 0 | - | 12 | 0 | - |

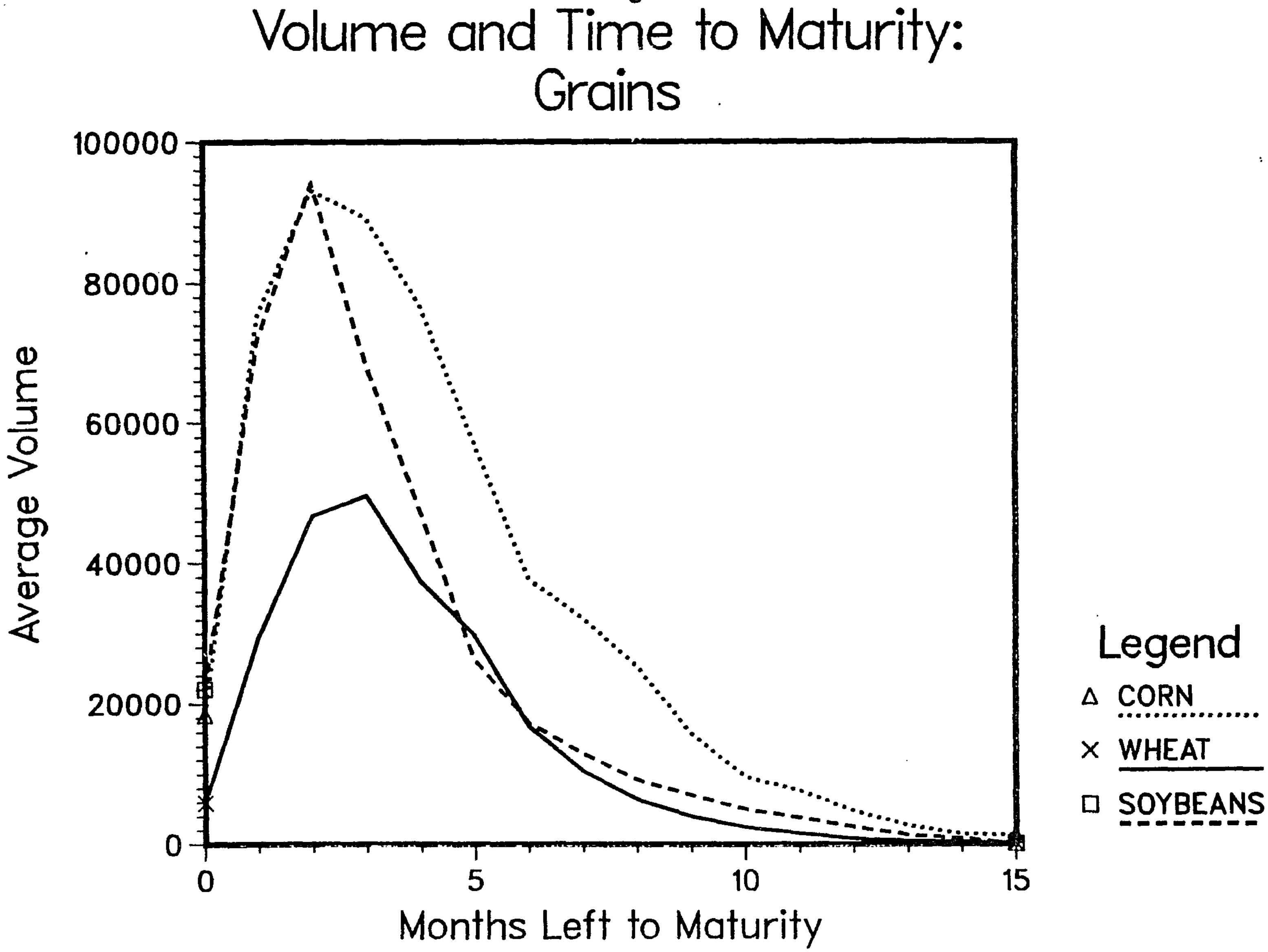
| | SOYOIL | | | COPPER | | | GOLD | | | SILVER | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MTM | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) |
| 0 | 2,136 | 44 | -.56 | 265 | 8 | -.87 | 1,213 | 6 | -.93 | 854 | 48 | -.49 |
| 1 | 4,874 | 100 | .17 | 2,033 | 63 | -.37 | 16,749 | 89 | -.11 | 1,683 | 94 | -.04 |
| 2 | 4,173 | 86 | .40 | 3,219 | 100 | .03 | 18,840 | 100 | .63 | 1,751 | 97 | -.03 |
| 3 | 2,989 | 61 | .68 | 3,114 | 97 | .64 | 11,533 | 61 | .96 | 1,797 | 100 | 1.13 |
| 4 | 1,783 | 37 | .45 | 1,895 | 59 | .97 | 5,871 | 31 | 1.09 | 844 | 45 | 1.52 |
| 5 | 1,231 | 25 | .73 | 961 | 30 | .46 | 2,808 | 15 | .74 | 335 | 19 | -.02 |
| 6 | 712 | 15 | .63 | 660 | 21 | .75 | 1,612 | 9 | .02 | 341 | 19 | .95 |
| 7 | 438 | 9 | .27 | 378 | 12 | .25 | 1,582 | 8 | .35 | 175 | 10 | -.18 |
| 8 | 344 | 7 | .60 | 302 | 9 | .32 | 1,170 | 6 | .00 | 214 | 12 | .75 |
| 9 | 215 | 4 | .35 | 229 | 7 | .53 | 1,170 | 6 | .17 | 122 | 7 | .26 |
| 10 | 159 | 3 | .73 | 150 | 5 | .26 | 1,000 | 5 | .02 | 97 | 5 | -.25 |
| 11 | 92 | 2 | .51 | 119 | 4 | .35 | 981 | 5 | -.03 | 129 | 7 | .04 |
| 12 | 61 | 1 | .07 | 88 | 3 | .24 | 1,014 | 5 | -.05 | 124 | 7 | .20 |
| 13 | 57 | 1 | 1.28 | 71 | 2 | .22 | 1,071 | 6 | .08 | 103 | 6 | .32 |
| 14 | 25 | 1 | .25 | 58 | 2 | .05 | 990 | 5 | .02 | 78 | 4 | .18 |
| 15 | 20 | 0 | - | 55 | 2 | 1.20 | 974 | 5 | .23 | 66 | 4 | .38 |
| 16 | | | | 25 | 1 | .56 | 789 | 4 | .11 | 48 | 3 | .12 |
| 17 | | | | 16 | 0 | -.27 | 713 | 4 | .30 | 43 | 2 | .43 |
| 18 | | | | 22 | 1 | .83 | 548 | 3 | .21 | 30 | 2 | -.25 |
| 19 | | | | 12 | 0 | .09 | 452 | 2 | .10 | 40 | 2 | .74 |
| 20 | | | | 11 | 0 | .22 | 412 | 2 | 1.34 | 23 | 1 | -.08 |
| 21 | | | | 9 | 0 | .50 | 176 | 1 | .04 | 25 | 1 | -.04 |
| 22 | | | | 6 | 0 | - | 170 | 1 | - | 26 | 1 | - |

Table 8 (continued)

| | G.N.M.A. | | | T-BONDS | | | T-BILLS | | |
|---|---|---|---|---|---|---|---|---|---|
| MTM | (1) | (2) | (3) | (1) | (2) | (3) | (1) | (2) | (3) |
| 0 | 337 | 7 | -.88 | 1,798 | 6 | -.91 | 2,411 | 22 | -.73 |
| 1 | 2,877 | 63 | -.27 | 20,547 | 74 | -.11 | 8,881 | 81 | -.19 |
| 2 | 3,928 | 86 | -.14 | 23,198 | 83 | -.17 | 11,003 | 100 | -.00 |
| 3 | 4,588 | 100 | .40 | 27,933 | 100 | .90 | 11,011 | 100 | .68 |
| 4 | 3,286 | 72 | .98 | 14,691 | 53 | 1.57 | 6,552 | 60 | .57 |
| 5 | 1,655 | 36 | .27 | 5,726 | 20 | .13 | 4,181 | 38 | .50 |
| 6 | 1,301 | 28 | .46 | 5,066 | 18 | .54 | 2,781 | 25 | .60 |
| 7 | 894 | 19 | .42 | 3,297 | 12 | .62 | 1,737 | 16 | .28 |
| 8 | 628 | 14 | .11 | 2,036 | 7 | -.00 | 1,352 | 12 | .31 |
| 9 | 567 | 12 | .27 | 2,044 | 7 | .49 | 1,030 | 9 | .66 |
| 10 | 445 | 10 | .03 | 1,369 | 5 | .34 | 621 | 6 | .64 |
| 11 | 431 | 9 | .10 | 1,020 | 4 | -.12 | 378 | 3 | .51 |
| 12 | 391 | 9 | .07 | 1,164 | 4 | .26 | 251 | 2 | .39 |
| 13 | 364 | 8 | .02 | 921 | 3 | .06 | 180 | 2 | .36 |
| 14 | 357 | 8 | -.11 | 871 | 3 | -.21 | 132 | 1 | -.07 |
| 15 | 400 | 9 | .11 | 1,107 | 4 | .41 | 142 | 1 | .52 |
| 16 | 360 | 8 | .08 | 783 | 3 | .18 | 93 | 1 | .75 |
| 17 | 333 | 7 | -.23 | 661 | 2 | -.26 | 53 | 1 | -.07 |
| 18 | 434 | 9 | .17 | 898 | 3 | .28 | 57 | 1 | .43 |
| 19 | 371 | 8 | .21 | 704 | 3 | .29 | 40 | 0 | .60 |
| 20 | 306 | 7 | -.37 | 546 | 2 | -.40 | 25 | 0 | -.07 |
| 21 | 484 | 11 | .27 | 913 | 3 | .53 | 27 | 0 | .50 |
| 22 | 381 | 8 | .15 | 596 | 2 | .12 | 18 | 0 | 1.57 |
| 23 | 330 | 7 | -.27 | 531 | 2 | -.24 | 7 | 0 | - |
| 24 | 451 | 10 | .52 | 695 | 2 | .28 | | | |
| 25 | 297 | 6 | .48 | 541 | 2 | .20 | | | |
| 26 | 201 | 4 | -.36 | 449 | 2 | -.24 | | | |
| 27 | 314 | 7 | .55 | 588 | 2 | .42 | | | |
| 28 | 203 | 4 | .41 | 413 | 1 | .38 | | | |
| 29 | 144 | 3 | .17 | 299 | 1 | -.08 | | | |
| 30 | 123 | 3 | .01 | 324 | 1 | .52 | | | |
| 31 | 122 | 3 | -.17 | 213 | 1 | .16 | | | |
| 32 | 147 | 3 | .79 | 184 | 1 | -.27 | | | |
| 33 | 82 | 2 | .37 | 252 | 1 | 1.83 | | | |
| 34 | 60 | 1 | -.58 | 89 | 0 | -.58 | | | |
| 35 | 142 | 3 | - | 211 | 1 | - | | | |

'MTM' stands for months to maturity.
The monthly average volume is in column (1).
Column (2) is the percentage proportion of each average volume relative to the highest average volume for that commodity.
Column (3) shows the rate of increase or decrease of the average volume for a given month to maturity, over the previous month to maturity.

Figure 13



Volume and Time to Maturity:
Grains
100000
80000
60000
40000
20000
0
Average Volume
0
5
10
15
Months Left to Maturity
Legend
CORN
WHEAT
SOYBEANS

Figure 14

# Volume and Time to Maturity: Soybean Meal and Oil

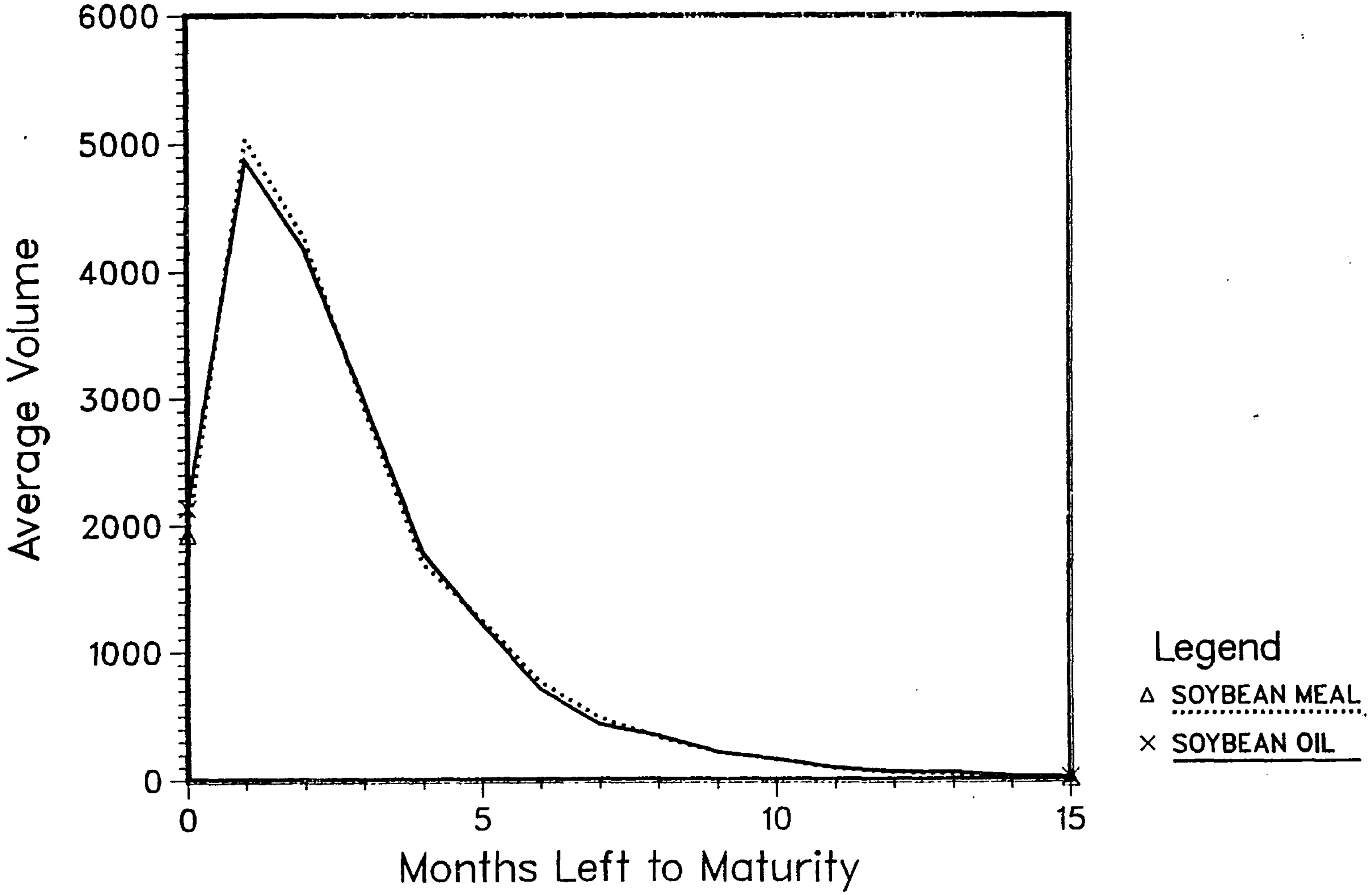


Figure 15

# Volume and Time to Maturity: Financials

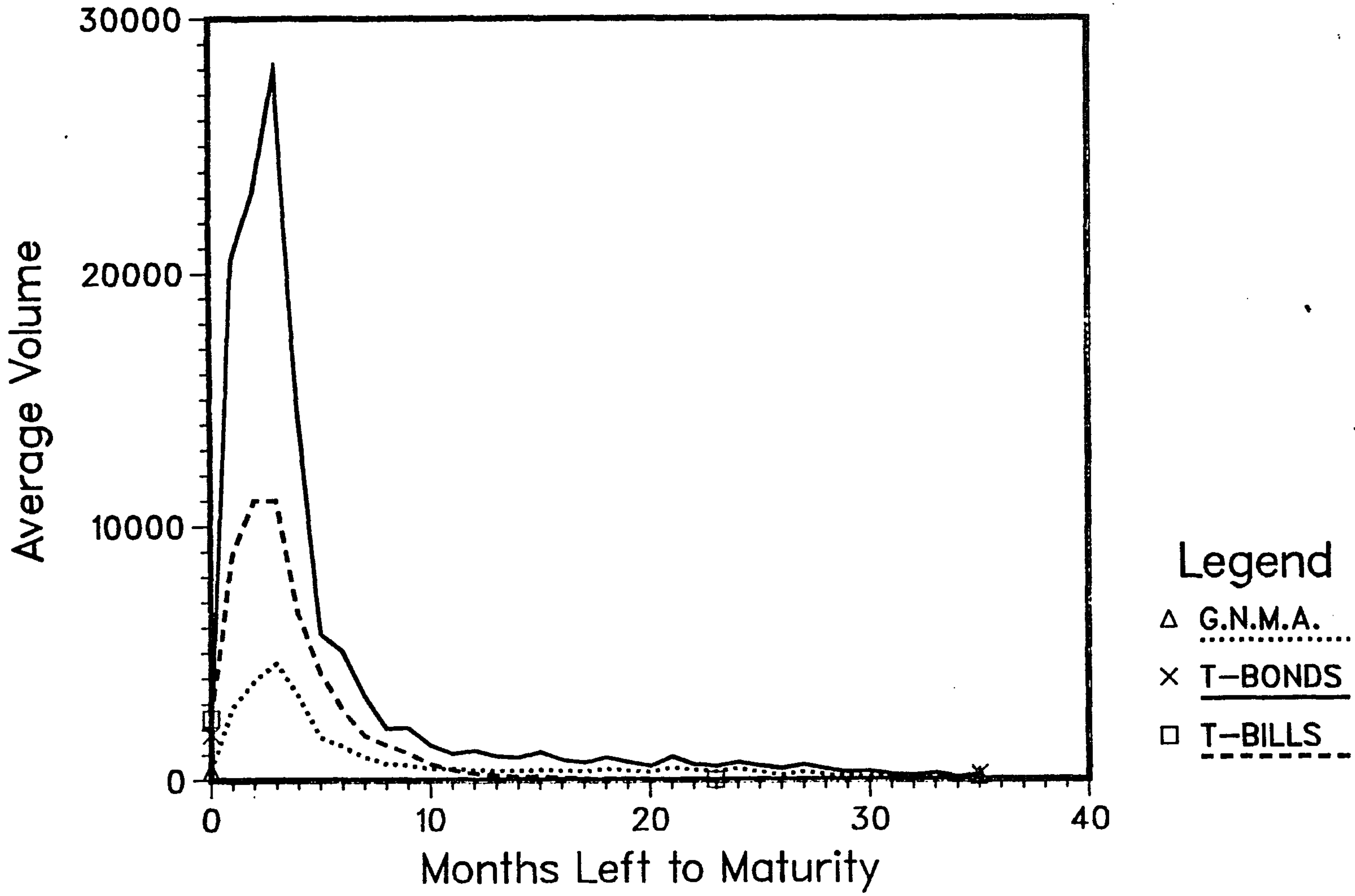
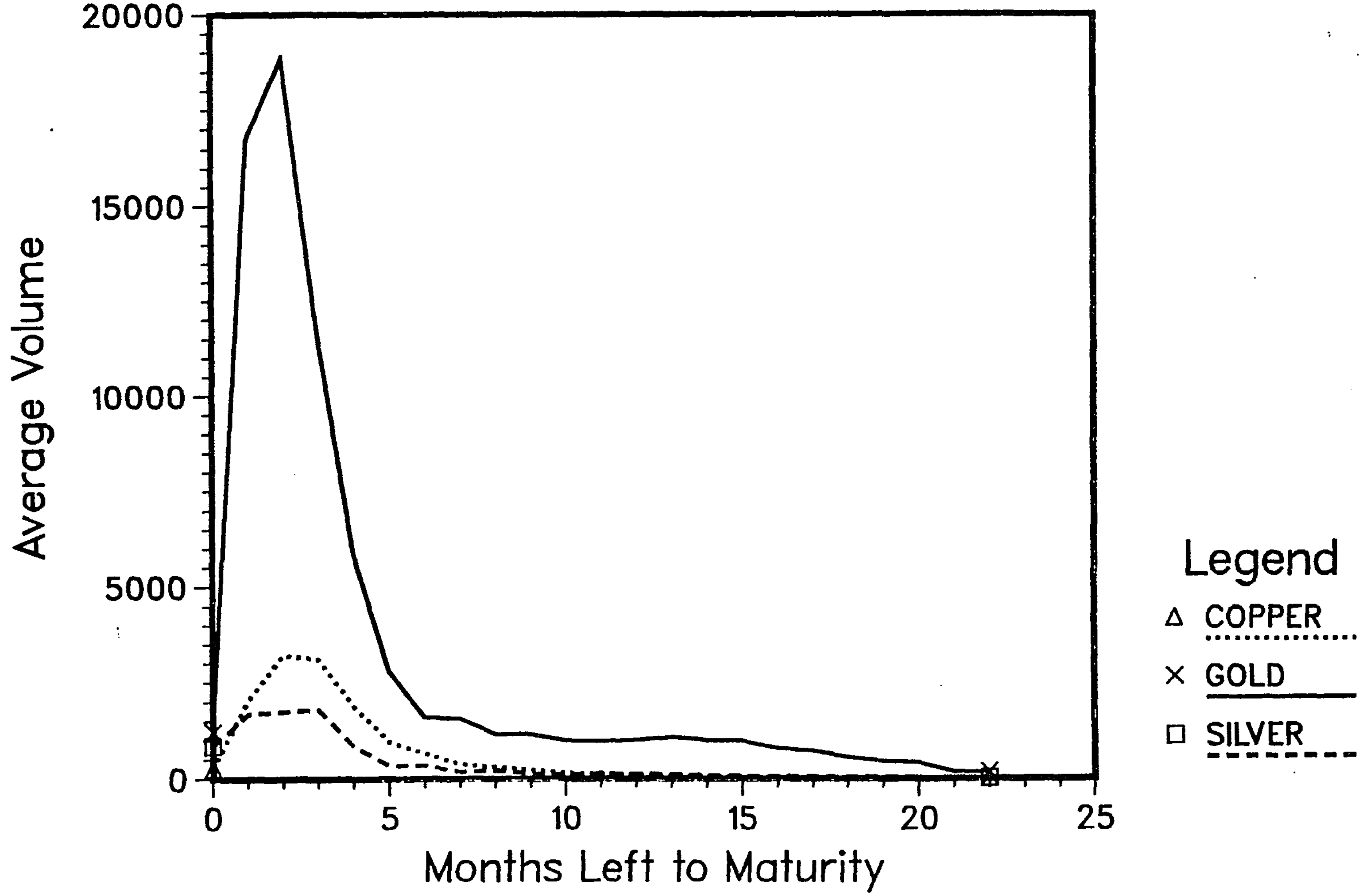


Figure 16

# Volume and Time to Maturity: Metals



interest. Also, silver with the smallest open interest has the lowest volume among the 11 commodities. Furthermore, in 7 out of 11 cases open interest and volume peaks are in the same month. Overall, it seems that monthly trading activity is captured successfully by both volume and open interest. To provide evidence on this assertion we calculate the correlation coefficients between the average open interest and volume from Tables 7 and 8. The evidence is presented in Table 9 through two correlation measures, one parametric (Pearson product-moment correlations) and one non-parametric (Spearman rank-order correlation). The correlation coefficients are high in general, while Spearman's coefficients are greater than Pearson's in all cases. The two highest Spearman's coefficients are for Treasury bills (.993) and wheat (.982). Wheat (.971) and copper (.957) are the two highest Pearson's coefficients. Both tests found the smallest correlation between open interest and volume for G.N.M.A. and gold. The smaller correlation coefficient for G.N.M.A. and gold relative to the other commodities is primarily due to having a rapid increase in open interest which is not accompanied by a similar behavior in average volume. One interesting observation is that soybeans, soybean meal and soybean oil have the same Spearman's rank order correlation coefficient (.947).

Both measures of correlation in Table 9 demonstrate that the average open interest and volume are equivalent proxies

TABLE 9

Correlation between Open Interest and Volume

| Commodity | Pearson Product Moment Correlations | Spearman Rank-Order Correlations |
| --- | --- | --- |
| Corn | .946 | .965 |
| Wheat | .971 | .982 |
| Soybeans | .893 | .947 |
| Soybean Meal | .882 | .947 |
| Soybean Oil | .898 | .947 |
| G.N.M.A. | .493 | .720 |
| Treasury bonds | .800 | .913 |
| Treasury bills | .954 | .993 |
| Copper | .957 | .967 |
| Gold | .512 | .645 |
| Silver | .747 | .876 |

Significance level at .01%

of trading activity. However, for our purposes, Spearman's rank correlations are stronger and more appropriate to use. The reason for this is that we are not primarily interested in relating the change of open interest in units to the change of volume in units but rather in measuring the relative ranking of average open interest as opposed to average volume. The results in Table 9 which are significant at the .01% level, suggest that studies in futures markets can use monthly averages of volume and of open interest interchangeably.

With respect to the differences of volume behavior across commodities, the 5 agriculturals exhibit smoother developments of volume than the rest. At delivery month, in corn, the soybean complex, T-bills and silver there is significantly higher trading volume in comparison to the other markets, where less than 10% of trading (relatively to the highest observed volume) occurs. In the financials and metals, volume increases at a very slow pace. Even 6 to 7 months before maturity the volume is only 20% of the highest observed volume for those markets. Since the open interest builds up faster than volume we might infer that the "extra" volume added abruptly during the 6 months before maturity is mostly due to "day trading", the speculative activity of day traders and scalpers. In the other months of trading it seems that volume is determined by the hedgers and mainly the "position traders", speculators (professional traders or public commodity traders) who initiate a futures position and hold it over a period of days, weeks or months. However, this observation should not lead one to argue that futures markets are liquid only during the 6 to 7 months before maturity and thin during the others. As long as the open interest is high or increases during the other months, position traders can provide a sufficiently liquid market. To the extent that the open interest is low during the distant months from maturity, some degree of thinness will be associated with these months.[31]

---

[31] On the basis of vast differences across markets in the average level of both volume and open interest, it could be argued that a market scoring low on both might be illiquid throughout the months of trading. This might be true with silver. However, if the silver futures market is less liquid as a whole, it could still be true that

Tables 7 and 8 help identify the "cut-off" months during which the contract moves from being thin to liquid. Since the identification of the precise "cut-off" month is difficult, it is appropriate to use multiple "cut-off" months within a range of the most likely months to maturity. These "cut-off" months and the associated empirical results are presented in the next chapter.

---

trading during distant months is even less liquid. It is this relative illiquidity within a particular contract that we try to analyze.

## Chapter 9

# EVIDENCE ON THE THINNESS RELATED PRICE VARIABILITY

To choose the range of "cut-off" months, we use the results of open interest in Table 7. We search for the month at which the changes in column (3) were decreasing substantially after a period of dramatic increases. If a substantial level of open interest has also been achieved (as column (2) indicated) we presume that around this month the contract has a liquid market. To avoid the possibility of an error in the identification of a month to maturity as a "cut-off" month, we take a 3-month interval of the would-be "cut-off" months (2-month interval in the case of gold). Then, we run three OLS regressions of equation (11) for each commodity, each time taking observations up to and including the "cut-off" month. The regression coefficients, F-statistics, and $R^2$ are all presented in Appendix B. In all cases except corn and Treasury bills, the $R^2$ is at acceptable levels, while the regression coefficients are significant and have the correct sign (positive "c" and negative "b"). We then use these coefficients to "extend" the regression line beyond the "cut-off" month and calculate the estimated errors as follows:

$$\text{error}_{tj} = N(V_{tj}) - \hat{c} - \hat{b}(T(j)-t). \qquad (24)$$

For each commodity and each "cut-off" month we calculate the number of positive and negative errors as well as the average estimated error. To analyze these results we test two statistical hypotheses.

(1) To test for the proportions of positive and negative errors we employ the sign test, a non-parametric test. The sign test is designed to determine whether significant differences exist between two populations of positive and negative errors. Our null hypothesis is:

$H(0): P(+)=P(-)=.5$ , against the alternative $H(a): P(+)\neq.5$

For large values of n (sample size) and the quantity $nP(+)P(-)$ greater than 3, we can approximate the binomial with a normal distribution and calculate the critical value:

$$z = (x/n - .5)/\sqrt{P(+)P(-)/n}$$

where, x is the number of positive errors. In Table 10 we present the number of positive and negative errors as well as the associated "z"-values for all months beyond the "cut-off" months. A single asterisk next to the z-value indicates significance at 10%, a double asterisk at 5% and a triple at 1%.

(2) To test the magnitude of the estimated error, we assume that the errors are approximately normally distributed with mean zero and standard deviation s. Our hypcthesis is formed as follows:

$H(0): Avg=0$, against the alternative $H(a): Avg\neq0$

TABLE 10

Estimated Errors and z-statistics

| Commo-dity | MTM | (+) | (-) | z | (+) | (-) | z | (+) | (-) | z |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 8 | | | 9 | | | 10 |
| | 9 | 25 | 30 | -.67 | | | - | | | - |
| C | 10 | 20 | 35 | -2.02** | 19 | 36 | -2.29** | | | - |
| O | 11 | 22 | 33 | -1.48 | 19 | 36 | -2.99*** | 22 | 33 | -1.48 |
| R | 12 | 18 | 13 | 0.90 | 16 | 15 | 0.16 | 18 | 13 | 0.90 |
| N | 13 | 8 | 21 | -2.41** | 8 | 21 | -2.41** | 8 | 21 | -2.41** |
| | 14 | 2 | 10 | -2.31** | 2 | 10 | -2.31** | 2 | 10 | -2.31** |
| | | | | 7 | | | 8 | | | 9 |
| | 8 | 36 | 18 | 2.45** | | | - | | | - |
| W | 9 | 40 | 15 | 3.37*** | 37 | 18 | 2.56** | | | - |
| H | 10 | 35 | 18 | 2.34** | 34 | 19 | 2.06** | 31 | 22 | 1.24 |
| E | 11 | 34 | 17 | 2.38** | 33 | 18 | 2.10** | 30 | 21 | 1.26 |
| A | 12 | 21 | 8 | 2.41** | 21 | 8 | 2.41** | 18 | 11 | 1.30 |
| T | 13 | 14 | 14 | 0.0 | 14 | 14 | 0.0 | 14 | 14 | 0.0 |
| | 14 | 4 | 6 | -0.63 | 4 | 6 | -0.63 | 4 | 6 | -0.63 |
| | | | | 8 | | | 9 | | | 10 |
| B | 9 | 42 | 35 | 0.80 | | | - | | | - |
| S E | 10 | 44 | 33 | 1.25 | 46 | 31 | 1.71* | | | - |
| O A | 11 | 45 | 30 | 1.73* | 45 | 30 | 1.73* | 45 | 30 | 1.73* |
| Y N | 12 | 17 | 12 | 0.93 | 19 | 10 | 1.67* | 19 | 10 | 1.67* |
| S | 13 | 11 | 12 | -0.21 | 11 | 12 | -0.21 | 11 | 12 | -0.21 |
| | 14 | 5 | 1 | 1.63 | 6 | 0 | 2.45** | 6 | 0 | 2.45** |
| | | | | 6 | | | 7 | | | 8 |
| | 7 | 43 | 46 | -0.32 | | | - | | | - |
| | 8 | 41 | 48 | -0.74 | 41 | 48 | -0.74 | | | - |
| M | 9 | 49 | 40 | 0.95 | 49 | 40 | 0.95 | 50 | 39 | 1.17 |
| S E | 10 | 56 | 32 | 2.56** | 54 | 34 | 2.13** | 60 | 28 | 3.41*** |
| O A | 11 | 44 | 34 | 1.13 | 44 | 34 | 1.13 | 44 | 34 | 1.13 |
| Y L | 12 | 26 | 15 | 1.72* | 26 | 15 | 1.72* | 26 | 15 | 1.72* |
| | 13 | 14 | 12 | 0.39 | 14 | 12 | 0.39 | 14 | 12 | 0.39 |
| | 14 | 4 | 3 | 0.38 | 4 | 3 | 0.38 | 4 | 3 | 0.38 |

Table 10 (Continued)

| | | 6 | | | 7 | | | 8 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 7 | 33 | 56 | -2.44** | | | - | | | - |
| S | 8 | 21 | 68 | -4.98*** | 27 | 62 | -3.71*** | | | - |
| O | 9 | 18 | 71 | -5.62*** | 31 | 58 | -2.86*** | 36 | 53 | -1.80* |
| Y | 10 | 20 | 68 | -5.12*** | 24 | 64 | -4.26*** | 27 | 61 | -3.62*** |
| O | 11 | 19 | 61 | -4.70*** | 22 | 58 | -4.03*** | 29 | 51 | -2.46** |
| I | 12 | 7 | 33 | -4.11*** | 11 | 29 | -2.85*** | 12 | 28 | -2.53** |
| L | 13 | 9 | 25 | -2.74*** | 11 | 23 | -2.06** | 12 | 22 | -1.72* |
| | 14 | 4 | 14 | -2.36** | 4 | 14 | -2.36** | 6 | 12 | -1.41 |

| | | 27 | | | 28 | | | 29 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 28 | 10 | 10 | 0.0 | | | - | | | - |
| | 29 | 10 | 10 | 0.0 | 10 | 10 | 0.0 | | | - |
| G | 30 | 10 | 9 | 0.23 | 10 | 9 | 0.23 | 10 | 9 | 0.23 |
| N | 31 | 11 | 7 | 0.94 | 11 | 7 | 0.94 | 11 | 7 | 0.94 |
| M | 32 | 11 | 7 | 0.94 | 11 | 7 | 0.94 | 11 | 7 | 0.94 |
| A | 33 | 6 | 1 | 1.89* | 6 | 1 | 1.89* | 6 | 1 | 1.89* |
| | 34 | 3 | 3 | 0.0 | 3 | 3 | 0.0 | 3 | 3 | 0.0 |
| | 35 | 5 | 1 | 1.63 | 5 | 1 | 1.63 | 5 | 1 | 1.63 |

| | | 27 | | | 28 | | | 29 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| T | 28 | 12 | 6 | 1.41 | | | - | | | - |
| R B | 29 | 11 | 7 | 0.94 | 10 | 8 | 0.47 | | | - |
| E O | 30 | 11 | 9 | 0.45 | 11 | 9 | 0.45 | 11 | 9 | 0.45 |
| A N | 31 | 11 | 7 | 0.94 | 11 | 7 | 0.94 | 11 | 7 | 0.94 |
| S D | 32 | 12 | 5 | 1.70* | 12 | 5 | 1.70* | 12 | 5 | 1.70* |
| U S | 33 | 3 | 2 | 0.45 | 3 | 2 | 0.45 | 2 | 3 | -0.45 |
| R | 34 | 2 | 2 | 0.0 | 2 | 2 | 0.0 | 2 | 2 | 0.0 |
| Y | 35 | 1 | 3 | -1.00 | 1 | 3 | -1.00 | 1 | 3 | -1.00 |

| | | 8 | | | 9 | | | 10 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 9 | 1 | 27 | -4.91*** | | | - | | | - |
| | 10 | 4 | 24 | -3.78*** | 6 | 22 | -3.02*** | | | - |
| | 11 | 4 | 24 | -3.78*** | 5 | 23 | -3.40*** | 5 | 23 | -3.40*** |
| T | 12 | 1 | 27 | -4.91*** | 5 | 23 | -3.40*** | 6 | 22 | -3.02*** |
| R B | 13 | 2 | 25 | -4.43*** | 4 | 23 | -3.66*** | 6 | 21 | -2.89*** |
| E I | 14 | 4 | 23 | -3.66*** | 4 | 23 | -3.66*** | 6 | 21 | -2.89*** |
| A L | 15 | 0 | 26 | -5.10*** | 1 | 25 | -4.71*** | 1 | 25 | -4.71*** |
| S L | 16 | 1 | 25 | -4.71*** | 3 | 23 | -3.92*** | 4 | 22 | -3.53*** |
| U S | 17 | 3 | 23 | -3.92*** | 3 | 23 | -3.92*** | 3 | 23 | -3.92*** |
| R | 18 | 1 | 22 | -4.38*** | 1 | 22 | -4.38*** | 1 | 22 | -4.38*** |
| Y | 19 | 2 | 21 | -3.96*** | 2 | 21 | -3.96*** | 2 | 21 | -3.96*** |
| | 20 | 0 | 22 | -4.69*** | 0 | 22 | -4.69*** | 0 | 22 | -4.69*** |
| | 21 | 1 | 22 | -4.38*** | 1 | 22 | -4.38*** | 1 | 22 | -4.38*** |
| | 22 | 0 | 23 | -4.80*** | 1 | 22 | -4.38*** | 1 | 22 | -4.38*** |
| | 23 | 1 | 21 | -4.26*** | 1 | 21 | -4.26*** | 1 | 21 | -4.26*** |

Table 10 (Continued)

| | | 7 | | | 8 | | | 9 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 8 | 24 | 23 | 0.15 | | | - | | | - |
| | 9 | 23 | 23 | 0.0 | 22 | 24 | -0.30 | | | - |
| | 10 | 25 | 21 | 0.59 | 24 | 22 | 0.30 | 25 | 21 | 0.59 |
| | 11 | 22 | 27 | -0.71 | 20 | 29 | -1.29 | 23 | 26 | -0.43 |
| C | 12 | 21 | 27 | 2.65*** | 18 | 10 | 1.51 | 22 | 6 | 3.02*** |
| O | 13 | 15 | 12 | 0.58 | 13 | 14 | -0.19 | 17 | 10 | 1.35 |
| P | 14 | 19 | 8 | 2.12** | 19 | 8 | 2.12** | 19 | 8 | 2.12** |
| P | 15 | 17 | 10 | 1.35 | 17 | 10 | 1.35 | 18 | 9 | 1.73* |
| E | 16 | 18 | 10 | 1.52 | 17 | 11 | 1.13 | 18 | 10 | 1.51 |
| R | 17 | 16 | 12 | 0.76 | 16 | 12 | 0.76 | 16 | 12 | 0.76 |
| | 18 | 22 | 6 | 3.02*** | 21 | 7 | 2.65*** | 22 | 6 | 3.02*** |
| | 19 | 17 | 10 | 1.35 | 15 | 12 | 0.58 | 17 | 10 | 1.35 |
| | 20 | 17 | 11 | 0.13 | 17 | 11 | 1.13 | 17 | 11 | 1.13 |
| | 21 | 20 | 7 | 2.51** | 18 | 9 | 1.73* | 20 | 7 | 2.50** |
| | 22 | 17 | 7 | 2.04** | 16 | 8 | 1.63 | 17 | 7 | 2.04** |

| | | 17 | | | 18 | | |
|---|---|---|---|---|---|---|---|
| G | 18 | 12 | 14 | -0.39 | | | - |
| O | 19 | 12 | 14 | -0.39 | 13 | 13 | 0.0 |
| L | 20 | 9 | 17 | -1.57 | 10 | 16 | -1.18 |
| D | 21 | 11 | 15 | -0.78 | 12 | 14 | -0.39 |
| | 22 | 9 | 16 | -1.40 | 10 | 15 | -1.00 |

| | | 12 | | | 13 | | | 14 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 13 | 19 | 7 | 2.35** | | | - | | | - |
| | 14 | 21 | 4 | 3.40*** | 21 | 4 | 3.40*** | | | - |
| S | 15 | 18 | 8 | 1.96** | 17 | 9 | 1.57 | 15 | 11 | 0.78 |
| I | 16 | 17 | 9 | 1.57 | 14 | 12 | 0.39 | 14 | 12 | 0.39 |
| L | 17 | 19 | 8 | 2.12** | 19 | 8 | 2.12** | 19 | 8 | 2.12** |
| V | 18 | 14 | 11 | 0.60 | 13 | 12 | 0.20 | 13 | 12 | 0.20 |
| E | 19 | 20 | 5 | 3.00*** | 16 | 9 | 1.40 | 16 | 9 | 1.40 |
| R | 20 | 17 | 8 | 1.80* | 16 | 9 | 1.40 | 15 | 10 | 1.00 |
| | 21 | 19 | 7 | 2.35** | 18 | 8 | 1.96** | 18 | 8 | 1.96** |
| | 22 | 14 | 8 | 1.28 | 14 | 8 | 1.28 | 13 | 9 | 0.85 |

(+) : Number of positive errors.
(-) : Number of negative errors.
* : Significant at the 10% level.
** : Significant at the 5% level.
*** : Significant at the 1% level.

For samples with less than 30 observations we use Student's t statistic with n-1 degrees of freedom:

$$t=(Avg)(\sqrt{n})/s$$

For sufficiently large samples ($n \geq 30$) we have taken advantage of the Central Limit Theorem and use $z=(Avg)(\sqrt{n})/s$ as our test statistic. Furthermore, with large samples we do not have to assume any population normality, so the standard deviation s is used as a satisfactory estimate of the unknown population standard deviation. Table 11 presents the average estimated errors (Avg) and the associated t-statistics. The asterisks show the three levels of significance we use, same as in Table 10, where the significance was based on the t-values only.

Tables 10 and 11 while testing the same hypothesis in two different ways produce virtually the same results: price variability during the illiquid months is a commodity-dependent phenomenon. During the illiquid months price variability for copper and silver is higher than what the "maturity effect" hypothesis suggests. Wheat and soymeal show higher variability in the illiquid months except during the very first months from contract initiation (months 13 and 14). Strong evidence that the variability is lower during the illiquid months is exhibited by soyoil and Treasury bills. Corn also has lower variability, but the results cannot be rigorously interpreted since the regression coefficients from Appendix B used to estimate the errors, are insignifi-

TABLE 11

Average Estimated Errors and their t-statistics

| Commodity | MTM | Avg | t | Avg | t | Avg | t |
|---|---|---|---|---|---|---|---|
| | | 8 | | 9 | | 10 | |
| | 9 | -0.0152 | 0.99 | - | | - | |
| C | 10 | -0.0182 | -0.87 | -0.0349 | -1.09 | - | |
| O | 11 | -0.0378 | -2.25** | -0.0455 | -2.71*** | -0.0356 | -2.12** |
| R | 12 | 0.0349 | 1.33 | 0.0261 | 1.00 | 0.0374 | 1.43 |
| N | 13 | -0.0790 | -2.47** | -0.0887 | -2.77*** | -0.0761 | -2.38** |
| | 14 | -0.1751 | -3.63*** | -0.1858 | -3.86*** | -0.1718 | -3.57*** |
| | | 7 | | 8 | | 9 | |
| | 8 | 0.0089 | 0.53 | - | | - | |
| W | 9 | 0.0468 | 3.40*** | 0.0424 | 3.07*** | - | |
| H | 10 | 0.0324 | 2.15** | 0.0272 | 1.80* | 0.0082 | 0.54 |
| E | 11 | 0.0581 | 2.56** | 0.0521 | 2.30** | 0.0303 | 1.34 |
| A | 12 | 0.0668 | 1.99* | 0.0601 | 1.79* | 0.0354 | 1.05 |
| T | 13 | 0.0572 | 1.52 | 0.0498 | 1.33 | 0.0222 | 0.59 |
| | 14 | -0.0384 | -0.50 | -0.0466 | -0.60 | -0.0771 | -0.99 |
| | | 8 | | 9 | | 10 | |
| B | 9 | -0.0104 | -0.66 | - | | - | |
| S E | 10 | -0.0117 | -0.57 | -0.0071 | -0.34 | - | |
| O A | 11 | -0.0078 | -0.37 | -0.0025 | -0.12 | 0.0003 | 0.02 |
| Y N | 12 | -0.0192 | -0.64 | -0.0131 | -0.44 | -0.0099 | -0.33 |
| S | 13 | -0.0281 | -0.49 | -0.0214 | -0.38 | -0.0178 | -0.31 |
| | 14 | 0.0959 | 2.98*** | 0.1033 | 3.21*** | 0.1072 | 3.33** |
| | | 6 | | 7 | | 8 | |
| | 7 | 0.0027 | 0.19 | - | | - | |
| | 8 | -0.0142 | -0.80 | -0.0162 | -0.91 | - | |
| M | 9 | 0.0040 | 0.24 | 0.0016 | 0.10 | 0.0100 | 0.61 |
| S E | 10 | 0.0568 | 2.73*** | 0.0541 | 2.60*** | 0.0638 | 3.07*** |
| O A | 11 | 0.0402 | 1.50 | 0.0371 | 1.38 | 0.0483 | 1.80* |
| Y L | 12 | 0.0927 | 2.43** | 0.0893 | 2.34** | 0.1018 | 2.67*** |
| | 13 | 0.1097 | 1.62 | 0.1059 | 1.56 | 0.1198 | 1.76* |
| | 14 | 0.2122 | 1.33 | 0.2081 | 1.31 | 0.2233 | 1.40 |

Table 11 (Continued)

| | | 6 | | 7 | | 8 | |
|---|---|---|---|---|---|---|---|
| SOYOIL | 7 | -0.0383 | -2.75*** | - | | - | |
| | 8 | -0.0651 | -4.37*** | -0.0433 | -2.90*** | - | |
| | 9 | -0.0823 | -5.27*** | -0.0563 | -3.61*** | -0.0347 | -2.22** |
| | 10 | -0.1188 | -6.36*** | -0.0887 | -4.75*** | -0.0634 | -3.40*** |
| | 11 | -0.1187 | -6.04*** | -0.0845 | -4.31*** | -0.0557 | -2.84*** |
| | 12 | -0.1866 | -4.50*** | -0.1484 | -3.58*** | -0.1159 | -2.79*** |
| | 13 | -0.2018 | -3.43*** | -0.1594 | -2.71*** | -0.1233 | -2.09** |
| | 14 | -0.1189 | -1.62 | -0.0724 | -0.99 | -0.0327 | -0.45 |
| | | **27** | | **28** | | **29** | |
| GNMA | 28 | 0.0136 | 0.70 | - | | - | |
| | 29 | -0.0005 | -0.02 | -0.0022 | -0.11 | - | |
| | 30 | 0.0437 | 1.46 | 0.0419 | 1.40 | 0.0422 | 1.41 |
| | 31 | 0.0538 | 1.80* | 0.0519 | 1.74* | 0.0522 | 1.74* |
| | 32 | 0.0127 | 0.39 | 0.0107 | 0.33 | 0.0110 | 0.34 |
| | 33 | 0.0605 | 2.18* | 0.0584 | 2.11* | 0.0587 | 2.12* |
| | 34 | -0.0006 | -0.02 | -0.0028 | -0.07 | -0.0025 | -0.06 |
| | 35 | 0.0729 | 2.67** | 0.0706 | 2.59** | 0.0709 | 2.60** |
| | | **27** | | **28** | | **29** | |
| TREASURY BONDS | 28 | 0.0143 | 0.75 | - | | - | |
| | 29 | 0.0202 | 1.06 | 0.0183 | 0.96 | - | |
| | 30 | 0.0461 | 1.76* | 0.0441 | 1.69 | 0.0417 | 1.60 |
| | 31 | 0.0254 | 1.03 | 0.0233 | 0.94 | 0.0208 | 0.84 |
| | 32 | 0.0568 | 2.15** | 0.0546 | 2.07* | 0.0520 | 1.97* |
| | 33 | 0.0044 | 0.21 | 0.0021 | 0.10 | -0.0006 | -0.03 |
| | 34 | -0.0448 | -1.06 | -0.0472 | -1.12 | -0.0500 | -1.19 |
| | 35 | -0.0035 | -0.12 | -0.0060 | -0.20 | -0.0090 | -0.30 |
| | | **8** | | **9** | | **10** | |
| TREASURY BILLS | 9 | -0.1550 | -6.67*** | - | | - | |
| | 10 | -0.1516 | -4.37*** | -0.0827 | -2.38** | - | |
| | 11 | -0.1755 | -5.23*** | -0.0963 | -2.87*** | -0.0632 | -1.88* |
| | 12 | -0.2383 | -6.56*** | -0.1488 | -4.10*** | -0.1112 | -3.06*** |
| | 13 | -0.2983 | -8.63*** | -0.1984 | -5.74*** | -0.1563 | -4.52*** |
| | 14 | -0.2922 | -6.56*** | -0.1819 | -4.08*** | -0.1353 | -3.04*** |
| | 15 | -0.4548 | -13.04*** | -0.3342 | -9.59*** | -0.2831 | -8.12*** |
| | 16 | -0.4225 | -10.64*** | -0.2916 | -7.35*** | -0.2360 | -5.95*** |
| | 17 | -0.4629 | -8.33*** | -0.3217 | -5.79*** | -0.2615 | -4.71*** |
| | 18 | -0.5930 | -12.76*** | -0.4414 | -9.50*** | -0.3768 | -8.11*** |
| | 19 | -0.5934 | -9.88*** | -0.4315 | -7.19*** | -0.3624 | -6.04*** |
| | 20 | -0.6983 | -20.23*** | -0.5260 | -15.24*** | -0.4524 | -13.11*** |
| | 21 | -0.7414 | -12.44*** | -0.5588 | -9.37*** | -0.4806 | -8.06*** |
| | 22 | -0.7974 | -12.66*** | -0.6045 | -9.60*** | -0.5218 | -8.29*** |
| | 23 | -0.7773 | -12.57*** | -0.5740 | -9.29*** | -0.4869 | -7.87*** |

Table 11 (Continued)

| | | 7 | | 8 | | 9 | |
|---|---|---|---|---|---|---|---|
| | 8 | 0.0058 | 0.59 | - | | - | |
| | 9 | -0.0060 | -0.96 | -0.0087 | -1.39 | - | |
| | 10 | -0.0005 | -0.07 | -0.0036 | -0.47 | -0.0001 | -0.01 |
| | 11 | -0.0184 | -1.82* | -0.0219 | -2.17** | -0.0179 | -1.76* |
| C | 12 | 0.0429 | 1.99* | 0.0390 | 1.80* | 0.0435 | 2.01* |
| O | 13 | 0.0116 | 0.74 | 0.0072 | 0.46 | 0.0123 | 0.78 |
| P | 14 | 0.0310 | 3.47*** | 0.0262 | 2.93*** | 0.0318 | 3.55*** |
| P | 15 | 0.0246 | 2.35** | 0.0194 | 1.85* | 0.0254 | 2.43** |
| E | 16 | 0.0183 | 1.34 | 0.0127 | 0.93 | 0.0192 | 1.41 |
| R | 17 | 0.0194 | 1.64 | 0.0133 | 1.13 | 0.0204 | 1.73* |
| | 18 | 0.0357 | 3.52*** | 0.0592 | 3.17*** | 0.0667 | 3.57*** |
| | 19 | 0.0181 | 1.06 | 0.0112 | 0.66 | 0.0193 | 1.12 |
| | 20 | 0.0305 | 1.33 | 0.0232 | 1.01 | 0.0317 | 1.39 |
| | 21 | 0.0608 | 3.05*** | 0.0531 | 2.66** | 0.0622 | 3.12*** |
| | 22 | 0.0688 | 2.52** | 0.0607 | 2.23** | 0.0702 | 2.58** |

| | | 17 | | 18 | |
|---|---|---|---|---|---|
| G | 18 | -0.0327 | -1.69 | - | |
| O | 19 | -0.0192 | -1.46 | -0.0132 | -1.00 |
| L | 20 | -0.0248 | -2.01* | -0.0184 | -1.49 |
| D | 21 | -0.0200 | -1.18 | -0.0131 | -0.78 |
| | 22 | -0.0298 | -2.20** | -0.0225 | -1.66 |

| | | 12 | | 13 | | 14 | |
|---|---|---|---|---|---|---|---|
| | 13 | 0.0308 | 1.55 | - | | - | |
| | 14 | 0.0268 | 3.68*** | 0.0205 | 2.82*** | - | |
| S | 15 | 0.0194 | 2.18** | 0.0125 | 1.41 | 0.0085 | 0.95 |
| I | 16 | 0.0492 | 1.50 | 0.0417 | 1.27 | 0.0373 | 1.14 |
| L | 17 | 0.0462 | 2.02* | 0.0380 | 1.67 | 0.0333 | 1.46 |
| V | 18 | 0.0170 | 1.58 | 0.0083 | 0.77 | 0.0031 | 0.29 |
| E | 19 | 0.0496 | 2.00* | 0.0402 | 1.62 | 0.0346 | 1.40 |
| R | 20 | 0.0487 | 2.14** | 0.0386 | 1.70 | 0.0327 | 1.44 |
| | 21 | 0.0585 | 1.70* | 0.0478 | 1.39 | 0.0415 | 1.21 |
| | 22 | 0.1003 | 1.57 | 0.0890 | 1.39 | 0.0823 | 1.29 |

Avg : Average Estimated Error.
* : Significant at the 10% level.
** : Significant at the 5% level.
*** : Significant at the 1% level.

cant. From Table 11, GNMA and Treasury bonds show a possible higher variability during the illiquid months. For the other commodities, soybeans and gold seem to have a price variability as suggested by the "maturity effect" hypothesis, but the evidence is not clear.

In statistically testing for the existence of positive or negative errors in Tables 10 and 11, we were concerned only with a single month to maturity at a time. In so doing, however, we limited our test on the null hypothesis. The "illiquid month hypothesis" as stated earlier implies a dichotomy between liquid and illiquid months and as such it presumes that all the errors we calculate from the illiquid months belong to the same population. We can therefore test whether all the errors from the illiquid months, collectively, are significantly different from zero. The results of both the tests appear in Table 12.

As expected, both z and t statistics are improved, thus presenting stronger evidence on the direction of the commodity-dependent variability. In all cases except soybeans, the two tests agree on the sign. They also agree in significance in all commodities but G.N.M.A. and T-bonds. At the 1% level of significance, wheat, soymeal, copper and silver have higher variability during the illiquid months. G.N.M.A. and T-bonds also exhibit higher variabilty with a significance level varying from 1% (t-test) to 5% and 10% in the sign test. Corn, soyoil, T-bills and gold have signifi-

TABLE 12

z- and t-statistics for all Estimated Errors

| Commodity | Cut-off Month | SIGN TEST H(0): P(+)=P(-)=.5 (+) | (-) | z | T-TEST H(0): Avg=0 Avg | t |
|---|---|---|---|---|---|---|
| Corn | 8 | 95 | 142 | -3.05*** | -.0238 | -2.47** |
| | 9 | 64 | 118 | -4.00*** | -.0436 | -3.78*** |
| | 10 | 50 | 77 | -2.40** | -.0396 | -2.87*** |
| Wheat | 7 | 184 | 96 | 5.26*** | .0394 | 4.49*** |
| | 8 | 143 | 83 | 3.99*** | .0403 | 4.01*** |
| | 9 | 97 | 74 | 1.76* | .0167 | 1.33 |
| Soybeans | 8 | 167 | 123 | 2.58*** | -.0084 | -0.82 |
| | 9 | 130 | 83 | 3.22*** | -.0024 | -0.18 |
| | 10 | 83 | 53 | 2.57** | -.0014 | -0.08 |
| Soymeal | 6 | 278 | 229 | 2.18** | .0321 | 3.54*** |
| | 7 | 232 | 186 | 2.25** | .0349 | 3.30*** |
| | 8 | 198 | 131 | 3.69*** | .0583 | 4.68*** |
| Soyoil | 6 | 133 | 399 | -11.53*** | -.1021 | -11.98*** |
| | 7 | 133 | 310 | -8.41*** | -.0840 | -8.68*** |
| | 8 | 124 | 230 | -5.63*** | -.0663 | -5.81*** |
| G.N.M.A. | 27 | 66 | 48 | 1.69* | .0276 | 2.69*** |
| | 28 | 56 | 38 | 1.86* | .0283 | 2.41** |
| | 29 | 45 | 29 | 1.86* | .0365 | 2.63*** |
| T-bonds | 27 | 63 | 41 | 2.16** | .0273 | 2.89*** |
| | 28 | 50 | 36 | 1.51 | .0278 | 2.60*** |
| | 29 | 39 | 29 | 1.21 | .0282 | 2.23** |
| T-bills | 8 | 25 | 355 | -16.93*** | -.4373 | -27.20*** |
| | 9 | 37 | 315 | -14.82*** | -.3277 | -21.48*** |
| | 10 | 37 | 287 | -13.89*** | -.2886 | -18.94*** |
| Copper | 7 | 292 | 195 | 4.40*** | .0196 | 5.13*** |
| | 8 | 253 | 187 | 3.15*** | .0161 | 3.97*** |
| | 9 | 251 | 143 | 5.44*** | .0253 | 5.66*** |
| Gold | 17 | 53 | 76 | -2.03** | -.0260 | -3.85*** |
| | 18 | 46 | 57 | -1.08 | -.0161 | -2.32** |
| Silver | 12 | 179 | 74 | 6.60*** | .0448 | 5.09*** |
| | 13 | 148 | 79 | 4.58*** | .0362 | 3.79*** |
| | 14 | 123 | 79 | 3.10*** | .0342 | 3.21*** |

Table 12 (Continued)

| | |
|---|---|
| (+) | : Number of positive errors. |
| (-) | : Number of negative errors. |
| Avg | : Average Estimated Error. |
| * | : Significant at the 10% level. |
| ** | : Significant at the 5% level. |
| *** | : Significant at the 1% level. |

cantly lower variability during the illiquid months. The evidence for soybeans is rather conflicting. With the sign test, at the 1% level of significance, we reject the null hypothesis of similar variability in the illiquid as in the liquid months. Statistically, more positive errors occur in the illiquid months. However, with the t-test we cannot reject the hypothesis that the average error is zero. At best the evidence for soybeans does not reject the null hypothesis and suggests that price variability is close to what the "maturity effect" hypothesis suggests.

## 9.1 CLASSIFYING CONTRACT MONTHS TO THIN AND LIQUID: HOW APPROPRIATE?

The evidence in Tables 10, 11 and 12 is based, to a large extent, on the sensitive technique which determined the possible "cut-off" months for each commodity. Therefore, before we conclude this chapter on the thinness related price variability, we should perform a parametric test and check our previous results. In Table 13 we present the regression results on an alternative version of equation (11):

$$\ln(Y) = c + bX + dX^2 + e \qquad (25)$$

By introducing the square of time to maturity, we are in effect testing for the hypothesis that price variability exhibits an "L-shaped" relationship with the time to maturity; distant months will have higher variability than predicted by equation (11).

The results in Table 13 are very persuasive. In 8 out of 11 cases we reject the null hypothesis that the variability has a linear relationship with time to maturity. Soymeal, GNMA, Treasury bonds, copper and silver have higher price variability while soyoil, Treasury bills, gold and corn lower than predicted by the simple linear model. We do not reject the null hypothesis of the linear relationship of price variability and time to maturity in the case of wheat and soybeans since the associated t-statistics for the "d" coefficient are insignificant. In general, the evidence in Table 13 is in concordance with the evidence in Tables 10, 11 and 12. This suggests that the procedure to determine the "cut-off" months based on open interest and volume data is meaningful.

Before ending this subject, it is necessary to point out that rejecting the null hypothesis cf linearity between price variability and time to maturity does not lead to the rejection of Samuelson's hypothesis on spot price generating process. Samuelson's hypothesis is valid as the evidence suggests in chapter 6 and Appendix B. The existence of an "L-shaped" or an inverse "L-shaped" curve captures the sen-

TABLE 13

Linear Regression Results: Maturity Effect

Regression Model: $\ln(N(V_{tj})) = c + b(T(j)-t) + d(T(j)-t)^2 + e$

| Commodity | DF | c | b | d | F-RATIO | PR>F | $R^2$ |
|---|---|---|---|---|---|---|---|
| CORN | 679 | -0.0317<br>(-1.75) | 0.0154<br>(2.60)** | -0.0012<br>(-2.95)** | 4.92 | .0075 | .014 |
| WHEAT | 656 | 0.1632<br>(7.77)** | -0.0278<br>(-4.01)** | 0.0004<br>(0.78) | 88.31 | .0001 | .212 |
| SOYBEANS | 903 | 0.1537<br>(8.41)** | -0.0220<br>(-3.55)** | -0.0002<br>(-0.50) | 131.38 | .0001 | .225 |
| SOYMEAL | 1039 | 0.2690<br>(12.68)** | -0.0570<br>(-7.87)** | 0.0018<br>(3.42)** | 176.42 | .0001 | .254 |
| SOYOIL | 1063 | 0.1227<br>(6.63)** | -0.0053<br>(-0.87) | -0.0016<br>(-3.66)** | 158.49 | .0001 | .230 |
| GNMA | 805 | 0.0809<br>(7.11)** | -0.0070<br>(-4.43)** | .00009<br>(1.90)* | 52.87 | .0001 | .116 |
| T-BONDS | 658 | 0.1727<br>(16.61)** | -0.0123<br>(-8.61)** | .00008<br>(1.94)* | 368.71 | .0001 | .529 |
| T-BILLS | 601 | 0.0387<br>(1.02) | 0.0212<br>(2.87)** | -0.0016<br>(-5.33)** | 57.90 | .0001 | .161 |
| COPPER | 905 | 0.1601<br>(21.55)** | -0.0205<br>(-11.85)** | 0.0002<br>(2.76)** | 610.20 | .0001 | .574 |
| GOLD | 889 | 0.0291<br>(5.14)** | -0.0002<br>(-0.13) | -0.0002<br>(-3.74)** | 106.76 | .0001 | .194 |
| SILVER | 877 | 0.0958<br>(10.16)** | -0.0149<br>(-6.75)** | 0.0003<br>(3.13)** | 104.51 | .0001 | .193 |

* Significant at the 6% level.
** Significant at the 1% level.

sitivity of price changes variability to thinness related influences; keeping the "maturity effect" constant, an additional source of variability -known as thinness- affects price behavior in illiquid markets.

## Chapter 10

## CONCLUSIONS AND IMPLICATIONS OF ESSAY I

On an extensive set of data, this study has provided strong evidence on the existence of: (1) the non-stationarity of shocks in spot prices, namely, the "year effect" and the "month effect"; (2) the "contract month effect" in futures prices; (3) the "maturity effect"; and (4) the thinness related changes in price variability.

Previous research in futures markets suffers from the inability to control the non-stationarity in prices. Such omission might have produced inaccurate empirical results. Furthermore, taking simple or logarithmic price changes is an insufficient way to control for the non-stationary shocks. There are additional steps to be taken in constructing price series free of such shocks. Studies in futures markets need to account for the "maturity effect" as well. In addition, dealing with agricultural commodities and metals, requires an adjustment or control for the "contract month effect".

Monthly averages of open interest and volume were found to change similarly. This observation suggests that either one can be used to measure the liquidity/illiquidity present in the futures markets.

Many studies disregard observations in the first few months from initiation of a contract because the market is thin. However, since some market participants do enter thin markets, it is critical to investigate the price variability they face. To the extent that price variability in distant months is greater than what is suggested by the maturity effect, liquidity premia might be attached to low open interest contracts. Since risk-averse investors demand higher returns to accept riskier investments, it would be interesting to investigate the existence of any liquidity premia during the low open interest months.

Differences in volatility patterns between near and distant contracts is bound to affect the correlation of futures prices with spot prices. Consequently, different hedging strategies can be constructed to exploit the differences in correlations.

Evidence on the different variability in the distant months, might help explain one puzzling phenomenon: clearing firms in futures markets, establish the margin requirements, i.e., minimum capital required to trade in the futures markets. For a given commodity, the margin is the same for all contracts regardless of time to maturity. Since the "maturity effect" evidence suggests lower variability during the distant months, a rational margin setting policy should require lower margins in these months. The absence of such a provision in reality, might rest upon the notion that far maturing contracts exhibit higher variability than the variability explained by the time to maturity and therefore, trading in such contracts may not entitle lower margins.

# ESSAY II: PRELIMINARY INVESTIGATION INTO THE STORAGE ASYMMETRY

# Chapter 11

## INTRODUCTION TO ESSAY II

When we compare financial futures with commodity futures we observe among other differences an asymmetric movement of commodities in time space. This asymmetry is induced by the laws of nature that require spring to always follow winter and always precede summer. So while it is possible to carry this year's crop over to the next year, it is impossible to transfer next year's crop for consumption today. Such "irreversibility" is common to other natural processes and help establish the notion that the arrow of time is moving forward.[32] Working's hypothesis that only current inventories determine futures prices, seems to rely implicitly on the asymmetry found in commodity markets.[33] Since next year's crop cannot be consumed today, no matter how abundant it is expected to be, it is only the current supplies that can be used today or carried over to the next period. Therefore,

---

[32] See Layzer (1975) and Georgescu-Roegen (1971) for a discussion on the concept of the "arrow of time". The term "irreversibility" used here is consistent with Georgescu-Roegen's definition: "... all processes which, though not reversible, can return to any previously attained phase.", page 197. One of his many examples of "irreversibility" parallels the notion of the "arrow of time": "... the process of the entire universe is unidirectional, i.e. irreversible", page 202.

[33] See Working (1942, 1948, 1949).

according to Working the current supplies should play the most important role in determining the constellation of all prices.

With respect to financial futures the above mentioned asymmetry, although implicitly present in the issuance of an underlying financial instrument, is technically very weak. Demand for and supply of a particular instrument determines its price which in turn can influence issuers to increase or decrease the outstanding volume to achieve desired levels. Demand for financial instruments is very elastic since they can be easily substituted with other assets of similar qualities.[34] The supply is also very responsive and flexible. So, while a farmer who has planted his grain can do nothing but wait and hope for a prosperous harvest, a firm has some freedom to increase (or decrease) its outstanding financial obligations if market conditions are favorable. Such flexibility in financial markets makes the problem of asymmetry less serious and almost nonexistent.

-------------------

[34] G.N.M.A. and Treasury bonds can be substituted with AAA corporate bonds with similar maturities while commercial paper of "blue chip" companies is an acceptable substitute for Treasury bills. In perfect capital markets, multiple claims can be combined in a portfolio with similar risk-return characteristics of the security to be substituted. In this sense, the degree of substitutability is very high in security markets. In contrast, despite the use of agricultural commodities as substitutes for each other, substitutability is rather limited in these markets.

The phenomenon of storage asymmetry is also present in metals. However, the broad differences among metals affect their sensitivity to this problem. On the one hand, precious metals like gold and silver have little storage asymmetry, if any. The fundamental reason is that the existing inventories are many times the size of a year's production. If the demand for gold or silver rises unexpectedly, the large inventories in place can be utilized to meet this demand. In this sense, any delay in the supply response caused by adjustment in the production process is neutralized by the existing inventories. These inventories operate as a "buffer" and thus help overcome the problem of storage asymmetry. On the other hand, copper and similar industrial metals have inventories at normal levels to meet the demand of the industry. Unanticipated rise in their demand can create shortages which last for a short period till the supply fully adjusts to the new levels of demand. The speed of adjustment depends largely upon the nature of the industry, capacity utilization, unemployment in the region, etc. The problem of storage asymmetry in copper is not neutralized as in the case of gold and silver but at best is not as serious as with agricultural commodities. In agricultural commodities there is a crop cycle with inflexible starting and ending points, so that the adjustment process never begins before or after the planting but only during its course.[35] In

---

[35] In the words of Georgescu-Roegen (1971): "... an elementary process cannot be started except during one specific

contrast, the adjustment process in metals, under normal circumstances, is not prohibited by a similar production cycle.[36]

Following the above considerations, our conjecture is that studying the different pattern of price behavior and different response to new information in futures markets would reveal the degree of storage asymmetry in each market. In chapter 12 we review the theories on storage and the factors that determine the intertemporal price relationships. Chapter 13 provides the theoretical foundation for the existence of storage asymmetry. The statistical considerations, methodology and empirical results on storage asymmetry are included in chapter 14. Our conclusions and suggestions are in chapter 15.

---

period dictated by nature.", page 251.

[36] As mentioned above, the supply side can respond to a given shock to the system either through a change in the level of new production or a change in the amount of the commodity stored. While for a wide spectrum of commodities, a change in the inventory holdings can be made with little delay, if any, the adjustment through production is closely related to the nature of the commodity and as such it varies widely.

## Chapter 12

## THEORIES OF INTERTEMPORAL PRICE RELATIONSHIPS

For storable commodities, the intertemporal price relations of various futures contracts are partially due to the cost of storing the commodity from one time period to another. In non-storable commodities, the constellation of futures prices is likely to be determined only by current expectations of the spot prices in the future.

Working (1949) and Telser (1958) considered the carrying charges (positive or negative) as the sole determinants of intertemporal price spreads. C(t,T) is the cost of storing the commodity from time t to time T.[37] If we denote with S(t) the spot price of commodity A and F(t,T) the price at time t of a futures contract maturing in time T, the following equation should hold:

$$F(t,T) = S(t) + C(t,T) \qquad (25)$$

If

$$F(t,T) > S(t) + C(t,T) \qquad (26)$$

then riskless arbitrage is profitable by buying the spot commodity and selling futures contracts. Since all arbitrageurs will take similar positions they will eliminate any remaining profits and force the equality again.

---

[37] In the literature, "cost of storage" and "cost of carrying" are used interchangeably to refer to the total costs incurred when storing the commodity from one period to another.

If $$F(t,T) < S(t) + C(t,T) \quad (27)$$

then arbitrageurs will sell the spot commodity and buy futures contracts to restore the equality. A similar mechanism can be illustrated for the price relationship of two futures contracts of different maturity. The marginal cost of storage will equal the price spread.

According to Working (1949) and Telser (1958) the marginal costs of storage have two components: (1) the marginal cost of physical storage (handling charges, interest, insurance, etc.) and (2) the marginal convenience yield (the advantage for suppliers and processors of the commodity to maintain necessary inventory that meets regular or unanticipated demand).[38] Brennan (1958) introduced a third component, namely the marginal risk aversion factor, to explain intertemporal price spread in relation to the holding of inventories. His "supply of storage" theory builds on Working's earlier arguments and provides a rationale for holding stocks under all possible spread relationships.

Figure 17 shows that as the spread between spot price at time t and expected price at t+1 increases, the amount of stocks carried from period t to period t+1 will increase; more of a commodity is stored as the spread -and thus prices- increase. The marginal risk aversion component is positively related with the amount of stocks, while the marginal

---

[38] The convenience yield is only valid under conditions of uncertainty. If we were to assume a supplier with perfect foresight of his demand function, the associated convenience yield would be zero.

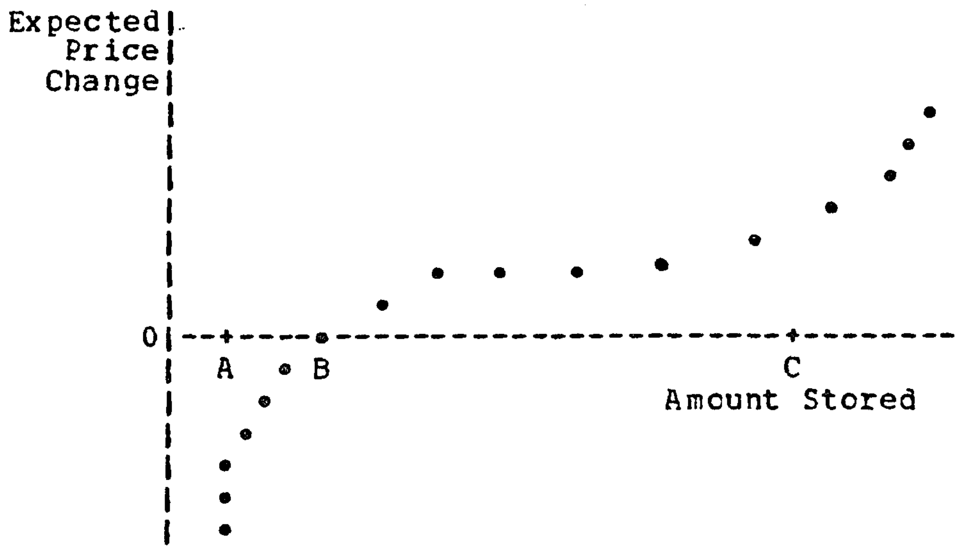



Figure 17: The Supply of Storage Curve

convenience yield is a decreasing function of stocks held, as it is seen in the range AB. When stocks exceed B (abundant storage) the marginal convenience yield is approximately zero. In general, the optimal amount to store, ex ante, in any given period will be at the level where the marginal cost of storage equals the expected price change.

In a context other than the theory of storage, Hirshleifer (1972) introduced an additional component of intertemporal price spreads. Hirshleifer dealt with illiquidity that arises due to the inability to change consumption or investment. This change is necessitated by the arrival of new information. This illiquidity is distinct from the familiar illiquidity due to the non-marketability of assets. So while an asset can be perfectly marketable it may lack physical liquidity. As an example, recently planted grain is an illiquid asset in the physical sense. Yet, if the farmer wants to sell his future crop (sell futures) he might find a liquid market among speculators.

Hirshleifer develops a three-period model in which uncertainty exists in the form of alternative possible states of nature. There are certain claims to consumption at time-0 and time-2 and contingent claims to consumption at time-1. (Such claims command prices P(0), P(1),[39] P(2), respectively, at current period 0). He assumes physical irreversibility in the sense that as new information enters the market, only the shorter-maturity investment can be re-evaluated. In the context of futures markets this means contracts nearer to maturity have greater flexibility in adjusting to new information (e.g. news about a good or bad crop). This flexibility is translated into a storage decision at the time of maturity. That is, whether to consume the crop or store it until the next period. In Hirshleifer's model, storage is used as an intertemporal production function that influences the consumption decision as uncertainty unfolds. By nature the intertemporal storage is only in one direction, i.e. there is no product transformation from period 2 to period 1. The further away a contract is from maturity, the greater the "inflexibility" (or lower usefulness) in ad-

---

[39] P(1) actually equals the sum of two contingent claim prices in period 1.

justing the present consumption and storage decision. Therefore, rational individuals will attach a liquidity premium to contracts near maturity.

According to Hirshleifer, in the most basic case, a liquidity premium is said to exist at t=0 if the ratio P(1)/P(0) exceeds the ratio P(2)/P(1). No liquidity premium will arise in the case where production possibilities (storage) are excluded. These results have a series of empirical implications across futures markets where storage is continuous (agricultural commodities, metals, financial futures) or discontinuous (Maine potatoes).[40]

In a recent paper Grauer and Litzenberger (1979) explicitly incorporate the problem of storage asymmetry in agricultural commodities. The "infeasibility" of transporting the commodity backwards in time puts in effect necessary arbitrage conditions which affect the constellation of futures prices and the spot-futures price relationship. Their time-state preference model prices commodity futures contracts in an economy with risky outcomes. In a perfectly competitive, two-period exchange economy where all individuals maximize utility of lifetime consumption, they derive the relation-

---

[40] Potatoes are grown in many regions and have different seasons of harvest. Crops are stored till a new crop from the next season is harvested. Maine potatoes -a major portion of the fall crop- are harvested in the late summer and fall and remain the sole source in the months of August through December. However, as the "early crop" becomes available in late winter, spring and early summer, the storage of Maine potatoes is continued in early spring.

ship between futures price and expected future spot price under the possibility of storage. In general, the price of a futures contract is a function of the expected future spot price, the inflation premium, the real social risk premium, and the gross real returns of nominal and real bonds. The real social risk premium and the marginal cost of physical storage impose an upper bound on the expected future spot price. Due to this upper bound the constellation of futures prices will differ from the constellation of prices determined in the absence of such a constraint.[41] It is then an empirical question of how contracts with different maturities are priced relatively to each other and how these relationships are altered in response to the asymmetry of storage.

The relationship of current and expected future spot prices is also examined by Ackley (1983). Although he ignores the problem of storage irreversibility when he states that "through changes in inventories, supply or demand in any particular year, in effect, may thus borrow from past and/or from future years' supply or demand", he stresses the influence of inventories on the behavior of spot and futures prices. The possibility of storage has a stabilizing effect on prices when demand or supply or both are random. This is

---

[41] The existence of storage asymmetry breaks the equality in (25). The spot-futures price relationship is then a weak inequality:

$$F(t,T) \leq S(t) + C(t,T) \qquad (28)$$

This is due to the fact that the arbitrage mechanism cannot operate in cases where supplies are limited.

due to immediate inventory adjustments, under rational expectations, as a response to news that affect future demand or supply or both. Such inventory responses smooth consumption over time and have stabilizing effects on the new equilibrium prices. It is then logical to expect that the size of existing inventory relative to the current production as well as the speed of its accumulation and depletion will influence the price behavior of a commodity.

In commodities with inventory levels many times that of the current production (e.g. gold, silver), quantities produced and/or consumed respond minimally and slowly to a given price change. In fact, large existing inventories neutralize the asymmetry of storage and reduce the possibility that inverted markets would exist.[42] In this case, price differential between two futures contracts of the same commodity should solely be due to the expected storage costs between these two maturities. "Storage asymmetry" premia on short maturity contracts should not be different from zero in these kinds of commodities. In the case of gold and silver, inventories are unable to play any stabilizing role on prices. Speculative behavior on future realization mainly determines the course of current and futures prices.[43]

------------------

[42] Inverted markets may exist for very short periods of time due to the costs of transferring the commodity in some form of an inventory to its final use. Jewelry or gold bars, for example, can be used for industrial purposes but there are labor or insurance costs when transformed or transfered to their final use or destination.

[43] This is due to the fact that the immense size of invento-

The situation is reversed, however, in commodities where the inventory levels are low relatively to the current production (e.g. grains). In this case, quantities consumed respond immediately to any price change, through adjustments in inventories. Quantities produced respond with a delay due to existing production cycle. The inventory stabilizes prices to new levels but because of relatively low inventory level the storage asymmetry and the possibility of inverted markets exist.[44] Therefore, storage asymmetry liquidity premia are expected to exist on near maturity contracts relatively to far maturing contracts. Spot and futures prices are determined relatively to the existing level of inventory and how unknown events might influence the future stocks.

---

ries determines the current price of gold. The inventory holders will continue storing the commodities as long as they expect to profit from higher prices in the future. Any changes in expectations about the future course of prices will not be followed by significant changes in the rate of production and/or consumption. The large size of inventories will respond to these changes, thus, introducing a destabilizing behavior on the path of prices.

[44] Contracts with shorter maturity have a greater flexibility which is translated into a decision to store or consume at the time of maturity. Shorter maturity claims have more degrees of freedom relative to longer maturity claims.

# Chapter 13

## MODELING STORAGE ASYMMETRY

Hirshleifer (1972) shows the illiquidity effect due to storage asymmetry in a simple three period model. As discussed in the previous chapter, one of his assumptions does not conform to reality. In a world of uncertainty, he considers second period's claim certain. With this assumption he introduces a strong preference for bringing commodity from period 2 for consumption in period 1 (if the "bad" state occurs in period 1). Since transferring the commodity backwards in time is impossible, the preference to do so imposes a liquidity premium on shorter maturity claims. His results therefore are stronger than if this assumption was relaxed.[45] The mere fact of introducing uncertainty in period 2 reduces the propensity of moving units from period 2 to period 1. More general result will be obtained if after relaxing this assumption we can still show liquidity premia.

---

[45] If we introduce uncertainty in period 2 the notion of "storage asymmetry" weakens. Since the possibility of two consecutive "bad" states exist, in such case there is no need to bring "bad" crops backwards for consumption today.

[46] As a result perfect marketability of the commodity is ensured. This assumption avoids the problem of confounding the "physical illiquidity" with the illiquidity derived from the imperfect marketability of the commodity.

We assume a perfectly competitive,[46] single good, three-period exchange economy. No production possibilities exist except the possibility of storage from early periods to later periods.[47] Individuals are endowed equal quantities of the same commodity at time-0. Uncertainty is introduced in the form of states of nature which completely describe all possible outcomes. Once a particular state is revealed, the size of the endowment is certain. At current period 0 the endowment W(0) is certain while in first period's W(1s) and second period's W(2s) are certain only after s (state of nature) is revealed. Without loss of generality, we partition the world in two states, s=A,B, where "A" is the "abundant" state (with probability "a") and "B" is the "bad" state (with probability "b"). While storing commodities forward (as an intertemporal product transformation process) is permitted, storing commodities backwards is impossible. This "storage asymmetry" renders greater flexibility to the claims in periods 0 and 1, since they can either be consumed in the same period, or stored for consumption in the next period. This is feasible as long as storage decision is made after part of the uncertainty is resolved. If storage was constrained to be made before the accumulation of some information at the beginning of period 0, all claims would be equally inflexible.

---

[47] In this sense, the "possibility of storage" coincides with Hirshleifer's "production transformation" term. This assumption excludes the use of land as an "extra" addition to the endowment.

At the beginning of period 0 the consumers have to price 7 contingent claims of consumption in the market which cover all possible time-paths of consumption:

C(0) = certain claim to current period 0 consumption with price P(0).

C(A) = contingent claim of consumption in period 1 if state A occurs, priced at P(A).

C(B) = contingent claim of consumption in period 1 if state B occurs, priced at P(B).

C(AA) = contingent claim of consumption in second period's state A, if state A occured in period 1, commanding a price of P(AA).

C(AB) = contingent claim of consumption in second period's state B, if state A occured in period 1, commanding a price of P(AB).

C(BA) = contingent claim of consumption in second period's state A, given that state B occured in period 1, commanding a price of P(BA).

C(BB) = contingent claim of consumption in second period's state B, given that state B occurred in period 1, commanding a price of P(BB).

The seven prices defined above are to be determined at time-0. Since an individual bids for commodity units to be consumed during the three periods (0, 1, 2) a certain unit of consumption would be assured only if he purchases all contingent claims for that period. Therefore,

$$P(1) = P(A) + P(B) \tag{28}$$

$$P(2) = P(AA) + P(AB) + P(BA) + P(BB) \qquad (29)$$

DEFINITION: At t=0 a liquidity premium is said to exist if:

$$P(1)/P(0) > P(2)/P(1) \qquad (30)$$

Equation (30) implies that the shorter maturity claims (period 0 and 1) are priced more "favorably" relative to the distant claim in period 2. This definition is similar to the notion that yields for a long-term investment are higher than yields on a short-term investment. However, (30) departs from the yield-curve notion. Since we have a pure exchange economy, interest rates or yields are effectively neutralized to zero so that any differences in prices -and consequently yields- are due only to the time-flexibility of each contingent claim.

## 13.1 INDIVIDUAL CHOICE PROBLEM

For simplicity we assume that individuals besides having identical endowments in a given state, share the same beliefs about uncertainty. Every individual has the same risk-averse utility function. The utility is derived from consumption at times 0,1 and 2:

$$\max U = \sum q(p)\ u\{C(0p),\ C(1p),\ C(2p)\} \qquad (31)$$

over all possible paths of consumption, where p is a possible "path" of time-states and q(p) its probability.

The four possible paths are shown in Figure 18.

Therefore:

$$U = a^2u\{C(0),C(A),C(AA)\} + abu\{C(0),C(A),C(AB)\}$$
$$+ bau\{C(0),C(B),C(BA)\} + b^2u\{C(0),C(B),C(BB)\}$$

| | | | Paths | Prob. |
|---|---|---|---|---|
| | C(A) < | C(AA) | C(0)-C(A)-C(AA) | $a^2$ |
| | | C(AB) | C(0)-C(A)-C(AB) | ab |
| C(0) < | | | | |
| | | C(BA) | C(0)-C(B)-C(BA) | ba |
| | C(B) < | C(BB) | C(0)-C(B)-C(BB) | $b^2$ |

Figure 18: Four Possible Paths of Consumption

If the utility function is time-additive, we can rewrite the above equation as:

$$U = (a^2+ab+ba+b^2)u(C(0))+a(a+b)u(C(A))+b(a+b)u(C(B))$$
$$+ a\{au(C(AA))+bu(C(AB))\}+b\{au(C(BA))+bu(C(BB))\}$$

Since a+b=1, we get:

$$U = u(C(0))+\{au(C(A))+bu(C(B))\}+\{a\{au(C(AA))+bu(C(AB))\}$$
$$+ b\{au(C(BA))+bu(C(BB))\}\} \qquad (32)$$

Implicit in (31) is the assumption that individuals obey von Neumann-Morgenstern axioms of rational choice under uncertainty. The assumption of the time additive utility function is sufficient to separate the consumption in each period over the commodities available in each state.

## 13.2 BACKWARD INDUCTION SYSTEM

At the beginning of time 0 the individual must price the contingent consumption goods and make a storage decision X(0) by transferring units of consumption C(0) into first period's consumption. The possibility of bad crops in periods 1 and 2 will command a positive storage X(0). At time 1 and when the "abundant" state A has been revealed, the individual will have an incentive to store part of his crop, X(A), into period 2 for consumption. On the other hand, if at time 1, the "bad" state B has occured, the individual will not store anything into next period but rather consume all his crop.[48]

The present problem of the storage decision fulfills the requirements of a three-stage dynamic system. In a dynamic process, any sequence of storage decision depends upon the realization of the state -and therefore outcome- in the previous period and must take into consideration information on future probability distributions. For this reason, backward induction is necessary and sufficient to use.[49] In such a process, we start at the beginning of the terminal period

---

[48] This is a rather reasonable assumption. In the years of terrible droughts, little or nothing is stored. In such years with severe droughts the phenomenon of inverted markets (spot prices higher than futures prices) is inevitable and intertemporal price spreads are almost "mirror images" of the convenience yield. As Figure 17 illustrates, little storage is made when price spreads are negative.

[49] For a formal presentation of the backward induction process, see Mossin (1968).

and maximize the expected utility from consumption at that period with respect to the storage decision variables. His decision or "derived" utility function is then taken to represent optimal preferences over the probability distribution in period 2. This "derived" utility function is taken into account during the optimization over the storage decision at the beginning of the prior to the last period. In this way, individuals can make an optimal decision at period 1 and price the contingent claims accordingly. The three stages involved are presented below.

STAGE 1: At the beginning of period 2 and after the state is revealed, the individual consumes his endowment in that state and any storage from the previous period. No storage decision is to be made. For a given X(A) stored from the previous period the consumption in period 2 is:

C(AA) = X(A) + W(2A), if state A occurs, or

C(AB) = X(A) + W(2B), if state B occurs.

If state B had occured in period 1, then second's period consumption is: C(BA) = W(2A), if state A occurs, or C(BB) = W(2B) if state B occurs.

STAGE 2: At the beginning of period 1, if state A has occured, for a given X(0) the individual must decide his consumption C(A) and the storage X(A) in such a way as to maximize expected utility from consumption over the two remaining periods 1 and 2:

$$U = \max_{X(A)} E(u) = \max_{X(A)} E\{u(C(A), C(AA), C(AB))\} =$$

$$= \max_{X(A)} \{u(C(A)) + au(C(AA)) + bu(C(AB))\} \quad (33)$$

subject to:

$$C(AA) = X(A) + W(2A)$$
$$C(AB) = X(A) + W(2B) \quad (34)$$
$$C(A) = X(0) + W(1A) - X(A)$$

If we take the derivatives with respect to X(A) in equations (34) we obtain:

$dC(AA)/dX(A)=1$, $dC(AB)/dX(A)=1$, $dC(A)/dX(A)=-1$

Maximizing (33) with respect to X(A):

$$dU/dX(A)=u'(A)dC(A)/dX(A) + au'(AA)dC(AA)/dX(A)$$
$$+ bu'(AB)dC(AB)/dX(A) = 0$$
$$u'(A)(-1) + au'(AA) + bu'(AB) = 0$$
$$u'(A) = au'(AA) + bu'(AB) \quad (35)$$

where ' denotes a first partial derivative of utility with respect to state-contingent consumption. Equation (35) states that X(A) will be determined at the point where the marginal utility from consumption in period 1, state A, is equated to a weighted average of marginal utilities from consumptions in second period's states A and B. The weights are the probabilities of state occurrence.

From equations (34) and (35) we can solve for the values of C(A), C(AA), C(AB) and X(A) that maximize (33). These optimal values can be denoted respectively: $C^+(A)$, $C^+(AA)$, $C^+(AB)$, $X^+(A)$. Then we can rewrite (35) as:

$$u'^+(A) = au'^+(AA) + bu'^+(AB) \quad (35')$$

At the beginning of period 1, if state B is revealed, the individual maximizes:

$$U = \max E(u) = \max\{u(C(B)) + au(C(BA)) + bu(C(BB))\} \quad (36)$$

subject to:

$$C(BA) = W(2A)$$
$$C(BB) = W(2B) \quad (37)$$
$$C(B) = W(1B) + X(0)$$

Since no storage is to be made for next period 2, for a given $X(0)$ the value of $C(BA)$, $C(BB)$ and $C(B)$ can be completely determined.

If the decision of storing nothing for period 2 when state B occurs in period 1 is to be optimal, the following condition must hold: the marginal utility from consumption in period 1B should be greater or equal to the expected marginal utility from consumption in period 2. With this condition there is no need of transporting the commodity from period 2 to 1B even if it was permissible to store backwards. Mathematically, we can write this condition as follows:

$$u'(W(1B)+X(0)) \geq au'(W(2A))+bu'(W(2B)) \quad (38)$$

or $u'(W(1B)+X(0)) \geq (1-b)u'(W(2A))+bu'(W(2B))$

or $u'(W(1B)+X(0))-u'(W(2A)) \geq b\{u'(W(2B))-u'(W(2A))\}$ (38')

The right hand size of (38') is always positive. The left hand size will be positive as long as: $W(1B)+X(0) < W(2A)$, a reasonable assumption, i.e., the size of a bad crop together with the previous period inventory cannot match the size of a "good" crop. If we also were to assume that for a given technology the "bad" endowments are equal across periods (W(1B)=W(2A)), then we can see that equation (38') will be satisfied for a wide range of values of the size of the endowments and the probability b that the "bad" state will occur.

STAGE 3: At the beginning of period 0, the problem of the individual is to maximize his expected lifetime utility from consumption with respect to the vector of storage decision variables {X(0), X(A)}:

$$U = \max_{X(0),X^+(A)} Eu\{C(0),C^+(A),C(B),C^+(AA),C^+(AB),C(BA),C(BB)\} =$$

$$= \max_{X(0),X^+(A)} Eu\{X(0),\ X^+(A)(X(0))\} \qquad (39)$$

subject to:

$$C(0) = W(0) - X(0)$$
$$C^+(A) = X(0) + W(1A) - X^+(A)$$
$$C^+(AA) = X^+(A) + W(2A)$$
$$C^+(AB) = X^+(A) + W(2B) \qquad (40)$$
$$C(B) = W(1B) + X(0)$$
$$C(BA) = W(2A)$$
$$C(BB) = W(2B)$$
$$u'^+(A) = au'^+(AA) + bu'^+(AB)$$

From (40) we can take the derivatives of the contingent claims of consumption with respect to X(0):

$dC(0)/dX(0)=-1$, $dC^+(AA)/dX(0)=dX^+(A)/dX(0)$

$dC^+(AB)/dX(0)=dX^+(A)/dX(0)$, $dC^+(A)/dX(0)=1-dX^+(A)/dX(0)$,

$dC(BA)/dX(0)=0$, $dC(BB)/dX(0)=0$, $dC(B)/dX(0)=1$

The utility function in (39) can be decomposed as in (32):

$$U = u(C(0)) + au\{C^+(A)\} + bu\{C(B)\} + a\{au(C^+(AA)) + bu(C^+(AB))\} + b\{au(C(BA)) + bu(C(BB))\} \quad (41)$$

Since $X^+(A)$ is a function of $X(0)$, we need maximize (41) only with respect to $X(0)$:

$$dU/dX(0) = u'(0)dC(0)/dX(0) + au'^+(A)dC^+(A)/dX(0) + bu'(B)dC(B)/dX(0) + a\{au'^+(AA)dC^+(AA)/dX(0) + bu'^+(AB)dC^+(AB)/dX(0)\} + b\{au'(BA)dC(BA)/dX(0) + bu'(BB)dC(BB)/dX(0)\} = 0$$

$$-u'(0) + au'^+(A)\{1-dX^+(A)/dX(0)\} + bu'(B) + a\{au'^+(AA)dX^+(A)/dX(0) + bu'^+(AB)dX^+(A)/dX(0)\}=0$$

$$-u'(0) + au'^+(A)\{1-dX^+(A)/dX(0)\} + bu'(B) + adX^+(A)/dX(0)\{au'^+(AA) + bu'^+(AB)\} = 0 \quad (42)$$

If we substitute (35') into equation (42) we get:

$$u'(0) = au'^+(A)\{1-dX^+(A)/dX(0)\} + bu'(B) + a\{u'^+(A)\}dX^+(A)/dX(0)$$

$$u'(0) = au'^+(A) + bu'(B) \quad (43)$$

Equation (43) states that the optimal amount of storage to be made at period 0 is determined at the point where the marginal utility from consumption in period 0 equals a weighted average of the marginal utilities in states A and B of period 1. The weights are the probabilities that the two states will occur.

## 13.3 INTERTEMPORAL PRICE RELATIONSHIPS

Within the traditional capital theory, price ratios of two time period claims equal the ratio of their marginal utilities:

$$P(1)/P(0)=(P(A)+P(B))/P(0)=(au'^{+}(A)+bu'(B))/u'(0) \qquad (44)$$

$$P(2)/P(1)=(P(AA)+P(AB)+P(BA)+P(BB))/P(1)=$$

$$(a^2u'^{+}(AA)+abu'^{+}(AB)+bau'(BA)+b^2u'(BB))/(au'^{+}(A)+bu'(B))=$$

$$(a\{au'^{+}(AA)+bu'^{+}(AB)\}+b\{au'(BA)+bu'(BB)\})/(au'^{+}(A)+bu'(B))=$$

$$(au'^{+}(A)+b\{au'(BA)+bu'(BB)\})/(au'^{+}(A)+bu'(B)) \qquad (45)$$

If the sure claim of consumption in period 0 is taken as the numeraire, then $P(0)=1$ and the price ratio in (44) using equation (43) becomes:

$$P(1)/P(0) = 1 \qquad (46)$$

To determine how $P(2)/P(1)$ is related to $P(1)/P(0)$, we take the difference $P(2)-P(1)$ from equation (45):

$$P(2)-P(1)=au'^{+}(A)+b\{au'(BA)+bu'(BB)\}-au'^{+}(A)-bu'(B)=$$

$$=b\{(au'(BA)+bu'(BB))-u'(B)\} \qquad (47)$$

If the sign of (47) is negative, then $P(2)/P(1) < 1$ (48)

(47) will be negative as long as:

$$u'(B) > au'(BA) + bu'(BB) \qquad (49)$$

Equation (49) requires the marginal utility from consumption in a "bad" state B to be greater than the expected marginal utility of the two states A and B. This is certain to occur if we assume that marginal utilities in the two "bad" states of period 1 and period 2 are equal, as viewed from time 0: $u'(B) = u'(BB)$. We can then rewrite equation (49):

$$(1-b)u'(B) > au'(BA) \text{ or } u'(B) > u'(BA) \qquad (50)$$

Since (50) will always be true, we can conclude that (48) holds so that in connection with (46) results in the following relationship:

$$P(1)/P(0) > P(2)/P(1) \qquad (51)$$

(51) asserts that individuals place liquidity premia on shorter maturity and more flexible consumptions C(0) and C(1) relatively to longer maturity and inflexible C(2). The result is obtained by the storage asymmetry of consumption units in period 2. If "backward" storage was permitted, all marginal utilities would be equalized and no liquidity premia would exist.

# Chapter 14

## STATISTICAL CONSIDERATIONS AND EMPIRICAL TESTINGS

### 14.1 TESTING THE STORAGE ASYMMETRY HYPOTHESIS: STATISTICAL CONSIDERATIONS

With our derivation in equation (51) we can construct the following null hypothesis:

> H(0): There is no intertemporal pricing difference among shorter and longer maturity futures contracts other than the implied cost of storage, i.e., $P(1)/P(0) \leq P(2)/P(1)$.
>
> H(1): Intertemporal pricing differences apart from the cost of storage include liquidity premia attached on the shorter maturity contracts, i.e., $P(1)/P(0) > P(2)/P(1)$.

Testing the null hypothesis on empirical grounds, while it seems intuitive, involves other considerations which complicate the methodology.

(1) One major problem is to effectively neutralize the cost of storage (physical storage, risk premium and convenience yield) and concentrate on any remaining difference that might be due to storage asymmetry. Furthermore, the longer the time between maturities, the more inappropriate is to regard the marginal cost as constant.

(2) Choosing the appropriate calendar months to observe the pricing differentials is another problem. Equation (51) has been derived under the assumption that the current en-

dowment is certain and at "normal" levels. If it were to be a certain "bad" endowment, prices would be inversely related and in that case, it is not clear how the price ratios would be determined. Since in agricultural commodities the inversion of markets is a frequent phenomenon during some months before the "new" crop arrives, avoiding these months seems appropriate.

(3) In Essay I of this study there is strong evidence that there are some non-stationarities in cash and futures price variability -and therefore pricing differentials- among various maturity contracts. The observed "month" and "maturity" effect if not taken into consideration can alone impose price differentials which may confound our tests.

## 14.2 METHODOLOGY

To empirically test the storage asymmetry hypothesis in the agricultural commodities and avoid the problems discussed above, a methodology is developed as follows: Daily price observations are taken from calendar months around late fall and early winter (October-January) to calculate the price ratios. During these months, the "month" effect is equally dispersed and it is very mild, as evidenced in section 5.2 and Anderson (1982). To alleviate the problem of the "maturity" effect we will test the intertemporal existence of price differentials in contracts which are only 2-3 months apart, so that the effect is minimal.

With respect to the cost of storage we will make the assumption that marginal costs of storage of 1-2 months are equal to the marginal costs of storage of the consecutive 1-2 months. To illustrate the mechanics of the empirical tests, suppose in October through January we observe the daily prices of four futures contracts which mature in March, May, July and September. The storage costs until March will be common to all four contracts. The assumption we make is that the storage costs from March to May are equal to the storage costs from May to July and equal to the storage costs from July to September.[50] We then create the following three price ratios from the trading days of October through January to see if this time series difference is significantly greater than zero:

P(May)/P(Mar), P(Jul)/P(May), P(Sep)/P(Jul).

If they are significantly positive we reject the null hypothesis that there are no intertemporal pricing differentials other than the storage costs. A mean difference test is run for the differences:

P(May)/P(Mar)-P(Jul)/P(May), P(Jul)/P(May)-P(Sep)/P(Jul).

---

[50] It should be mentioned that this assumption is in line with the earlier theoretical derivations as long as the costs of storage are expressed in a percentage form of futures prices. For example, if r refers to the storage costs from March to May and from May to July we can express the price of a May futures as a multiple of the March futures contract: P(May)=(1+r)P(Mar), and the price of July futures as: P(Jul)=(1+r)P(May). Then:
P(May)/P(Mar)=P(Jul)/P(May)=1+r , and
P(May)/P(Mar)-P(Jul)/P(May)=0. Any positive deviation of this difference from zero will signify the existence of price differences other than the costs of storage.

The selection of the four contracts is made to capture price differences in contracts to be delivered in different crops. For wheat and the soybean complex the March and May futures are "old" crop contracts, while the September is a "new" crop contract. In this sense, the July futures is an "intermediate" contract. For corn, since the harvest comes later in the year, the March, May and July futures are considered "old" crop contracts, while the September futures "intermediate" contract.[51] For empirical purposes, the selection of these contracts utilizes the best available proxies for the existent "old"-"new" crop price differentials. Study of pricing differentials of the same contracts in two or three consecutive years either is not feasible (there are no agricultural contracts traded two years before maturity) or introduces biases ("year effects") with unknown implications.

## 14.3 EMPIRICAL RESULTS ON INTERTEMPORAL PRICE RATIOS

The results for the "storage asymmetry" hypothesis appear in Table 14 for all agricultural commodities in the sample. All possible ratios from contracts maturing not more than 2 months apart were constructed. We then took their differences and created time series of the ratios and the ratio-differences. Ratios across contracts were calculated on a

---

[51] The December contract is a "new" crop futures but it is not appropriate to use in the study since the July-September time difference is not comparable to the September-December time difference.

TABLE 14

Intertemporal Price Ratios and Storage Asymmetry

| Commodity | Price Ratios | Obs. | Average | St.Dev. | T-Ratio |
|---|---|---|---|---|---|
| | R1=Pmay/Pmar-1 | 939 | .0213 | .0160 | 40.83 |
| | R2=Pjul/Pmay-1 | 939 | .0115 | .0123 | 28.69 |
| Corn | R3=Psep/Pjul-1 | 939 | -.0090 | .0210 | -13.20 |
| | R1-R2 | 939 | .0098 | .0064 | 47.12 |
| | R2-R3 | 939 | .0205 | .0130 | 48.18 |
| | R1=Pmay/Pmar-1 | 930 | .0015 | .0253 | 1.84a |
| | R2=Pjul/Pmay-1 | 930 | -.0274 | .0437 | -19.12 |
| Wheat | R3=Psep/Pjul-1 | 930 | .0161 | .0093 | 52.60 |
| | R1-R2 | 930 | .0289 | .0274 | 32.18 |
| | R2-R3 | 930 | -.0435 | .0371 | -35.78 |
| | R1=Pmar/Pjan-1 | 852 | .0178 | .0107 | 48.63 |
| | R2=Pmay/Pmar-1 | 852 | .0135 | .0120 | 32.71 |
| | R3=Pjul/Pmay-1 | 852 | .0090 | .0109 | 24.19 |
| | R4=Psep/Pjul-1 | 852 | -.0274 | .0313 | -25.56 |
| Soybeans | R5=Paug/Pjul-1 | 852 | -.0036 | .0084 | -12.48 |
| | R6=Psep/Paug-1 | 852 | -.0241 | .0243 | -28.88 |
| | R1-R2 | 852 | .0043 | .0053 | 23.80 |
| | R2-R3 | 852 | .0045 | .0039 | 33.40 |
| | R3-R4 | 852 | .0364 | .0252 | 42.13 |
| | R5-R6 | 852 | .0205 | .0180 | 33.24 |
| | R1=Pmar/Pjan-1 | 837 | .0106 | .0263 | 11.61 |
| | R2=Pmay/Pmar-1 | 837 | .0065 | .0202 | 9.38 |
| | R3=Pjul/Pmay-1 | 837 | .0092 | .0133 | 19.98 |
| | R4=Psep/Pjul-1 | 837 | -.0113 | .0286 | -11.40 |
| Soymeal | R5=Paug/Pjul-1 | 837 | .0006 | .0094 | 1.82a |
| | R6=Psep/Paug-1 | 837 | -.0120 | .0218 | -15.94 |
| | R1-R2 | 837 | .0040 | .0157 | 7.39 |
| | R2-R3 | 837 | -.0027 | .0134 | -5.73 |
| | R3-R4 | 837 | .0205 | .0227 | 26.10 |
| | R5-R6 | 837 | .0126 | .0171 | 21.29 |
| | R1=Pmar/Pjan-1 | 830 | .0032 | .0295 | 3.13 |
| | R2=Pmay/Pmar-1 | 830 | .0037 | .0207 | 5.12 |
| | R3=Pjul/Pmay-1 | 830 | .0048 | .0163 | 8.40 |
| | R4=Psep/Pjul-1 | 830 | -.0103 | .0204 | -14.52 |
| Soyoil | R5=Paug/Pjul-1 | 830 | -.0037 | .0099 | -10.88 |
| | R6=Psep/Paug-1 | 830 | -.0067 | .0124 | -15.46 |
| | R1-R2 | 830 | -.0005 | .0130 | -1.05b |
| | R2-R3 | 830 | -.0011 | .0079 | -3.93 |
| | R3-R4 | 830 | .0150 | .0130 | 33.35 |
| | R5-R6 | 830 | .0029 | .0090 | 9.39 |

a= significance level at 7%, b= significance level at 10%

day-by-day basis as long as there were observations for all the considered contracts. For the soybean complex we had more price ratios because there are more contracts traded than for corn or wheat. On a large number of observations ranging from 830 (soybean oil) to 939 (corn) we tested the hypothesis whether the price ratios minus unity and the differences of price ratios are different from zero.[52] The T-ratios along with the averages and their standard deviations of these time series are provided for all feasible combinations of contracts. All T-ratios are significant at the .01% level except one which is insignificant and two which are significant at the 7% level.

The frequency of the positive sign in the difference of price ratios is very high. Out of 16 ratio-differences, 12 are positive. Of the rest 4 negatives, one is insignificantly different from zero. The remaining three are one each in wheat, soybean meal and soybean oil. It should be mentioned that the negative ratio-difference for soybean meal and oil involves the same contracts. Both commodities are less storable relatively to grains so that the "storage asymmetry" is not expected to be equally strong. However, it will still be true that for contracts maturing in nearby months the "storage asymmetry" will strongly prevail. The negative sign in the ratio-differences in wheat, in conjuc-

---

[52] Instead of testing the hypothesis that price ratios are different from unity, we subtracted unity from the ratios and tested the equivalent hypothesis that are different from zero.

tion with the price ratios that make up this difference has to do with a non-uniform pricing of the May contract versus July versus September. May is more favorably priced to July than July is priced to September. In all other contracts the positive sign reinforces the notion that "old" crop contracts are more favorably priced to "new" crop contracts or contracts maturing in more distant months. In sum, the results do not support the null hypothesis. "Storage asymmetry", the alternative hypothesis, is valid and meaningful in the five examined agricultural commodities.

## Chapter 15

## CONCLUSIONS AND SUGGESTIONS OF ESSAY II

In agricultural commodities, there is one universal truth dictated by nature: once the farmers plant the seeds there is little they can do to change the expected size of the crop either upwards or downwards. The planted crop by inheritance cannot adjust to later revealing information. On the contrary, what retains complete flexibility in moving along the direction imposed by some new information is the "old" crop in the form of existing inventories; it can be entirely consumed, partly stored, or even partly destroyed (e.g. coffee producers occasionally decide to reduce excess production by burning millions of tons of their product). This "flexibility" was found, both on theoretical and empirical grounds, to impose "storage asymmetry" premia on prices of the most flexible contracts.

The possibility of storage as a process of moving real income forward over time together with the size of existing inventories largely determine the degree of "physical irreversibility". Intertemporal pricing in the financial and precious metals futures markets is not expected to be influenced by any "storage asymmetry" premia. In these markets the existence of storage asymmetry is neutralized by the immense size of existing inventories used as a "buffer" when new information imposes price adjustments.

The model developed here derives the existence of "storage asymmetry" in a partial equilibrium context. However, certain assumptions while seem restrictive do not alter the dimensions of the derived hypothesis. The "physical irreversibility" premium is an additional component in the price of storage as advanced by Brennan (1958). Its existence is appealing on intuitive grounds and is documented by empirical testings.

One possible extension of this study is to investigate the "storage asymmetry" in financial and metals futures contracts and develop a uniform measure of the degree of storage asymmetry for all markets. It would then be possible to examine inter-commodity different response to new information as well as idiosyncratic pricing behavior each commodity exhibits.

TABLE 15

APPENDIX A

The Month Effect in Spot Prices

Geometrically Normalized Average Spot Variances

| Commodity | OBS | DF | F-VALUE | PR>F |
|---|---|---|---|---|
| Corn | 132 | 11/120 | 4.08 | .0001 |
| Wheat | 80 | 11/68 | 0.77 | .6716 |
| Soybeans | 132 | 11/120 | 2.37 | .0111 |
| Soybean Meal | 132 | 11/120 | 1.07 | .3896 |
| Soybean Oil | 82 | 11/70 | 1.56 | .1301 |
| GNMA | 61 | 11/49 | 1.16 | .3398 |
| T-bills | 41 | 11/29 | 0.66 | .7671 |
| Copper | 62 | 11/50 | 1.32 | .2414 |
| Gold | 61 | 11/49 | 1.93 | .0586 |
| Silver | 93 | 11/81 | 0.69 | .7490 |

# TABLE 16

## APPENDIX B

Linear Regression Results Based on Selected Cut-off Months

Regression Model: $\ln(N(V_{tj})) = c + b(T(j) - t) + e$

| Commodity | Months Included | DF | c | b | F-RATIO | PR>F | $R^2$ |
|---|---|---|---|---|---|---|---|
| CORN | 8 | 442 | -0.0064 | 0.0022 | 0.60 | .4396 | .001 |
| | | | (-0.45)* | (0.77)* | | | |
| | 9 | 497 | -0.0097 | 0.0032 | 1.89 | .1697 | .004 |
| | | | (-0.75)* | (1.38)* | | | |
| | 10 | 552 | -0.0048 | 0.0018 | 0.82 | .3646 | .002 |
| | | | (-0.38)* | (0.91)* | | | |
| WHEAT | 7 | 377 | 0.1669 | -0.0276 | 41.88 | .0001 | .100 |
| | | | (8.76) | (-6.47) | | | |
| | 8 | 431 | 0.1647 | -0.0268 | 62.93 | .0001 | .127 |
| | | | (9.64) | (-7.93) | | | |
| | 9 | 486 | 0.1552 | -0.0240 | 76.96 | .0001 | .137 |
| | | | (10.08) | (-8.77) | | | |
| SOY BEANS | 8 | 614 | 0.1591 | -0.0243 | 79.14 | .0001 | .114 |
| | | | (11.55) | (-8.89) | | | |
| | 9 | 691 | 0.1614 | -0.0250 | 122.38 | .0001 | .151 |
| | | | (12.72) | (-11.06) | | | |
| | 10 | 768 | 0.1628 | -0.0253 | 167.43 | .0001 | .179 |
| | | | (13.40) | (-12.94) | | | |
| SOY MEAL | 6 | 532 | 0.2404 | -0.0399 | 65.25 | .0001 | .105 |
| | | | (12.22) | (-7.89) | | | |
| | 7 | 621 | 0.2397 | -0.0396 | 106.29 | .0001 | .146 |
| | | | (13.96) | (-10.31) | | | |
| | 8 | 710 | 0.2436 | -0.0409 | 175.54 | .0001 | .198 |
| | | | (15.63) | (-13.25) | | | |
| SOY OIL | 6 | 532 | 0.1233 | -0.0110 | 6.58 | .0106 | .012 |
| | | | (7.40) | (-2.57) | | | |
| | 7 | 621 | 0.1342 | -0.0151 | 21.00 | .0001 | .033 |
| | | | (9.12) | (-4.58) | | | |
| | 8 | 710 | 0.1450 | -0.0187 | 49.84 | .0001 | .066 |
| | | | (10.85) | (-7.06) | | | |
| GNMA | 27 | 692 | 0.0716 | -0.0048 | 81.00 | .0001 | .105 |
| | | | (8.77) | (-9.00) | | | |
| | 28 | 712 | 0.0708 | -0.0047 | 87.16 | .0001 | .109 |
| | | | (8.87) | (-9.34) | | | |
| | 29 | 732 | 0.0709 | -0.0047 | 97.65 | .0001 | .118 |
| | | | (9.09) | (-9.88) | | | |

Appendix B (Continued)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| T | 27 | 555 | 0.1640 | -0.0103 | 505.40 | .0001 | .477 |
| B | | | (22.76) | (-22.48) | | | |
| O | 28 | 573 | 0.1630 | -0.0102 | 550.13 | .0001 | .490 |
| N | | | (23.07) | (-23.45) | | | |
| D | 29 | 591 | 0.1619 | -0.0101 | 594.98 | .0001 | .502 |
| S | | | (23.34) | (-24.39) | | | |
| T | 8 | 222 | 0.0013 | 0.0238 | 4.68 | .0315 | .021 |
| B | | | (0.02)* | (2.16) | | | |
| I | 9 | 250 | 0.0358 | 0.0135 | 2.35 | .1266 | .009 |
| L | | | (0.72)* | (1.53)* | | | |
| L | 10 | 278 | 0.0523 | 0.0090 | 1.54 | .2158 | .006 |
| S | | | (1.17)* | (1.24)* | | | |
| C | 7 | 419 | 0.1567 | -0.0183 | 67.90 | .0001 | .140 |
| O | | | (17.65) | (-8.24) | | | |
| P | 8 | 466 | 0.1557 | -0.0179 | 102.03 | .0001 | .180 |
| P | | | (19.27) | (-10.10) | | | |
| E | 9 | 512 | 0.1571 | -0.0184 | 163.33 | .0001 | .242 |
| R | | | (21.33) | (-12.78) | | | |
| G | 17 | 761 | 0.0393 | -0.0039 | 66.06 | .0001 | .080 |
| O | | | (9.36) | (-8.13) | | | |
| L | 18 | 787 | 0.0415 | -0.0044 | 90.38 | .0001 | .103 |
| D | | | (9.89) | (-9.51) | | | |
| S | 12 | 625 | 0.0885 | -0.0113 | 108.75 | .0001 | .148 |
| I | | | (12.42) | (-10.43) | | | |
| L | 13 | 651 | 0.0861 | -0.0106 | 113.37 | .0001 | .148 |
| V | | | (12.37) | (-10.65) | | | |
| E | 14 | 676 | 0.0845 | -0.0103 | 127.75 | .0001 | .159 |
| R | | | (12.67) | (-11.30) | | | |

* Insignificant at 5%.

## BIBLIOGRAPHY


Ackley, Gardner. Commodities and Capital: Prices and Quantities. American Economic Review, March 1983:1-16.

Anderson, Ronald W. The Determinants of the Volatility of Futures Prices. Center for the Study of Futures Markets, CSFM Working Paper Series #33, 1982:32-40.

Anderson, Roland. W. and Danthine, Jean-Pierre. The Time Pattern of Hedging and the Volatility of Futures Prices. Center for the Study of Futures Markets, CSFM Working Paper Series #7, 1980.

Beckers, Stan. Variances of Security Price Returns Based on High, Low and Closing Prices. Journal of Business, January 1983:97-112.

Bodie, Zvi and Rosansky, Victor. Risk and Return in Commodity Futures. Financial Analysts Journal, May-June 1980:27-39.

Bradley, James V. Distribution-Free Statistical Tests. Prentice-Hall, Englewood Cliffs, N.J., 1968.

Brennan, Michael. The Supply of Storage. American Economic Review, March 1958:50-72.

Castelino, Mark. Futures Markets:The Maturity Effect on Risk and Return. Unpublished Ph.D. Dissertation, The City University of New York, September 1981:32-40.

Castelino, Mark and Francis, Jack C. Basis Speculation in Commodity Futures: The Maturity Effect. Journal of Futures Markets, Summer 1982:195-206.

Cohen, Kalman J., Ness, Walter L.,Okuda, Hitoshi, Schwartz, Robert A., and Whitcomb, David K. The Determinants of Common Stock Returns Volatility:An International Comparison. Journal of Finance, May 1976:733-740.

Cohen, Kalman J., Maier, Steven, Schwartz, Robert A. and Whitcomb, David K. The Returns Generation Process, Returns Variance and the Effect of Thinness in Securities Markets. Journal of Finance, March 1978:149-167.

Copeland, Thomas E. A Model of Asset Trading Under the Assumption of Sequential Informational Arrival. Journal of Finance, September 1976:1149-1168.

Copeland, Thomas E. A Probability Model of Asset Trading. Journal of Financial and Quantitative Analysis, November 1977:563-578.

Copeland, Thomas E. Liquidity Changes Following Stock Splits. Journal of Finance, March 1979:115-141.

Cornell, Bradford. The Relationship between Volume and Price Variability in Futures Markets. Journal of Futures Markets, Fall 1981:303-316.

Cox, Charles C. Futures Trading and Market Information. Journal of Political Economy, December 1976:1215-1237.

Dusak, Katherine. Futures Trading and Investor Returns:An Investigation of Commodity Markets Risk Premiums. Journal of Political Economy, November-December 1973:1387-1406.

Epps, Thomas W. Security Price Changes and Transaction Volume: Theory and Evidence. American Economic Review, September 1975:586-597.

Garbade, Kenneth D. Securities Markets. McGraw-Hill, 1982.

Figlewski, Stephen. Futures Trading and Volatility in the GNMA Market. Journal of Finance, May 1981:445-456.

Garman, Mark B. and Klass, Michael J. On the Estimation of Security Price Volatilities from Historical Data. Journal of Business, January 1980:67-78.

Georgescu-Roegen, Nicholas. The Entropy Law and the Economic Process, Harvard University Press, Cambridge, MA., 1971.

Gibbons, Jean Dickinson. Nonparametric Methods for Quantitative Analysis. Holt, Rinehart and Winston, 1976.

Grauer Frederick L. A. and Litzenberger Robert H. The Pricing of Commodity Futures Contracts, Nominal bonds and Other Risky Assets under Commodity Price Uncertainty. Journal of Finance, March 1979:69-83.

Gray, Roger W. The Characteristic Bias in Some Thin Futures Markets. As reprinted in Peck (1977), 1960:83-100.

Hicks, Sir John R. Value and Capital, Second Edition, Oxford University Press, London, 1946.

Hill, Joanne and Schneeweis, Thomas. The Hedging Effectiveness of Foreign Currency Futures, Journal of Financial Research, Spring 1982:95-104.

Hirshleifer, Jack. Liquidity, Uncertainty and the Accumulation of Information. In C.F.Carter (Ed.), Uncertainty and Expectation in Economics: Essays in Honor of G.L.S. Shackle, Clifton, N.J., A.M.Kelly, 1972:136-147.

Houthakker, Hendrik S. Can Speculators Forecast Prices? Review of Economics and Statistics, 1957:143-151.

Layzer, David. The Arrow of Time. Scientific American, December 1975:56-69.

Leuthold, Raymond M. The Price Performance of the Futures Market of a Nonstorable Commodity: Live Beef Cattle. As reprinted in Peck (1977), 1974:375-385.

Miller, Katherine Dusak. The Relation Between Volatility and Maturity in Futures Contracts. In R.M. Leuthold (ed.) Commodity Markets and Futures Prices. Chicago Merchantile Exchange, 1979:25-36.

Mossin Jan. Optimal Multiperiod Portfolio Policies. Journal of Business, April 1968:215-229.

Papaioannou, George. Thinness and Short-Run Price Dependence in the Athens Stock Exchange, Greek Economic Review, December 1982:315-333.

Parkinson, Michael. The Extreme Value Method for Estimating the Variance of the Rate of Return. Journal of Business, January 1980:61-66.

Peck, Anne E. Selected Writings on Futures Markets. Vol. 2, Chicago Board of Trade, Chicago, 1977.

Rutledge, D.J.S. A Note on the Variability of Futures Prices. Review of Economics and Statistics, February 1976:118-120.

Samuelson, Paul A. Proof that Properly Anticipated Prices Fluctuate Randomly. Industrial Management Review, Spring 1965:41-49.

Samuelson, Paul A. Is Real-World Price a Tale Told by the Idiot of Chance? Review of Economics and Statistics, Vol. 58, 1976:120-123.

Stein, Jerome L. Spot, Forward and Futures. Research in Finance, 1979:225-310.

Stigler, George J. Public Regulation of the Securities Markets. _Journal of Business_, April, 1964:117-142.

Telser Lester G. Futures Trading and the Storage of Cotton and Wheat. _As reprinted in Peck (1977)_, 1958:105-129.:969-1000.

Telser Lester G. Why There are Organized Futures Markets? _Journal of Law and Economics_, April 1981:1-22.

Telser, Lester G. and Higinbotham, Harlow N. Organized Futures Markets: Costs and Benefits. _Journal of Political Economy_, October 1977:969-1000.

Tomek, William and Gray, Roger W. Temporal Relationships Among Prices on Commodity Futures Markets:Their Allocative and Stabilizing Roles. _As reprinted in Peck (1977)_, 1970:137-148.

Weymar, Helmut F. The Dynamics of the World Cocoa Market. _As reprinted in Peck (1977)_, 1968:131-136.

Working, Holbrook. Quotations on Commodity Futures as Price Forecasts. _Econometrica_, 1942:39-52.

Working, Holbrook. Theory of the Inverse Carrying Charge in Futures Markets. _As reprinted in Working (1977)_, 1948:3-24.

Working, Holbrook. The Theory of Price of Storage. _As reprinted in Working (1977)_, 1949:25-31.

Working, Holbrook. Economic Functions of Futures Markets. _As reprinted in Working (1977)_, 1970:267-297.

Working, Holbrook. _Selected Writings of Holbrook Working_. Chicago Board of Trade, Chicago, 1977.

## VITAE

| | |
|---|---|
| NAME: | Nikolaos T. Milonas |
| DATE OF BIRTH: | April 16, 1954 |
| PLACE OF BIRTH: | Dimaras, Kavala, Greece |
| DEGREES: | Diploma of Business, Graduate Industrial School of Thessaloniki, 1977 |
| | Master of Business Administration, Baruch College, C.U.N.Y., 1980 |
| | Master of Philosophy, The City University of New York, 1984 |
| | Doctor of Philosophy, The City University of New York, 1984 |