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The Message in Petroleum Futures Prices

by

David Banack

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled, "The Message in Petroleum Futures Prices" submitted by David Banack in partial fulfillment of the requirements for the degree of Master of Arts.

Supervisor, Dr. A. Serletis
Department of Economics

Dr. A.J. MacFadyen
Department of Economics

Dr. P. Chang
Faculty of Management

Date January 30, 1990

ABSTRACT

The petroleum futures market is a relatively new futures market and is proving to be very successful. In spite of this success, and because the market is new, little academic research has been done in this area. Other commodity and financial futures markets are well studied and the applications used in these studies can be applied to the petroleum futures market. This thesis adapts the efficient markets hypothesis and the time-varying risk premium and spot price forecastability theory of the basis, to the petroleum futures market. Recent advances in econometric theory are used in conjunction with these theories to examine the term structure of futures prices of heating oil, crude oil and unleaded gasoline - the most traded of the petroleum commodities.

To our knowledge, there is no other work available that tests these particular theories in the petroleum futures market, or that uses a similar econometric approach. Therefore, it is hoped that this thesis contributes original and meaningful work to a body of knowledge in need of analytical study.

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CHAPTER 1: INTRODUCTION

This thesis examines prices in the petroleum futures market. This market is very young and has recently experienced a growth surge that promises to continue unabated for several years to come. This alone is reason to bring the petroleum futures market to the attention of academic researchers with a preference to remain at the frontiers of economic knowledge. But to our knowledge, there has been little research done in this area. In fact, the economic theory as well as the econometric techniques employed in this thesis have not been elsewhere applied to the petroleum futures market. Therefore, this thesis deals, in timely fashion, with a relatively new and dynamic topic and does so with traditional as well as little trodden statistical techniques. It is hoped that this effort will contribute new and useful work to the still sparse body of literature on the petroleum futures market.

Deregulation of the petroleum industry has caused it to become increasingly competitive. Price volatility accompanies deregulation as pricing is left to the actions of OPEC (the Organization of Petroleum Exporting Countries), independent producers and consumers as well as the unpredictable whims of nature. This increased price volatility is partially responsible for the recent growth and popularity of the petroleum futures market.

Futures markets are well known to provide price discovery and risk transfer services to those agents who require them. The petroleum futures market is no different. The volatile nature of the industry motivates many agents to avail themselves of these services. Buyers and sellers of petroleum futures contracts are either transferring price risk to other parties or speculating on future price movements. While the risk transfer and price discovery mechanisms of the petroleum futures market are available in this volatile price environment, a question that arises is whether or not these functions are actually reflected in the term structure of petroleum futures prices.[1] This is the primary question asked in this thesis. The answer is the content of Chapter 3 and Chapter 4.

In particular, we take two different approaches to examine heating oil, crude oil and unleaded gasoline futures prices. Each approach directly deals with price discovery and risk transference. Chapter 3 examines whether petroleum futures prices are absent of risk premiums and therefore are efficient predictors of the future spot price, or in fact, whether they are biased by a risk adjustment factor. Chapter 4 examines the same concepts of price forecastability and risk adjustment, but does so in the context of the basis - defined as the difference between a futures price and the spot price at a given moment in time. This chapter also differs from Chapter 3 by including an adjustment which allows for a risk premium that can vary with time rather than one which is forced to be constant. The two approaches complement each other. They are not so much differing theories as they are differing viewpoints on the same idea. Obviously, two viewpoints provide a broader perspective from which to observe phenomena and draw conclusions.

The econometrics employed in these technical chapters is somewhat unique as it includes the relatively new applications of cointegration and unit root analysis. Chapter 3 explains the theory and application of unit root and cointegration analysis. Cointegration theory deals specifically with the analysis of non-stationary time series and allows researchers to test relationships without first manipulating data into stationary form. If variables are cointegrated, then they are related in a long run fashion as described by some particular economic theory. But before establishing whether cointegration exists we must first determine the order of integration of the individual time series, that is, we must test for unit roots. A series with one unit root means that it is stationary in first differences. To

[1] The phrase "term structure" refers to a range of different maturity futures contract prices of the same commodity.

determine the number of unit roots we will use a specific statistical test which allows for series drift and trend. A particular mathematical criterion is calculated for each of many regressions and the lowest value determines the optimal lag length of the regression chosen for the unit root test. These concepts and the mechanics of this test will be presented in Chapter 3. If the number of unit roots in all series is the same, then the theoretical relationship between these variables is tested for cointegration to determine if they are related in a long run fashion. Cointegration is established if the cointegrating regression is integrated of order zero. The unit roots of the cointegrating regression are determined in a similar manner as for the individual series themselves. The theory and mechanics of this test are also presented in Chapter 3. While Chapter 4 uses these same procedures, it is not necessary to re-explain them, so only the results are presented and discussed.

However, before getting into technical analysis of the specific theories, we must first explain what a futures market is. Chapter 2 differs dramatically from the technical chapters of this work. Its descriptive tone provides an easy to understand description of futures markets in general and, of course, specifically focuses on the petroleum futures market. It provides a base from which to reference when reading the more difficult theory and econometrics in this thesis. Chapter 2 compares futures markets to other markets and the specific industrial make-up that feeds the growth of these markets is explained. The conditions necessary and desirable for the success of futures contracts are listed and discussed in the context of the petroleum market. The simple futures market activities of speculation, hedging and arbitrage, often overwhelming to the uninitiated, are presented in an elementary fashion. This is done to remove some of the mystique surrounding the agents who use these markets and to generate insight to the theoretical concepts explained in later sections.

The contrast in style between Chapter 2, and Chapter 3 and 4, is for clarity sake. Chapter 2 eases the reader into a general understanding of futures markets and focuses on the petroleum market in particular. It gets slightly more complicated near the end, when basic futures market activities are explained. Chapter 3 and Chapter 4 present to the now "conditioned" reader a rigorous and specific analysis of two aspects of the petroleum futures market - the functions of risk transference and price discovery. The progression from "broad" to specific is accompanied by increasing conceptual complexity but this occurs gradually so as not to overwhelm the reader as he goes along.

Chapter 2 can stand alone as a general introduction to the petroleum futures market and futures markets in general. If one already understands the basics of these markets, then Chapter 3 and Chapter 4 can also stand alone as independent analyses of two distinct theories applied to the petroleum futures market.[1] These three chapters are brought together in Chapter 5, the concluding chapter to this thesis. The general knowledge in Chapter 2 and the technical results of Chapter 3 and Chapter 4 are fused to provide some simple observations and conclusions on the petroleum futures market and futures markets in general.

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[1] They are distinct in theoretical approach, but are similar in concept.

CHAPTER 2: FUTURES MARKETS and PETROLEUM.

2.1 Introduction.

Futures markets arose as a natural consequence in the development of commodity markets. Initially, commodity markets provided a centralized "location" where buyers and sellers could easily meet to exchange goods without needing to search each other out independently. This provided a more efficient means of trading. Then came forward markets where buyers and sellers could formalize the details of their trade ahead of the actual date of exchange. This allowed those involved to eliminate price risk so one could have more confidence in making long range business plans. Later on, standardized forward contracts appeared to further facilitate trading. And now there exists a wide range of commodities that are traded in a market similar to the forward market but with some very distinct differences - the futures market.

The first section of this chapter will briefly explain the differences and similarities between cash markets, forward markets, and futures markets in a generic sense. Following this is a summary of the organization of futures markets. Since petroleum futures markets are similar to commodity futures markets in general, this discussion will also be from a generic stance, but when necessary, specific reference will be made to the New York Mercantile Exchange (NYMEX). NYMEX is the world's most active energy market and offers futures trading in crude oil, heating oil, unleaded gasoline, propane, and residual fuel oil. Next is presented a discussion of the requirements for the longevity of any futures contract and an evaluation of whether the petroleum industry meets these requirements as well as some concrete evidence of their success. And finally, the chapter takes a look into the various futures market participants, namely, hedgers, speculators and arbitragers, and presents examples of their activities. This chapter is written in a conversational tone. Its purpose is to provide descriptive analysis and a broad awareness of the workings of the futures market in the petroleum industry.

2.2 Cash, Forward and Futures Markets.

The cash or spot market is the simplest of the three markets to be considered. This market is also referred to as the physical or "actuals" market. Deals in the spot market are completed in the short term, usually on a daily basis. Producers who find themselves with extra product or consumers who find themselves short of product will often resort to spot transactions to sell or purchase the extra as needed. Traders must actively seek each other out to make spot deals and hence, are aware of their trading partner's identity. Although payment and delivery of the commodity occurs almost immediately, there is still a slight risk that the other party may not honor the deal.

A forward contract is used primarily to lock in the future purchase or sale price of a commodity. In the forward market the physical transfer of the commodity is not to take place until some previously agreed upon date. Similar to the cash market, participants in the forward market must actively search each other out to enter into a contract. Participants in the forward market tap their network of business contacts to engage in over the counter deals. In contrast, futures contracts are traded in centrally organized exchanges. The specifics of the forward contract are typically not standardized. Rather they are distinct and must be mutually arranged and agreed upon by both parties for each contract entered. Since the terms of each forward contract can be vastly different, they are not readily transferable. Because of the time element involved, these contracts carry a greater degree of risk than contracts executed in the spot market. For example, the participants may have limited knowledge of those they are dealing with so the risk of default is ever present. If default does occur, a trader may face costly litigation procedures so time and effort is spent to find partners with reliable reputations.

Futures markets are similar to forward markets in that they both have contracts that are specified for delivery of the good to occur at a later date. The primary difference is that with a forward contract delivery is planned, expected and almost always takes place, while on a futures contract delivery is rare. In fact, only about 1 percent of all futures contracts result in delivery. They are used primarily as temporary substitutes for an eventual purchase or sale of a commodity in the physical market. Futures contracts are useful as a hedging facility as well as a speculative opportunity. A hedger, for example, will use the futures market for protection from adverse spot price changes and plan on closing out the futures position when ready to engage in a cash market transaction. In this sense a futures contract is more of a financial instrument than a merchandising contract. However, a trader still has the choice to make or take delivery on any futures contract in his or her possession. From the speculative point of view, futures are a "bet" on the direction of price movement. A speculator engages in futures trading with the hope that favorable price movement will yield windfall profits but is not interested in the exchange of the physical good itself.[1]

Futures contracts are highly standardized. Each contract is for a fixed amount of a specified quality of product, to be delivered at a certain place during a certain time period. Traders can only buy and sell volumes of futures contracts in proportion to the standard contract volume. For some commodities various alternative grades are deliverable but pre-specified price discounts and premiums are applied. This rigorous contract standardization allows easy transfer between traders which in turn gives futures contracts much more liquidity than forward contracts. Traders entering the market know the exact specifications of the

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[1] Speculators and Hedgers will be discussed more thoroughly later in this chapter.

futures contract they wish to buy or sell. A forward contract could be developed that was highly standardized and easily transferred, but it would still be traded on an individual basis where the parties actually sought each other out and ultimately faced the risk of default. The futures trading environment is an impersonal one and the risk of default to the trader is virtually zero.

In contrast to the spot or forward markets, anyone entering the futures market need not waste much time and effort searching for a suitable trading partner. Futures exchanges generate significant trading volume so buyers and sellers are readily available to accommodate new entrants. There needs to be no "physical" contact between parties to a transaction so the actual identities of the participants in a trade are rarely known to each other. The exchange's clearing house becomes legally involved in all members' dealings, essentially making these trades unilateral in nature. That is, each trader becomes responsible to the clearing house and the clearing house guarantees all members' trades. Therefore, the risk of default to any individual trader is reduced to zero. Futures traders need not be concerned about the good faith or reliability of other traders in the market. As long as they trade with other members then the trade is guaranteed by the clearing house.

2.3 The Organization of Futures Markets.

Petroleum futures markets are organized in the same manner as other commodity futures markets. They consist primarily of the commodity exchange, the clearing house and a variety of agents and agencies who avail themselves of the benefits of the organization. The New York Mercantile Exchange is the primary petroleum futures exchange and includes contracts for crude oil, heating oil and unleaded gasoline. The other major petroleum exchange, the International Petroleum Exchange (IPE) in London, also deals in petroleum futures but to a much less significant degree than the NYMEX.

The commodity exchange is the central focus of trading activity in the futures market. It is the place where buyers and sellers meet to make deals on the contracts specific to the exchange. The largest volume of trade in petroleum futures in the United States occurs at the New York Mercantile Exchange. This and other U.S. exchanges are governed by the Commodity Futures Trading Commission (CFTC), the commodity regulatory arm of the federal government. The exchange, usually through a board of directors, supervises the ongoing activities. It establishes the specifics of the contracts to be traded, sets daily price change limits, initial deposit margin requirements, and develops and enforces delivery procedures. It also establishes and enforces guidelines to prevent unfair trading practices such as cornering the market, or market "squeezes", sometimes used to manipulate prices.

All deals executed in the exchange are immediately displayed through electronic media to buyers and sellers at the exchange, at exchanges around the world and to companies with an active interest in this market. This readily available information allows participants over the world to witness market fluctuations and act on them accordingly. The effective means of communication and ease of trading futures contracts suggests that the price of a contract at any given time is likely the best reflection of the prevailing supply and demand conditions for that contract.

The exchange is a non-profit association of members organized to facilitate futures trading. Membership fees partially cover the operating expenses of the exchange. Some members are allowed to trade in the rings or pits of the exchanges' trading floor. These particular members, called "floor brokers", communicate their trading activity through "open-outcry" and standardized hand signals. Floor brokers may trade for themselves but usually trade for the account of others. They buy and sell from other exchange members and are most often completely unaware of the identity of the customer who originated the trade. Their activities, like those of the exchange itself, are governed by the CFTC with whom they must register annually. Any major infractions of the rules set out by the CFTC may result in licence suspension.

A large portion of futures trading takes place through commission houses rather than directly from a customer to a floor broker. A customer wishing to trade commodity futures can simply contact a commission house to perform all of the required transactions. The commission house then contacts other members of the commodity exchange (floor brokers) and executes the trade on behalf of the original customer. In return for carrying the customers trading account the house collects a commission on each trade. The commission house consists of various departments to deal with its own administration. Like the exchange itself, the commission house must establish and collect initial deposit margin requirements, maintain its own bookkeeping of trading positions to ensure its financial solvency, and make arrangements to facilitate delivery. Of course, the commission house is responsible to the commodity exchange with which it trades and must, in turn, abide by its guidelines with respect to margin deposits and other trading practices.

The Clearing house is usually a separately organized and administered yet integral part of the commodity exchange. The NYMEX has its clearing house operating as a separate department within the exchange itself. The clearing house carefully monitors and records all activities of the exchange and its members. One of the most important functions of the clearing house is to ensure that all of its members' trades on the exchange are honored. It does this by legally entering into all trading agreements and in essence becomes the ultimate partner to all house members' trades. This unilateral nature of trade with the clearing house helps to ensure the financial integrity of the exchange. If a trading partner defaults then the clearing house intervenes and assumes the obligations of the defaulting party. This responsibility of the clearing house greatly facilitates trade in that customers do not have to spend costly effort to determine the financial reliability of their partner in each and every trade. Rather, they can be assured that any trade with a clearing house member will be, if necessary, guaranteed by the clearing house. It is important to note that only deals between clearing house members in good standing are guaranteed by the clearing house.

The clearing house is able to finance its guarantee of trades by requiring a sizable guarantee deposit from all members, collecting the initial margin requirements for each trade, and keeping on hand a reserve of funds. At the end of each trading day the exchange determines the settlement price for each contract and members are required to pay additional margin requirements or have their accounts credited, depending on the nature of the price movement. This ensures that profits or losses are not carried too far forward and allows the clearing house to liquidate bad contracts with minimal financial loss.

The elaborate organization of a futures market does not alone ensure the successful trading life of new contracts. While a reliable exchange must exist, there are other factors that have a strong influence on the longevity of any particular contract. The next section of this chapter will detail general prerequisites for a successful futures contract and specifically focus on how the petroleum industry supports its futures market

2.4 Conditions for the Longevity of Futures Contracts.

The recent success and increased trade of petroleum futures likely had as its impetus the unprecedented price volatility that has plagued the petroleum industry over the last 15 years. Decreased government involvement, increased use of oil for political ends, and "decentralization" leading to a larger number of relatively smaller participants in the industry, all contributed to increased price volatility and the spawning of the petroleum futures market. This section will provide a brief summary of the prerequisites for a successful futures contract and examine whether or not they are found in the petroleum industry.

There is no concrete set of conditions deemed necessary for the success of a futures contract. Some factors are of primary necessity, but there are others which are desirable. The more of these desirable characteristics that are present in the industry, the better the chance there is for a viable futures contract.

Unpredictable price volatility is the most important prerequisite for a successful futures contract. Commodity price uncertainty is the main motivation for hedgers to enter the futures market. They wish to reduce the effect of adverse price movements and can do so by first establishing and then offsetting futures positions in conjunction with their positions in the physical market. If prices were constant or predictable then dealers in the commodity would face little or no price risk and consequently have little use for futures contracts. Speculators are attracted to futures trading pitting their expectations of future price movements against others' in the market. Again, if price were constant or too predictable speculators would have nothing to speculate about and would quickly take their funds to higher risk more lucrative markets.

The more competition there is in determining the market price of a commodity, the greater the chance of a successful futures contract. It is important that any one group does not have too much power over market price. A decentralized industry with diffused market power provides more potential futures market participants than a structure characterized by a few large vertically integrated firms. Since a vertically integrated firm can rely on trade within its organization at a relatively predictable price, an industry of this type would have little use for a futures market. A non-integrated industrial structure is characterized by firms who are not assured of reliable trade within the organization. They are also open to a much greater price risk. These firms are more likely to seek risk reduction through hedging with futures. Since they face greater risk, they are also much more likely to pay close attention to supply and demand conditions and develop their own expectation of future cash prices. Acting on these expectations increases the speculative volume of futures contracts and hence, to this extent, speculative volume in futures trading also depends on market structure. In keeping with the idea of a competitively determined price, it should be noted that that the government should have as passive a role as possible in the price determining process. If government policy strongly controls price then the price risk faced by traders will be substantially reduced, thus reducing the need for hedging and impairing the success of a futures contract for that particular commodity.

A potential futures commodity should be homogeneous in character to make it easy to identify and accurately specify in the contract. However, homogeneity does not have to be perfect. Slight differences in quality can be accounted for in the futures contract by specifying certain price premiums or discounts regarding the product grade. In the same vein, a futures contract will stand a greater chance of success if there exists related products whose prices are correlated with that of the future's price. This allows the use of a specific futures contract to hedge the physical market activities of related products. Strong price correlation between the futures contract and these related products provides opportunity for successful "cross-hedging" and aids the survival of the contract.

A futures market commodity should be capable of being stored. This gives producers and users of the product the freedom to time their trading and storing activities based storage costs, interest rates and opportunity costs, and their own market perceptions, while at the same time reducing the risk of doing so through the use of futures hedging. A commodity that is non-storable restricts the freedom to optimally time futures transactions to maximize profits in physical market activities.

The specifics of a futures contract must be set up so as not deter select groups of possible traders. It should not favor any one trading interest. As a simple example, if the contract was standardized for a very large volume many smaller hedgers and speculators could not enter the market possibly removing the liquidity necessary for the contract's success. It is also important that the physical traders of the commodity have an active say in the development of the contract. They provide knowledgeable input on contract volume, delivery locations, delivery standards, maturity months and other specifications that meet the needs of other participants in the market. This information is necessary in order to develop a contract that will encourage the industry to use futures in their daily trading activity. Buyers and sellers of the physical good must both be active in the trading of the futures contract. Their knowledge of both sides of the market will be transmitted through their trading activities helping to ensure that the futures price structure reflects commercial movements in supply and demand and that price is not distorted by heavy trading from one group or the other.

To best ensure that futures prices reflect commercial movements in supply and demand there must exist a a viable delivery procedure. Although delivery in the futures market is rare, the option to make or take delivery on a maturing contract provides the necessary link between spot and futures prices. The possibility of delivery ensures that the futures price will come into line with the prevailing spot price. If it did not, then arbitrage opportunities would arise quickly forcing it to do so. A poor delivery mechanism will weaken the futures/spot price link and the futures market will not adequately reflect physical supply and demand conditions. This would ultimately discourage the use of the futures contract.

Hedgers and speculators have a somewhat symbiotic relationship in the futures market. Hedgers are attracted to the futures market to reduce price risk but there must necessarily be someone willing to assume this risk. Speculators, attracted by the potentially large profits, are the willing recipients of this transfer of risk. Although the presence of hedgers is fundamental to the functioning of a futures market, speculators provide the added liquidity to ensure a smoother continuous exchange of contracts.

The larger the cash value of the commodity the greater will be the interest that both hedgers and speculators have in the futures contract. Traders with a high valued inventory have more to lose from unfavorable price movements and are more likely to seek risk reduction using futures than are traders with low value inventory. Similarly, speculators are more likely put their wits (and money) into a market where potential profits are large. So a commodity that the market places a high value on stands a better chance of success being traded on a futures market than does one with a low market value. Finally, a large volume of trade will better sustain a futures contract than a low volume will. A large volume of trade ultimately makes it easier to find willing buyers and sellers thus reducing the cost of transaction. Obviously the lower the cost of transaction the more effective futures trading will be.

This has been a description of most of the conditions that are desirable to ensure the success of a futures contract. As mentioned, not all of these criteria need be present for a contract to survive. One of the most important conditions is the volatility of prices. Prices must be sufficiently unpredictable that traders are attracted to the futures market, finding it necessary and desirable to hedge their physical market activities. The industrial structure and contract specification must be of the kind that inspires the need for commercial traders to want to temporarily substitute futures contracts for their eventual merchandising agreements. The necessity of speculators to take up the net long or short positions of hedgers is equally important to the success of a futures contract as the involvement of the hedgers themselves. Speculators provide added liquidity to the market and their intelligent anticipation of market conditions helps ensure that futures prices reflect commercial movements in supply and demand. In what follows is a look at whether the petroleum industry meets these requirements.

2.5 Survival of the Petroleum Futures Contracts.

This thesis is concerned with three petroleum products being traded on the NYMEX: crude oil, unleaded gasoline, and heating oil. Heating oil began trading on November 14, 1978, gasoline on October 5, 1981, and crude oil on March 30, 1983. All three contracts are enjoying a successful trading life.

They are successful because the petroleum industry meets many of the conditions described in the last section which are desirable for futures contract trading. The inherent characteristics of these petroleum products readily lend themselves to be traded on a futures exchange. Petroleum products are relatively homogeneous and can be specified in a standardized contract. There are also various grades that are deliverable, for example, on the crude oil contract. Discounts and premiums for these grades are clearly detailed in the contract. Price movements of other petroleum products are correlated with the price movements of the standard contracts allowing cross-hedging of these related products using the standard contracts. Therefore, is not necessary to have a futures contract for every petroleum product.

The value and volume of petroleum and related products greatly enhances the benefits derived from, and the desire to engage in petroleum futures trading. Petroleum is the most important energy source in the world today. All industrialized countries depend on it in one way or another in almost every kind of economic activity. As one writer puts it, "in the oil business, the potential hedging volume is not large, but huge" (Banks, p. 203). This large volume and value of trade in petroleum and related products sets a good background to encourage speculators and hedgers alike to use the petroleum futures markets. The Futures Industry Association concurs, writing that the "potential growth in energy futures is enormous" (Futures Industry Association, p.117).

Traditionally, the importance of petroleum to the world economy has led to a large degree of government regulation of the industry and prevented it from being as competitive as it otherwise might have been. As previously mentioned, this type of control tends to reduce the price risk that traders face and reduces their need to hedge. Of course, decreased hedging results in decreased use of futures markets and reduces the chances for a successful futures contract. It should be noted however, that the amount of government involvement in the oil industry has not been sufficient to prevent the huge price swings, primarily brought about by the actions of OPEC, that have characterized the industry over the past 15 years. The recent trend towards deregulation of the industry and decreased government involvement will reduce market controlling influences and further enhance the competitiveness of price determination. This should increase the risk of unpredictable price changes and encourage even more traders to become involved in the futures market.

Further evidence that futures contracts in petroleum and its products should survive stems from the ongoing structural change of the industry that has occurred over the last 15 years. Over this period of time the industry has become increasingly decentralized (Prast and Lax, p.58). It is no longer characterized solely by tightly controlled, vertically integrated companies. Rather there is a diversity of independent and non-integrated refiners, distributors, traders, storage operations, private and state owned companies and governments involved which has resulted in a greater volume of oil moving outside the integrated channels that previously dominated the industry. Although the majority of larger firms' petroleum needs are met under contract, this decentralization along with the expanded trade of national companies (eg. OPEC), provide the multinationals with less assurance of supply. They watch the spot market more closely now as they may be forced to use it at the last minute to meet requirements or sell off a sudden excess of oil. Of course, this means that these multinationals and the growing group of smaller enterprises mentioned above, all face the risk of spot market price fluctuations and can appreciate the use of futures trading to minimize this risk. Continuing decentralization of the industry will serve to place more firms in a position of market unsureness and provide the impetus for them to explore the benefits of futures trading.

Finally, there is no question that the petroleum industry meets the most important criterion for a successful futures contract - it is in a chronic state of price volatility. The oil shocks of 1973 and 1979 were, no doubt, very influential in the growth of futures trading in petroleum products. The drastic price changes were unlike any others ever experienced and caused great uncertainty in the market. These OPEC supply shocks, forcing large price increases, put in to motion the economic forces that lead to a reduction in the quantity of oil demanded as consumers substitute away from petroleum as an energy source, as well as a reduction in oil demand as consumers move away from energy consumption in general. At the same time, these large price increases tend to encourage new supply on to the market. These two forces further added to the price volatility that OPEC initially created. Although OPEC seems to have temporarily lost some of its control over the industry supply, petroleum prices are still relatively volatile and unpredictable. Since the petroleum industry is characterized by highly inelastic short run supply and demand curves then, even without a large disruptive influence of OPEC, economic theory predicts there will still be large changes in price for very small shifts in supply and demand, which can occur frequently in the petroleum industry.

Aside from the OPEC supply shocks or what has now become a combination of announcement effects and output control, the normal yearly production/consumption cycle of the petroleum industry has inherent price destabilizing forces. During the heating oil peak season for example (i.e., the cold season), the demand for heating oil will be relatively high and inventories will be decreasing causing upward pressure on price. The opposite is the case for off-season periods. The low demand and inventory accumulation will put downward pressure on price. Of course the magnitude of these pressures is not easily predictable and when their effect is combined with an inelastic supply and demand, the influence of OPEC and its effects on consumption and production, the obvious conclusion to be drawn is that this industry will be characterized, at least for the foreseeable future, by unpredictable price volatility. Therefore, futures contracts are, and will continue to be, a valuable and necessary risk management tool in the petroleum industry.

Petroleum futures are serving their purpose. There are certain revealing indications that show this. The number of deliveries on futures contracts as a percentage of total trade is very low. In fact, it is about one percent. This indicates that the futures contract is serving very well as a temporary substitute for an eventual merchandising agreement. Therefore, traders are not using the contracts for actual sales or purchases of the physical good but as risk management tools. As well, there is a high degree of cash convergence of maturing futures to spot prices indicating that the delivery mechanism in place is ensuring that these futures reflect commercial movements in supply and demand, and that a maturing futures contract is a near perfect substitute for spot oil (Prast and Lax, p.89). This highlights the fact that the petroleum futures market is an extremely good price discovery mechanism for the world oil industry. In fact, "...the price paid for the majority of the almost 50 million (barrels per day) of crude oil consumed in the free world is determined by the price bid or asked for maybe 1/100 of that volume...", that is, the price of the current NYMEX crude oil contract (Hall, p.36).

Evidence of the success of NYMEX's energy contracts can be found by looking at trading volume and open interest statistics. Both have shown considerable growth for each contract since their introduction. NYMEX's heating oil contract has been trading for over ten years now. Its volume has grown from 34 thousand contracts in 1979 to over five million contracts in 1988 and continues to grow (NYMEX,1988, p.21 and McFadden, 1989, p.37). Daily open interest, the number of contracts outstanding, is widely regarded as a measure of liquidity in the market and peaked as high as 98,000 for the heating oil contracts in 1988. Open interest on the crude oil contract doubled this at about 200,000 contracts per day. In 1988 alone crude volume reached a record 20 million contracts, 40 percent above that in 1987. The gasoline contract also broke its volume record coming in at three million contracts for the 1988 trading year. Including all energy futures and options volume, 1988 saw 33 million contracts set the exchange record at the NYMEX (McFadden, 1989, p.37).

2.6 Actors in the Futures Market.

The next few sections of this chapter will present a brief description of the three main activities in a futures market. Simple examples of the mechanics of futures trading are presented to provide a practical understanding of the usefulness of futures markets. There are three primary actors in the futures market. For descriptive purposes it is convenient to describe speculators, hedgers and arbitragers as entirely separate entities but the definitional lines blur as trades become sophisticated and traders find it beneficial to wear more than one hat.

The first activity to be considered is that of the hedger. Hedging is the largest component of trading in the futures market. A futures contract could not survive without a significant hedging interest. In fact, these contracts are specifically set up to cater to the needs of hedgers. A hedger is involved in some stage of the commercial life of a physical good, either buying or selling, and is faced with the uncertainty of price changes of that good. The futures market is viewed as a convenient mechanism to transfer this risk to others, mainly speculators, thus providing the hedger with a more certain profit margin from which to base future business plans.

This risk may not be entirely reduced. The trader, upon hedging, is no longer concerned with price changes in the physical market but with changes in the relation between the futures price and the physical price. This relationship is called the "basis". More specifically, for this work, the basis is defined as the difference between the futures price of any given maturity month future and the current spot price of the commodity. The trader who hedges using futures is substituting a basis risk for the price risk he would have otherwise faced had he left the value of his good to be determined at the whim of the spot market. In general, futures prices and spot prices tend to move together and the resulting basis risk is therefore lower than the original price risk. This reduction in risk will become more clear in the section on hedging to follow.

A rigid and somewhat dated view of hedgers describes them from the point of view of forward markets rather than futures markets. This view was held at least in part by Keynes, Hicks and Kaldor (Goss, pp.29-31). Hedgers were assumed to be "pure" hedgers, always carrying a full hedge equal to the exact value of their physical market transactions. If they had any expectations of market trends they did not act on them in their hedging practices but left this to the more sophisticated speculators. Further, because the hedge was executed in a forward market the position taken was a certain one and therefore risk was entirely eliminated.

Later a more dynamic and less rigid view of hedging evolved and is much more applicable as applied to futures rather than forward markets. Working contributed to this more realistic view of hedging (Goss pp.31-32, Johnson p.211). In this case the hedger is viewed as an active rather than passive participant in the futures market. Since hedgers are dealing in the physical good it is very likely that they do have expectations of future market conditions. This newer view of the hedger assumes that he/she will not always carry a full hedge but will over or under-hedge spot market transactions based on personal expectations of future events. For example, it would be unwise for a trader who plans on selling stock to hedge all of it in a continually rising price market. Although doing so would establish a more predictable profit margin, it reduces the level of profit the hedger could otherwise obtain on unhedged stock. If this sell hedger believes that the trend of rising prices will continue he/she should under-hedge spot market commitments thereby partially reducing the risk of loss (with the hedged component) if market expectations are wrong, but gaining somewhat of a windfall profit on the eventual sale of unhedged stock if the market does continue to rise. In this scenario the lines between a speculator and hedger blur but it is safe to say that hedging can and does involve a speculative element.

Lastly, and following from the above, the new concept of hedging does not always involve an entire reduction of risk. As mentioned, a futures hedge substitutes a basis risk for a price risk. Only on a full hedge, and if the basis remains the same at the close as it was at its opening, is the risk entirely eliminated.[1] In this case the spot and futures prices would be perfectly positively correlated. More commonly though, the spot and futures prices do not move in exact parallel fashion and there results an unexpected profit or loss when the hedge is closed out. However, with a properly working futures market, futures and spot prices

[1] Here, the hedger closes out the futures position before these contracts reach maturity.

will approximate each other's movement and the resulting profit or loss will be less than that if the stock were left unhedged.

In general then, the primary motivation for hedgers to use futures markets is to reduce risk and provide a predictable profit margin from which to place more security in long range business plans. Hedging also assists buying and selling and storage decisions by allowing traders more freedom to optimally time their transactions in their best interests. And, as explained, hedgers can be quite knowledgeable of the industry. They may act on their market expectations combining a speculative element with their hedging activities thereby taking on a little added risk for possible greater gain.

2.6.1 Mechanics of Hedging.

Hedging can be executed on the part of the buyer or seller of the physical good. Someone using futures who is not engaged, or who will not be engaged in a physical transaction, is not classified as a hedger. In terms of the physical or actuals market, a trader who is in possession of the commodity is said to be "long" in that good, and a trader who is not in possession is said to be "short". In terms of the futures market, a trader who owns a contract to potentially take delivery of a product is said to be long in that future, and one who owns a contract to potentially deliver the product is said to be short in that future.

Hedging has grown into a sophisticated set of complicated strategies. A good description of the various possibilities can be found in chapter 3 of Prast and Lax or any hedging handbook.[1] A pure hedge includes the simple mechanics of taking a futures position that is equal but opposite in stance to ones position in the physical or cash market, and then

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[1] Or through a long conversation with someone who makes their living as a trader.

reversing or cancelling the futures position just prior to the actual physical trade. Some of the more simple techniques are explained here to outline the basics of hedging.

2.6.2 Selling or Short Hedge.

A selling or short hedge begins with a trader who is long in the commodity, or soon will be. Usually the sell hedger is a producer who plans on selling the inventory sometime in the future. The sell hedger's motivation to hedge is for protection against the risk of a price fall between now and the point in time when the commodity will be sold. It is best for a sell hedger to hedge in a falling market. If there was a rising market the astute hedger would likely only hedge part of the stock, or perhaps not even hedge at all, taking a chance on making windfall profits on the unhedged stock. In this later case the trader would be acting more like a speculator in the physical market than a risk averse hedger. In any case, if the market is characterized by falling prices, it is wise for the sell hedger to at least carry a full hedge.

The simplest type of selling hedge is one where the trader holds the futures contract into its last trading month and then offsets his position just prior to maturity. Consider, for example, a producer who believes that the market is bearish and will have 1000 barrels of crude to sell in "T" months time. If the current price of crude oil is $15.00 per barrel, the trader values the inventory at $15,000. In order to fix with a high degree of certainty the revenue to be received on the eventual spot sale the trader will hedge this inventory using futures. The futures leg of the transaction is opened by going short in futures, that is, selling futures contracts for the equivalent amount of crude inventory to be later sold on the spot market. With the futures contract, the trader is essentially promising to deliver crude at some future date, in this case, in T months time. If the price of T-month futures contracts is currently \$16.00 (i.e. \$16.00 per barrel for the standard 1000 barrel contract volume), then the original position is as shown in the first column of Table 2.1.[1]

TABLE 2.1: SELL HEDGE (held to maturity)

	Initial Position	Final Position	Overall Position
Cash Leg	Long in crude. Buys or values inventory at: S_t = \$15.00	Short in crude. Sells crude in spot market: S_T = \$14.00	Loss of \$1.00/bbl
Futures Leg	Opens short in crude futures. Sells at: F_t = \$16.00	Closes long in crude futures. Buys at: F_T = \$14.00	Gain of \$2.00/bbl
			Net Gain: \$1.00/bbl or \$1000/1000bbls.

Just prior to contract maturity the trader, rather than having to make delivery on the futures contract, will reverse his or her position. There are many reasons why a spot market delivery may be more preferable than delivery on the futures contract. The most likely reason is that the delivery location for a spot market transaction may be more suitable to the trader. Other reasons might be that the grade of oil may not be deliverable on the futures contract, or the trader may wish to establish a reliable trading partner or perhaps seek out new ones.

If, as expected, the market does continue to decline, resulting in lower prices, then the trader completes the hedge as shown in columns two and three of Table 1. The spot price has dropped to \$14.00 per barrel. The trader sells the oil spot and makes an opportunity loss of \$1.00 per barrel or \$1000 on the sale. However, when a futures contract is at or

1 "t" represents the (current) time period at the opening of the hedge and "T" represents the time period at the close of the hedge.

near maturity, its price must approximate the prevailing spot price or arbitrage opportunities will quickly force it to do so. This implies that the basis narrows to zero.[1] Therefore, the futures price follows the spot price and drops to $14.00 per barrel. The hedger closes out his futures leg with an offsetting purchase of a contract of the same maturity month. The financial position on the futures leg is a profit of $2.00 per barrel or $2000 on the 1000 barrel contract. The traders net gain can be expressed as the gain in one market minus the loss in the other.[2] In this case, its the gain in the futures market minus the loss in the spot market:

$$
\begin{aligned}
\text{Net Gain} &= (F_{selling} - F_{buying}) - (S_{original} - S_{selling}) \\
&= (F_t - F_T) - (S_t - S_T) \\
&= (16.00 - 14.00) - (15.00 - 14.00) \\
&= 2.00 - 1.00 \\
&= \$1.00 \text{ per barrel.}
\end{aligned}
$$

In this example it is important to note that had the hedger not used futures and simply relied on the spot market to carry out the trade then he would have suffered an opportunity loss of $1.00 per barrel.[3] In this particular case, the loss of $1.00 per barrel spot still occurs but is compensated for by the futures gain of $2.00 per barrel. By holding the hedge to a point just prior to the futures maturity, where the futures price must approximately equal the prevailing spot price, the trader was able to lock in and receive the futures price prevailing at the time when the hedge was initiated.[4]

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1 The basis usually does not narrow exactly to zero. The futures price should be slightly lower than the spot price at maturity to reflect the handing and transaction costs or inconvenience of owning the future and being forced to make or take delivery at a specific location. For simplicity, it is assumed that the maturing futures price is equal to the spot price prevailing at that time.

2 This net gain excludes the storage and opportunity costs, if any, of holding the inventory until the eventual physical sale.

3 The opportunity loss results because the trader sells the commodity spot at $1.00 less at the close of the hedge than he could have received at the time of its opening. This is the unprotected price risk.

4 The hedger receives $14.00 per barrel spot on the final transaction plus the futures leg profit of $2.00 per barrel which equals the original futures price of $16.00 per barrel. Or, another way to see this, the original spot price was $15.00 per barrel minus the loss of $1.00 per barrel on the spot leg plus the

As occurred in this example, when a futures contract approaches maturity, the basis will always narrow.[1] Contango or forwardation is the condition where the futures price of a commodity is higher than the current spot price. Conversely, backwardation occurs when the opposite is true. During the life of a futures contract the basis, whether in contango or backwardation, will widen or narrow in reflection of market conditions and the astute trader will realize profits on these movements. Since it is possible for hedgers to offset their futures commitments before their contracts near maturity, they pay close attention to what is happening to the basis in the hope of capturing these extra profits.

For a producer or seller, an unexpected profit is made when contango declines on a hedge closed out before the futures maturity date. The relative changes in spot and futures prices are such that the gain on the futures leg of the transaction is greater than the loss on the cash leg. Essentially this results in the seller receiving more for the product than the original spot price at which the inventory was initially valued.

FIGURE 2.1: DECLINING CONTANGO

Opening Position	Closing Position (before maturity)
F_t = \$17.00 (short in futures)	F_{t+n} = \$15.75 (long in futures)
Basis = \$2.00	Basis = \$1.75
S_t = \$15.00 (long product)	S_{t+n} = \$14.00 (short product)

The basis narrowed from \$2.00 to \$1.75 resulting in a windfall profit of \$0.25 per bbl. on this sell hedge. The seller essentially receives \$15.25 per barrel.

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gain on the futures leg of \$2.00 per barrel equals the original futures price of \$16.00 per barrel.

[1] Arbitrage opportunities force this to occur. See Section 2.6.4 for more on arbitrage.

In Figure 2.1 we can see that the trader gains $1.25 on the futures leg and loses $1.00 on the spot or cash leg. Overall there is a windfall gain of $0.25 above the original spot price of $15.00. In this particular case both the spot and futures prices declined while contango decreased causing the windfall profit. The spot price could have risen with a falling futures price, or both prices could have risen, but as long as contango had decreased at the closing position there would still have been a windfall profit above the original spot price. If the basis had remained the same throughout the hedge then the profit or loss on the spot leg of the trade would cancel that on the futures leg of the trade. This occurrence is known as a perfect hedge and the seller essentially receives the spot price prevailing at the initiation of the hedge. This rarely happens though. Although spot and futures prices theoretically move together, there are too many uncertainties that can influence price and therefore they are very unlikely to be perfectly positively correlated.

If the trader had closed out on increased rather than decreased contango, the final position would have shown a net loss. The relative futures and spot price changes would have been such that the gain on the futures leg of the transaction would be less than the loss on the cash leg and the seller would stand to receive less than the original spot price. A trader faced with such a possibility would likely try to hold the position until contango was favorable.

As mentioned, backwardation occurs when the spot price is above the futures price. The profit or loss situations are perfectly opposite to those for the case of contango. In backwardation cases the sell hedger makes a windfall profit if backwardation increases and a loss if it narrows. Again, if backwardation remains the same the final position net profit is zero and the trader has executed a perfect hedge.

2.6.3 Buying or Long Hedge.

A long hedge is initiated by a trader who is short in the commodity and wishes to purchase sometime in the future. The long hedger's motivation to hedge is to seek protection from the risk that the cash price will rise between now and the time of the eventual purchase of the commodity. As already shown, a short hedger finds it most opportune to hedge in a bearish market. The case for a long hedger is just the opposite. A long hedger finds it best to hedge when the market is rising.

Consider a refiner who finds that crude oil inventory will not meet input requirements and will be forced to enter the spot market in the near future to make up the shortcoming. If the market is bearish, the refinery owner may count on the price dropping and choose not to hedge the eventual spot purchase. If the market continues to fall then the refiner benefits from what can be termed an opportunity gain of the difference between the original spot price and that at the time of the actual purchase. Of course, if the market rises over this period the refiner stands to incur an opportunity loss if the eventual purchase price is above the original spot level. Therefore, the refiner will be more inclined to hedge buying activities in a bull, rather than a bear market.

The mechanics and outcome of a long hedge carried to a point just prior to the futures maturity date are reverse to those of a short hedge. Assume that the current spot price of crude oil is $15.00 per barrel in a rising market and the refiner will need an additional 1000 barrels of crude in T months time. The refiner seeks to protect himself from a large cash price increase and initiates a hedge by purchasing a T-month futures contract for 1000 barrels of crude oil. If the market is characterized by contango and the T-month futures price is $16.00 then the trader's initial position is as shown in column one of Table 2.

TABLE 2.2: BUY HEDGE (held to maturity)

	Initial Position	Final Position	Overall Position
Cash Leg	Short in crude, spot price is: S_t=\$15.00.	Long in crude, buys crude spot: S_T=\$16.50.	Loss of \$1.50/bbl.
Futures Leg	Opens, long in crude futures. Buys at: F_t=\$16.00.	Closes, short in crude futures. Sells at: F_T=\$16.50.	Gain of \$0.50/bbl.
			Net Loss: \$1.00/bbl or \$1000/1000 bbls.

When the trader enters the spot market for the crude purchase at time T and closes out the futures position, his final stance is as indicated in columns two and three of Table 2. In this case the market did continue to rise and the spot price went to \$16.50 per barrel. Had the trader not hedged this transaction, he would be forced to take a loss of \$1.50 per barrel.[1] But because the hedge was executed this loss will be minimized. Note that the futures price has also risen to \$16.50.[2] The trader closes out the hedge by offsetting the initial futures purchase with a futures sale of equivalent volume. The gain on the futures leg is \$0.50 per barrel. The trader's net gain (or loss in this case) can be expressed as the profit in the futures market minus the loss in the spot market.

$$
\begin{aligned}
\text{Net Gain (Loss)} &= (F_{selling} - F_{buying}) - (S_{buying} - S_{original}) \\
&= (F_T - F_t) - (S_T - S_t) \\
&= (16.50-16.00) - (16.50 - 15.00) \\
&= -\$1.00 \text{ per barrel.}
\end{aligned}
$$

As in the sell hedge example, it is important to note that the overall loss or gain is less with hedged transactions than without. In this buy hedge example the loss was reduced from

1 The trader would be paying \$1.50 more in the spot market at time T, as compared to the spot price prevailing at time t when he first knew he would be needing the extra crude.
2 Again, it is assumed for simplicity that the basis narrows to zero at, or just prior to maturity of the futures contract.

what would have been $1.50 per barrel without a hedge, to $1.00 per barrel under a full hedge, as compared to the original spot price. Therefore, by holding the hedge to the maturity of the futures contract, the trader locked in the original futures price.[1]

As mentioned earlier, traders can offset their futures positions anytime during the life of the contract and need not wait until the contract nears maturity. It was explained that a sell hedger will enjoy a windfall profit above the original spot price if contango has declined when the hedge is closed out. A buy hedger will suffer an unexpected loss in this case. The buy hedger would see a windfall profit above the original spot price if contango widened. Similarly, if the market is inverted in a state of backwardation, then the sell hedger loses if backwardation declines while the buy hedger gains a windfall profit. Of course, if backwardation or forwardation remain constant throughout the hedge then a buy or sell hedge will be perfect in the sense that net profit will be zero, and the price received or paid will essentially be the spot price that prevailed at the time the hedge was initiated.

2.6.4 Speculation and Arbitrage.

Two other main actors in the futures market are speculators and arbitragers. Their involvement primarily adds liquidity and ensures that the futures market remains economically linked to the physical market. Speculators include a large group of traders who are in the futures market primarily for the prospect of capital gains. Although hedgers do take speculative positions, a pure speculator is rarely involved or interested in the

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1 A loss of $1.00 per barrel as compared to the original spot price, means, that with an original spot price of $15.00 per barrel, when including the "loss", the trader essentially pays $16.00 per barrel which is the original futures price. Or, another way to see this is that the final spot price that the trader paid was $16.50. Add to this the gain on the futures leg of $0.50 per barrel which gives, in effect, an actual purchase price of $16.00 per barrel - the original price of the futures contract.

buying and selling of the physical good. In fact, having to make or take delivery of a commodity would present quite a dilemma for a speculator who has no use for, or ready access to the product. To a speculator, the futures market is simply a convenient mechanism to take on risk for possible financial gain. Based on their own price projections they engage in futures trading with full intentions of closing out their positions before the contract matures. There is no cash or physical leg to a purely speculative futures position.

A simple example of speculative activity is as follows. If a speculator believes that the market is bullish, he will go long in futures and close out the contract some time before the maturity date. If the futures price has risen in the interim, then the trader enjoys a profit. On the other hand, if a speculator believes the market is bearish, he will open short in futures and buy back later, hopefully at a lower price, thereby also enjoying a profit. A more complicated speculative strategy would be to open long and short in futures contracts of different maturity, known as trading in spreads. In doing so, the speculator is hedging somewhat because when closing out both positions, the gain (loss) on one leg of the trade will be partially offset by the loss (gain) on the other leg.

The speculative element in futures markets helps to ensure that futures prices will reflect current and expected supply and demand conditions. "The futures market will produce a price that reflects some average of the beliefs of the market participants" (Carlton, p.241). The information sets of intelligent speculators will provide a price structure in the futures market that can be thought of as forecasts of prices to come. Any misinformed speculators will quickly leave the market suffering too many losses, or be forced to become much more informed participants. In order to remain a profitable speculator one must keep abreast of industry developments and, inevitably, their knowledge of market supply and demand conditions will be reflected in the prices of futures contracts which they are trading.

Speculation provides much of the liquidity necessary for the efficient operation of a futures market. Without speculators, there would be no one to take up the net long or short positions of hedgers in the market. Although futures markets are set up to accommodate, and depend heavily on hedging activity, the effectiveness of hedging depends primarily on speculation (Gray, 1978a, pp.224-225).

Another actor in the futures market pursues arbitrage opportunities. The arbitrager is not interested in the temporal profitability of futures trading but in differences between prices that exist at the same moment in time. This trader looks for a simultaneous purchase and sale of futures contracts which would result in a certain and immediate profit. An arbitrager can also profit from combined spot and futures market activities. For example, if a particular futures price is greater than the current spot price by more than all possible carrying charges, then the trader can enjoy a certain profit by simultaneously selling futures and buying the commodity spot, storing it until the contract matures and then making delivery on the future. By delivering on the futures contract the profit will be the difference between the futures price and what was paid spot plus the carrying charges incurred. In the manner briefly outlined, arbitrage activities quickly eliminate price discrepancies between identical futures contracts and also bring current or nearby futures prices into line with spot market conditions.

2.7 Summary.

Commodity futures contracts are very liquid financial instruments primarily used as temporary substitutes for eventual merchandising agreements. They are highly standardized with specifics such as delivery time, location and quality of the commodity clearly indicated to futures market participants. These standardized contracts are traded in organized exchanges whose function aids the price discovery and dissemination process. The exchange provides a financially solvent environment for traders to carry out their day to day operations.

These day to day operations include complex hedging strategies in conjunction with speculative and arbitrage opportunities. The largest component of futures trading is the hedging interest but hedging and speculative activity are are complementary functions and the success of one depends heavily on the success of the other. Simple examples of hedging and speculation are presented earlier in this chapter.

Several market conditions are desirable to ensure the longevity of any particular futures contract. Of primary necessity is price volatility. If this were absent, hedgers would have little use for the risk transfer mechanism that futures markets provide and speculative activity would surely be unprofitable. Without question, the petroleum industry is characterized by price volatility and it also meets several other of the previously described necessary conditions. Hence, today we observe a viable and growing petroleum futures market.

Price discovery and risk transference mechanisms are readily apparent in the petroleum futures market. Something not so evident is the manner in which they can be detected. In particular, the curiosity examined in this thesis is whether the price discovery function of petroleum futures prices yields a term structure of futures prices that are reliable predictors of the future spot price. The complementary concern is whether this term structure of successively longer term to maturity futures prices accounts for the risk transference service that these markets provide. The remainder of this thesis will examine in detail two very different approaches used to detect evidence of the risk transfer and predictive nature of futures prices in the petroleum industry.

CHAPTER 3: EFFICIENCY OR BIAS IN THE PETROLEUM FUTURES MARKET.

3.1 Introduction

In this chapter we change the approach from a general description of futures markets and the petroleum industry to a focussed and specific theory of futures markets as applied to petroleum markets. In particular, we search for evidence that petroleum futures prices are either efficient predictors of the future spot price or whether the futures price contains a bias in the form of a risk premium. In doing so we use recent advances in the field of applied econometrics and in particular the concept of cointegration (see Engle and Granger) which explicitly deals with the analysis of the relationship between nonstationary time series.

We develop the economic theory and introduce the concept of cointegration in the next few sections. A brief summary of data statistics is then followed by detailed empirical discussion of the unit root analysis and presentation of the cointegration tests and results. After this, conclusions are summarized and the fundamental theory in this chapter is bridged to the next.

As mentioned elsewhere, the results of this chapter are tied together with the results of Chapter 4 and presented in the concluding chapter of this thesis.

3.2 Theoretical Framework: Efficiency and Biasedness.

In asset market models the Efficient Markets Hypothesis (EMH) consists of two parts.[1] The first is that agents are risk neutral and the second is that their expectations are rationally formed. Following Fama, a well noted authority on efficient capital markets theory, and adapting Hallwood and MacDonald's specific approach, we develop this theory in the following manner (Hallwood and MacDonald, pp. 136-138).

We first assume that traders are risk neutral and jointly set the commodity's futures price at time t to be equal to its expected future spot price:

(3.1) $F(t,T) = E_t(S(T))$,

where F(t,T) is the futures price prevailing at the present time t for maturity of the contract and subsequent delivery of the commodity at a later time T, and $E_t(S(T))$ is the expectation held at time t of the spot price to prevail later at T.[2] Equation (3.1) is the market equilibrium relationship. In an efficient markets world with risk neutral investors, speculation will ensure that (3.1) holds continuously.

The assumption that agents are rational requires that:

(3.2) $S(T) = E_t(S(T)) + u_T$,

---

1 The Efficient Markets Hypothesis is the hypothesis that all information is utilized immediately by agents, new information is available to all agents at the same time and new information is immediately incorporated into market prices. In this perfect knowledge world there is no need for any type of risk adjustment as there exists no risk.

2 This assumes risk neutrality, zero transaction costs and no other impediments to arbitrage.

where $S(T)$ is the spot price realized at T and u_T is a white noise error term representing the fact that while expectations are rational, they can be wrong in an individual case but on average will be correct.

Combining (3.1) and (3.2) we obtain the market efficiency condition:

(3.3) $S(T) = F(t,T) + u_T$.

Equation (3.3) states that the spot price of the commodity at time T, S(T), should be equal to its futures price prevailing earlier at time t for maturity at T, F(t,T), plus a random white noise error term. Thus, if both (3.1) and (3.2) hold then F(t,T) is an unbiased predictor of S(T). This is the joint hypothesis of unbiasedness as stated in (3.3).[1]

The sensitivity of the EMH with respect to the assumed joint hypothesis may be demonstrated by assuming that agents are rational so that equation (3.2) continues to hold, but they demand a risk premium to hold the futures contract. This risk premium is in compensation for the uncertainty of the future spot price. Instead of equation (3.1) we now have:

(3.4) $F(t,T) = E_t(S(T)) + RP(t,T)$,

where RP(t,T) is the risk premium that agents demand to hold the futures contract from t to T. The risk premium can be expressed as:

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[1] The "hypothesis of unbiasedness" and "hypothesis of market efficiency" are used synonymously.

(3.5) $RP(t,T) = RP + v_t$,

where RP is the mean of the risk premium and v_t is a white noise error allowing for random variation of the premium over time.

From (3.4), (3.5) and (3.2) we now obtain:

(3.6) $S(T) = F(t,T) + u_T - RP - v_t$,

where, F(t,T) is a "noisy" predictor of S(T).

The above analysis leads us to rearrange equation (3.6) into an econometrically testable form as:

(3.7) $S(T) = a + bF(t,T) + e(t,T)$.

If agents are risk neutral, then unbiased prediction implies that $a = 0$ and $b = 1$ and e(t,T) should be serially uncorrelated. If, on the other hand, agents are risk averse so that the coefficient a is not zero, then we have a futures price that is a "risk-biased" predictor of the future spot price.[1]

3.3 Cointegration of Spot and Futures Prices.

Usually in testing for market efficiency researchers regress the future spot price, S(T), on the futures price, F(t,T), as in equation (3.7). In this specification, market efficiency in the

[1] Note that the risk premium, a, is captured as a constant. This point will become meaningful for comparison purposes in the following chapter.

absence of a risk premium requires that the constant term be zero and the slope coefficient be one. Of course, in the presence of a risk premium, "risk-biased prediction" requires that the constant is not zero and the slope is not equal to one.

In this chapter we test for market efficiency by asking if S(T) and F(t,T) are cointegrated. Very briefly, the basic idea behind cointegration is to find a linear combination of individually nonstationary time series that is itself stationary. For example, assume that both time series S(T) and F(t,T) are nonstationary and must be differenced to induce stationarity.[1] A linear combination of these variables such as:

$$(3.8) \quad S(T) - a - bF(t,T) = u(t,T)$$

is usually also nonstationary.[2] However, if a test shows that u(t,T) is in fact stationary then S(T) and F(t,T) are said to be cointegrated. The existence of cointegration between variables provides strong support that the series move together reflecting a long run or steady state relationship as suggested by some particular economic theory. Further, the stationary combination of the two nonstationary series, as expressed by equation (3.8), measures the extent that the relation between S(T) and F(t,T) differs from equilibrium and is therefore called the equilibrium error.

It is to be emphasized that cointegration is necessary for market efficiency where, in theory, the spot and futures prices match each other exactly, as well as for biased prediction, whereby the spot and futures prices move together through time, yet the futures price is a biased predictor of the future spot price.

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[1] Note that this means they have the same time series properties.
[2] This equation is virtually the same as equation (3.7)

In the following section the data and summary statistics are presented. Time series theory and properties, including unit root analysis, are looked at in Section 3.5.[1] Cointegration theory is examined in more detail and the cointegration tests are presented in Section 3.6.

3.4 Data and Summary Statistics

All data used herein originate at the New York Mercantile Exchange and are supplied by the Commodity Futures Trading Commission. Future/spot price analyses are carried out on three petroleum commodities - heating oil, crude oil and unleaded gasoline.The futures prices in all cases are for the one-month, two-month, three-month and six-month maturity contracts. The delivery location of these contracts is the same point as that where the relevant spot price is determined. This location is the New York Harbor for heating oil and unleaded gasoline, while for crude oil the delivery point is Cushing, Oklahoma.

A strong feature of this thesis is that the data set is very complete. All series are daily and the sample sizes for heating oil, crude oil and unleaded gasoline are 1279, 1276 and 830 respectively. Heating oil and crude oil observations range from July 1, 1983 to August 31, 1988 while the unleaded gasoline series ends on the same date but begins on March 14, 1985. Some observations for the different series were omitted to ensure consistency across the different maturity futures and spot prices.

Of the summary statistics calculated, only the standard deviations of the variables are reported, to give some indication of the variability of the data. These standard deviations can be found in Table 3.1.

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[1] Unit Root analysis, an integral part of time series analysis, will be reintroduced and explained in Section 3.5.

TABLE 3.1

STANDARD DEVIATIONS: ALL COMMODITIES

Prices in Natural Logs	Commodity Heating Oil	Crude Oil	Unleaded Gasoline
Spot price	.27750	.29977	.24507
One-month future	.27652	.29990	.24046
Two-month future	.27638	.29680	.23031
Three-month future	.27474	.29406	.22293
Six-month future	.26384	.28749	.21918

Note: All series are daily.

3.5 Time Series Properties: Univariate Tests for Unit Roots

Most economic time series tend to depart from any given value with time. They are inherently nonstationary in the sense that their mean and variance depend on time. Since most statistical tests have been developed for stationary processes it has, in the past, been necessary to adjust the data to ensure stationarity.

One popular approach to do this has been to de-trend the nonstationary time series either by differencing or regressing the series on a time variable. This practice has been questioned by Engle and Granger (1987). It is argued that de-trending the data in the above fashion disregards important relationships that may be found in the levels of the series. Therefore, an alternate method of managing nonstationary series is extremely useful.

It is not necessary to de-trend the individual series in a model if we find that the model's series are "integrated" of the same order. This is the task we now face. The first step in testing for cointegration among variables is to determine the order of integration of the individual time series. A time series is said to contain a unit root or be integrated of order one, denoted I(1), if it requires differencing one time to become a stationary process, denoted I(0). Most economic time series are I(1) but higher orders are possible. The only drawback with finding a time series of higher order of integration is that series with different orders of integration cannot be used in the same model to test for cointegration. If the relevant series do not have the same time series properties then it makes no sense to postulate and test for a "time" relationship between them - it makes no sense to test for cointegration. Cointegration is only possible between variables with the same time series properties, that is, they must have the same number of unit roots.

To determine the unit roots of the series we use the Augmented Dickey-Fuller (ADF) test expanded to accommodate a possible time trend and/or drift as proposed by Phillips and Perron (1988)[1]. The method is to perform a t-test on the parameter a in the following regressions:

(3.9) $\Delta Z_t = aZ_{t-1} + \Sigma i_{1,N} b_i \Delta Z_{t-i} + e_t,$

(3.10) $\Delta Z_t = c + aZ_{t-1} + \Sigma i_{1,N} b_i \Delta Z_{t-i} + e_t,$ and

(3.11) $\Delta Z_t = c + d(t-n/2) + aZ_{t-1} + \Sigma i_{1,N} b_i \Delta Z_{t-i} + e_t$

where Z_t is the log of the series in question (Δ represents the first difference of Z_t).[2] We include the variable ΔZ_{t-i} to ensure stationarity in this testing procedure. Therefore, the order of the autoregression, N, must first be arbitrarily chosen or determined using

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1 We allow for trend and drift in the series to check "all possibilities" before drawing conclusions about the time series properties of the data.

2 In these equations, "n" is the number of observations, "N" is the number of lags, "c" is a constant included in the regression to capture any drift in the series, and "t-n/2" is a time variable used to capture any trend.

statistical criterion. Following Engle and Yoo (1987) we chose to use Schwarz's criterion to determine the optimal lag length. Schwarz's criterion is defined as follows:

$$SC = n*\log(SSR/n) + q*\log(n)$$

where q is the number of parameters in the regression, SSR is the sum of squared residuals and n is the number of observations. We select an upper bound for N (we chose ten) in equations (3.9), (3.10) and (3.11) and calculate the SC for each regression. That lag length of ΔZ which has the lowest SC is our optimal lag length. Once the model has been correctly specified as such we perform t-tests on parameter a for each of the three optimal models.

The null hypothesis of a unit root in the series (H_0: a=0) is tested using specially tabulated asymptotic critical values (see Fuller,1976,Table 8.5.2). The unit root null will be rejected if a is statistically significant. If a is not statistically significant then there exists at least one unit root. If a first unit root is detected then we test the series for a second unit root, that is, for a unit root in the first difference of the series. We do so by initially first differencing the series so that Z_t in equations (3.9), (3.10) and (3.11) becomes $Z_t - Z_{t-1}$[1]. Then the procedure of optimal lag length selection using Schwarz's criterion and t-testing is repeated to determine if the series has another unit root.[2] This process is continued until the null of yet another unit root is rejected and we have discovered the order of integrability of the series (i.e., the number of unit roots).

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1 Essentially, the "new" variable is the original variable differenced twice.
2 The series would now have two unit roots which means it would have to be differenced twice to become stationary.

3.5.1 Unit Root Results

For equation (3.9) the null hypothesis of a unit root (without allowing for drift or trend) is tested against the stationary alternative. The asymptotic critical t-values specific to this model at the one percent, five percent and ten percent levels of significance are -2.58, -1.95 and -1.62 respectively (see Fuller, 1976, Table 8.5.2). It can be seen from the first column of Table 3.2 that for all spot and futures prices of heating oil, crude oil and unleaded gasoline we fail to reject the null hypothesis of a unit root at all of the mentioned levels of significance. Thus, using equation (3.9) we found that all of these series contain at least one unit root.

We tested each series for a second unit root (again, without allowing for drift or trend). The results of this test, presented in column one of Table 3.3, show that this time we reject the null of another unit root for all series. We therefore tentatively conclude that, prior to accounting for a possible trend and/or drift, all series contain one unit root.

The next step is to test the unit root null after allowing for any possible drift in the series. For equation (3.10) the null of a unit root with drift is tested against the stationary alternative. At the one percent, five percent and ten percent levels of significance the critical t-values are -3.43, -2.86 and -2.57, respectively (see Fuller, 1976, Table 8.5.2). The second column in Table 3.2 shows the relevant calculated t-statistics. Once again we see that for all prices for heating oil, crude oil and unleaded gasoline we fail to reject the null hypothesis at the three levels of significance. After allowing for drift we conclude that these series contain at least one unit root so we test for a second. The associated t-values in column 2 of Table 3.3 show that we clearly reject the null when we test for the existence of a second unit root. Therefore after further unit root analysis, this time with allowance for drift, we concur with our previous findings that all series contain one unit root.

TABLE 3.2

TESTS FOR A SINGLE UNIT ROOT: ALL COMMODITIES

Tests for a first unit root alone, with drift, and with drift and trend in the spot price and the one-month, two-month, three-month and six-month futures prices.

Commodity & prices in natural logarithms	Type of Unit Root Test: ADF		ADF(c)		ADF(c,t)	
HEATING OIL						
Spot price	.03193	(2)	-1.33878	(2)	-2.37581	(2)
One-month future	-.00510	(0)	-1.43399	(0)	-2.47731	(0)
Two-month future	.20703	(0)	-1.27013	(0)	-2.09027	(0)
Three-month future	.24459	(0)	-1.28469	(0)	-1.98694	(0)
Six-month future	.36663	(0)	-1.33927	(0)	-1.89878	(0)
CRUDE OIL						
Spot price	-1.01036	(0)	-1.35612	(0)	-2.15823	(0)
One-month future	-1.03168	(0)	-1.32099	(0)	-2.10344	(0)
Two-month future	-1.14898	(0)	-1.17044	(0)	-1.85271	(0)
Three-month future	-1.09960	(0)	-1.26901	(0)	-1.98802	(0)
Six-month future	-1.22464	(0)	-1.14939	(0)	-1.78163	(0)
UNLEADED GASOLINE						
Spot price	-.02429	(0)	-1.82431	(0)	-1.77030	(0)
One-month future	.09140	(0)	-1.78887	(0)	-1.72471	(0)
Two-month future	.29150	(0)	-1.72110	(0)	-1.68324	(0)
Three-month future	.41064	(0)	-1.69495	(0)	-1.69589	(0)
Six-month future	.52654	(0)	-1.63961	(0)	-1.60240	(0)

Notes: 1)ADF - unit root alone test.
ADF(c) - unit root with drift test.
ADF(c,t) - unit root with drift and trend.
2)Reject the null of a unit root at the **1%, *5% and +10% levels of significance.
3)The numbers in brackets are the optimal lag lengths for the autoregressive processes in equations (3.9), (3.10) and (3.11).

TABLE 3.3

TESTS FOR A SECOND UNIT ROOT: ALL COMMODITIES

Tests for a second unit root alone, with drift, and with drift and trend in the spot price and the one-month, two-month, three-month and six-month futures prices.

Commodity & prices in first differences of natural logarithms	Type of Unit Root Test ADF		ADF(c)		ADF(c,t)	
HEATING OIL						
Spot price	-33.7790**	(1)	-33.7828**	(1)	-33.7702**	(1)
One-month future	-35.5641**	(0)	-35.5668**	(0)	-35.5531**	(0)
Two-month future	-33.5236**	(0)	-33.5308**	(0)	-33.5177**	(0)
Three-month future	-34.1817**	(0)	-34.1916**	(0)	-34.1783**	(0)
Six-month future	-36.9178**	(0)	-36.9382**	(0)	-36.9259**	(0)
CRUDE OIL						
Spot price	-36.5114**	(0)	-36.5199**	(0)	-36.5055**	(0)
One-month future	-35.8643**	(0)	-35.8733**	(0)	-35.8593**	(0)
Two-month future	-34.5139**	(0)	-34.5285**	(0)	-34.5150**	(0)
Three-month future	-37.4877**	(0)	-37.5027**	(0)	-37.4880**	(0)
Six-month future	-34.6010**	(0)	-34.6206**	(0)	-34.6072**	(0)
UNLEADED GASOLINE						
Spot price	-32.7829**	(0)	-32.7849**	(0)	-32.7829**	(0)
One-month future	-27.9893**	(0)	-27.9926**	(0)	-27.9891**	(0)
Two-month future	-27.3526**	(0)	-27.3634**	(0)	-27.3585**	(0)
Three-month future	-27.1846**	(0)	-27.2000**	(0)	-27.1923**	(0)
Six-month future	-27.9408**	(0)	-27.9622**	(0)	-27.9549**	(0)

Notes: 1)ADF - unit root alone test.
ADF(c) - unit root with drift test.
ADF(c,t) - unit root with drift and trend.
2)Reject the null of a unit root at the **1%, *5% and +10% levels of significance.
3)The numbers in brackets are the optimal lag lengths for the autoregressive processes in equations (3.9), (3.10) and (3.11).

The final step is to test the unit root null after allowing for both a possible drift and trend in the series. For equation (3.11), the null of a unit root with drift as well as trend is tested against the stationary alternative. The critical values for this null hypothesis at the one percent, five percent and ten percent levels are -3.96, -3.41 and -3.12, respectively (see Fuller, 1976, Table 8.5.2). The calculated t-values in column 3 of Table 3.2 are all less than the three critical values indicating that we again fail to reject the null for all series. There is at least one unit root found using equation (3.11). We test for a second unit root. Column 3 of Table 3.3 shows that we reject the null of a second unit root for all series. Therefore, after allowing for drift as well as trend, we are once again in agreement with the previous result that all series contain one unit root.

The upshot of this exhaustive three-way examination of the time series properties of the data is that we safely conclude on overwhelming evidence that there exists only one unit root in all series considered. Allowing for a possible trend and/ or drift and trend in the series does not alter this result. On the basis of this compelling evidence we are sure that all series are stationary after first differencing or are integrated of order one, I(1). However, as mentioned earlier, the use of levels in the data is the preferred form. Since all futures and spot price series are I(1), the prerequisite of equal order integration has been met to perform cointegration tests on the economic relationship as described by equation (3.7). To this task we now turn.

3.6 Tests of Cointegration.

The basic idea behind cointegration is that two variables are cointegrated if a linear combination of these series is integrated of order zero. We have found that all pairs of spot and futures prices are integrated of order one, that is, they have one unit root. These possess a similar stochastic trend in that they all need to be differenced once to become stationary. However, differencing the data is not the preferred thing to do in this case since this can remove long-run information and, in the form used presently, the efficient markets hypothesis applies to the levels of the series. We test for cointegration between the variables levels to see if there exists some long-run equilibrium relationship as posited by the efficient markets hypothesis.

We begin by using ordinary least squares to estimate equation (3.7) rewritten here for reference:

$$(3.7) \quad S(T) = a + bF(t,T) + e(t,T)$$

to obtain the OLS residuals, e(t,T). Since all series are I(1) the null hypothesis of no cointegration is accepted or rejected based on whether or not a unit root is found in these residuals. If the residuals are found to be I(0) then we reject the null and conclude that the relevant spot and futures petroleum prices are cointegrated and that equation (3.7) holds.[1] Since the OLS residuals, by construction, have zero mean, the appropriate regression equation to test unit for roots is equation (3.9). We repeat it here:

$$(3.9) \quad \Delta Z_t = aZ_{t-1} + \Sigma i_{1,N} b_i \Delta Z_{t-i} + e_t .$$

3.6.1 Cointegration Results

The calculated t-values for the ADF tests on the residuals of equation (3.7) as well as the R-squared and (a,b) statistics are presented in Table 3.4. We now use the simulated critical values in Engle and Yoo (1987, Table 2) rather than those reported by Dickey and Fuller. The Dickey-Fuller critical values are not appropriate when testing for a unit root in the residuals as they lead us to find cointegration more often than we should. This occurs because with finite samples the estimated residuals appear more stationary than their true values. The Engle and Yoo critical values account for the number of variables in the cointegrating regression. For this reason, they are the appropriate ones to use when testing

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[1] Note that the order of integration of the residuals would be one less than that of the variables themselves. This satisfies the cointegration criterion.

the order of integration of residuals. The values for the t-statistic at the one percent, five percent and ten percent levels of significance are -4.00, -3.37 and -3.02 respectively (see Engle and Yoo, 1987, Table 2).

TABLE 3.4

TESTS OF COINTEGRATION BETWEEN SPOT AND FUTURES PRICES

$$S(t) = a + bF(t,T) + e_t$$

Commodity	Coefficient Estimates		Standard Errors		Summary Statistics	
& Prices	a	b	s(a)	s(b)	R-square	ADF(Res.)
HEATING OIL						
One-month	-.03449	.94427	-.00557	.00982	.8806	-6.4855(1)**
Two-month	-.05431	.90782	.00700	.01226	.8163	-4.6287(1)**
Three-month	-.07546	.87519	.00816	.01429	.7558	-3.9124(1)*
Six-month	-.15690	.74702	.01191	.02106	.5228	-2.3483(2)
CRUDE OIL						
One-month	.17188	.94083	.02919	.00939	.8886	-5.4258(0)**
Two-month	.35460	.88019	.04275	.01377	.7677	-3.6927(0)*
Three-month	.50960	.82833	.05102	.01644	.6763	-2.9266(0)
Six-month	1.02851	.65396	.07070	.02277	.4174	-1.9988(0)
UNLEADED GASOLINE						
One-month	-.09495	.86220	.01085	.01635	.7693	-4.0832(0)**
Two-month	-.16803	.75130	.01500	.02242	.5802	-2.9153(0)
Three-month	-.20785	.69883	.01638	.02435	.5100	-2.7747(0)
Six-month	-.50228	.28787	.01981	.02907	.1186	-2.4427(0)

Notes: 1)ADF(Res)- cointegration test results.
- reject null of a unit root at the **1%, *5% and +10% level of significance.
2) Spot and futures prices are in natural logarithms.
3) As elsewhere in this thesis, t represents the current day and T can be one, two, three or six months hence.

As shown in Table 3.4 the null hypothesis of a unit root is rejected at the one percent level for the one-month futures contract of all three commodities and also for the two-month contract for heating oil. The two-month crude oil contract and the three-month heating oil contract t-statistics also indicate a rejection of the null hypothesis at the lower five percent level of significance. The rejection of the null implies that the order of integration of the residuals in equation (3.7) has been reduced by one from that of the individual series in the equation. Therefore, these series are cointegrated and have a long run relationship of the form described by equation (3.7).

It is not surprising that the nearby futures prices are cointegrated with the spot prices for all commodities. Arbitrage opportunities force the nearby contract's price to align itself with the spot price as the contract approaches maturity.[1] This means that the spot and futures prices must move together. For the three commodities other contracts, notably the more distant ones, we fail to reject the null of a unit root which implies that these particular pairs of spot and futures prices are not cointegrated or that their is no evident long run relationship. It is also not surprising that we reject the efficiency hypothesis for contracts with a longer term to maturity. Spot and futures arbitrage opportunities are less available and not as obvious in the distant contracts. The futures contracts of six month maturity, for example, need not bear so close a relationship to the cash market as the nearbys do. They will tend to move with the cash prices but inexact correlation does not present clear cases of profitable arbitrage opportunities. Therefore, it may be the case that distant futures prices contain less predictive information than nearby futures prices have.

Looking closer at the results presented in Table 3.4, we now examine the coefficients a and b and the R-squared statistic. The estimates for a and b as well as the R-squared values for all equations are consistent with the cointegration results. The cointegrated series, i.e. the nearbys, all have high R-squared values which get progressively smaller as the term to maturity of the futures contract increases. As mentioned, arbitrage opportunities and

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[1] For more on this see Chapter 2.

potential monetary losses force the nearbys to follow the spot price more closely so we do expect the high R-squared values that we observe in these relationships.

In the same fashion that R-squared is high and gets progressively smaller with increasing term to maturity of the futures contracts, the coefficient a is close to zero and b is close to one for the three nearby contracts and in all cases a gets larger and b gets smaller as term to maturity increases. The observation that the slope coefficients are large becoming smaller with increasing term to maturity indicates that there is more "predictive" information found in the nearby contract prices than there is in the distants. The observation that the risk premium coefficients are small at first and grow with increasing term to maturity indicates that there is greater risk and therefore a greater premium demanded on distant contracts than there is on nearbys. Both of these observations make intuitively sound economic sense. It seems that the efficient markets hypothesis is supported by the nearby contract results, that is, these futures prices contain virtually no risk premium but have high predictive power. In contrast, the lesser predictive power of the distant contract prices is clearly biased by a significant risk premium.

However the fact remains that only the nearby futures prices are consistently cointegrated with their spot price across the three commodities. We do not find the same empirical support for the distant contracts prices. But this does not mean that the distant prices do not reflect a risk premium and a forecast of the future spot price as the regression coefficients indicate . The fact that these coefficients were statistically significant suggests that the contrary cointegration results for the distant futures prices may be in part caused by the manner in which we tested the theory. Note that equation (3.7) allows for only a constant risk premium. It is not a large leap in logic to see that a risk premium may well vary with time. The following chapter carries this idea into analysis.

3.7 Conclusion

In this chapter we developed the efficient market hypothesis as it applies to asset markets. It was implied that this hypothesis may not be the most realistic interpretation of a market as risky as the petroleum commodities futures market so a risk premium was built in to the theory. This allowed us to consider both the efficient markets hypothesis as applied to the petroleum futures market as well as allowing for the possibility that these futures prices may indeed be biased by a constant risk premium.

A relatively new statistical procedure, unit root analysis, was applied to determine the time series properties of the data. It was found that all series had the same number of unit roots and thus cointegration tests could be performed on the relationships as described by the relevant economic theory.

It was found that all one-month crude oil, heating oil and unleaded gasoline futures prices were cointegrated with their relevant spot price. Cointegration was also evident between a three-month and a few two-month prices and their associated spot price. The size of the regression coefficients in equation (3.7) lead us to believe that these particular futures prices are efficient predictors of the future spot price.

However, the cointegration results were negative for all of the most distant futures contract prices as well as for several of the "in between" maturity length contracts. It was observed though, that the risk premium was relatively larger and the forecast component was smaller on these particular contracts as compared to the nearby contracts. This suggest that, barring the cointegration results, the more distant futures prices are "risk-biased" predictors of the future spot price. In fact, the statistically significant coefficients support this conclusion.

We can, perhaps, further clarify and support these results by a more accurate specification of the theoretical test.

In view of this, we will approach the unbiased/biased prediction theory of futures markets from a slightly different basis. We suggest that a constant risk premium as used in the present theory may be too restricting when applied to the highly volatile petroleum futures market. In the next chapter we look into a more recent and popular theory of futures markets which also examines the forecast power of futures prices but specifically allows for a time-varying risk premium. We feel that this alternative approach can only add completeness and strength to our conclusions drawn from this work.

CHAPTER 4: THE TIME-VARYING RISK PREMIUM AND FORECAST THEORY OF THE BASIS IN THE PETROLEUM FUTURES MARKET

4.1 Introduction

In this chapter we use a popular theory of futures markets to detect evidence of the forecastabilty of future spot prices and risk premiums in futures prices. In contrast to the last chapter, the risk premium component will be time-varying rather than fixed and all empirical work will be done in the context of the "basis" - a time relationship between any given futures price and the current spot price. For this thesis, the basis is simply the difference between any given futures price and the current spot price of the same commodity.

The motivation to perform such analysis to detect very near the same phenomena as did Chapter 3, but under different methodology, arises in an attempt to round out and add gravity to conclusions drawn from this work. In the previous chapter we found that the nearby futures prices were cointegrated with their associated spot price. This result, though not surprising, does prove that these series move together. The magnitude of the regression coefficients suggested that the nearby futures prices are efficient predictors of the future spot price because the risk premium is virtually zero, while the more distant futures prices are risk-biased predictors of the future spot price since they contain a significant premium component. This later observation was not supported by the cointegration results, however, and thus provides further stimulus to examine similar concepts under alternative methodology.

The following theoretical section will derive and explain the forecastability and time-varying risk premium theory of futures prices and provide detailed interpretation of the relevant coefficients. After this, the data and select summary statistics will be presented followed by an explanation of the time series properties of the series. Finally, the empirical results will be discussed and the chapter will be concluded.

4.2 Time-Varying Risk Premium and Forecast Power of the Basis

The theory of forecast power and risk premium begins in the same manner as the traditional efficient markets hypothesis did in the last chapter. In essence, the current theory suggests that the basis, which is the difference between any given futures price and the current spot price observed at any time, reflects a forecast of the change in the future spot price and a time-varying risk premium.[1]

We develop this theory by first looking at the forecast component alone. It can be argued that the futures price at time t for delivery at time T must approximate the spot price expected to prevail at time T. Expressed symbolically:

(4.1) $F(t,T) \sim E_t(S(T))$,

where $F(t,T)$ is the futures price for the commodity prevailing at time t for delivery at a later time T, and $E_t(S(T))$ is the expectation held at time t of the future spot price to prevail at time T.

1 As adapted from Kolb, Chapter 2 and French and Fama.

If $F(t,T)$ were to diverge sharply from $E_t(S(T))$ then arbitrage opportunities would result. Traders, taking advantage of these arbitrage opportunities, would quickly force the futures price into line with the expected future spot price. For example, if $F(t,T)$ were to be substantially greater than $E_t(S(T))$ a trader could take advantage of this situation by initially selling futures at time t. Then, at the futures maturity date of time T, the trader could purchase the commodity spot and make delivery on the maturing futures contract.[1] With this action, the trader secures a profit equal to the difference between the relatively high selling price of the futures contract and the relatively low purchase price of the commodity spot.[2] Conversely, if $F(t,T)$ were to be substantially lower than $E_t(S(T))$, a speculator could buy futures at time t, take delivery at its maturity time T, and immediately sell the good at the relatively higher spot price then prevailing, thereby securing a profit of the difference between the two.[3]

The above described speculative activity ensures that the futures price of a commodity should approximate the expected future spot price. Transaction costs are part of the reason why the two prices will only be approximately equal. A profitable speculative opportunity may seem to exist given ones futures expectations and the prevailing futures price. But, taking into account transaction costs can turn the picture into an unprofitable one, preventing speculators from pursuing the opportunity thereby allowing small differences between $F(t,T)$ and $E_t(S(T))$ to exist.

But a very important factor, the risk premium, can explain larger differences between the current futures price and the expected future spot price of a commodity. This factor stems

1 This action could occur just prior to the futures maturity date.
2 This happens if expectations prove correct and the spot price at "T" turns out to be lower than F(t,T). Note that we are ignoring transaction and handling costs here.
3 Again, this only occurs if expectations of a higher spot price prove true.

from the fact that a particular trader's expectation of the future spot price may simply be wrong. Assuming that traders are risk averse then the chance factor in speculative activity implies that a risk premium will be demanded. This idea alone is no different than that presented in the last chapter, however, this particular theoretical approach allows for a time-varying risk premium rather than simply a constant risk premium. This may be more appropriate since risks fluctuate with industry conditions and likely so should risk premiums. Therefore, under this theoretical approach, a futures price should not only reflect the expected future spot price but also the associated time-varying risk premium. Equation (4.1) can now be expanded to include this time-varying risk premium component as follows:

(4.2) $F(t,T) = E_t(S(T)) + RP(t,T),$

where RP(t,T) is the risk premium demanded at time t to hold the futures contract to its maturity at time T.[1]

The futures price as a forecast of future spot price and the risk premium hypotheses are combined into the forecast power and risk premium theory of the basis. The theory states that the basis at any time should be equal to, and vary with, the sum of the expected change in the commodity's spot price and a time-varying risk premium (French and Fama, p.62). Equation (4.2) can be transformed to express this theory of the basis by subtracting the current spot price of the commodity from both sides of the equation and rearranging as follows[2]:

1 The equation ignores the relatively minor transaction costs.

2 $F(t,T) = Et(S(T)) + RP(t,T)$

$F(t,T) - S(t) = Et(S(T)) - S(t) + RP(t,T)$ and, since $S(t) = Et(S(t))$,

$F(t,T) - S(t) = Et(S(T)) - Et(S(t)) + RP(t,T)$ or,

$F(t,T) - S(t) = Et(S(T) - S(t)) + RP(t,T)$

(4.3) $F(t,T) - S(t) = E_t(S(T) - S(t)) + RP(t,T)$,

where $F(t,T) - S(t)$ is the basis observed at time t for a futures contract maturing at time T, $E_t(S(T) - S(t))$ is the expectation held at time t of the change in the commodities spot price from time t to T and $RP(t,T)$ is the premium as defined earlier.

If the spot price of the commodity is not expected to change from time t to time T, if $E_t(S(T)) = S(t)$, then the expectation at time t of the change in spot price from time t to T is zero or, $E_t(S(T) - S(t)) = 0$. In this case the basis will reflect the risk premium alone.[1] If $E_t(S(T) - S(t))$ is not zero then the basis will reflect both the risk premium and the expected change in spot price.

Continuing with this theory we assume that traders are "rational" and that in aggregate their expectations will be accurate. Using this assumption, equation (4.3) now becomes:

(4.4) $F(t,T) - S(t) = (S(T) - S(t)) + RP(t,T) + e(t,T)$,

or in words, the basis at any time t should be equal to, and vary with, the actual change in spot price from t to T plus the realized time-varying risk premium and an error term.[2] As

1 This is what Keynes had in mind when describing the concept of normal backwardation of forward prices - a situation where, as Keynes believed, hedgers were predominantly long so speculators were short, thereby creating a declining term structure of forward prices as term to maturity increased. The successively lower forward prices as the term increased, was due to the larger risk premiums demanded for the greater uncertainty over the longer time period. The expected future spot price in such a situation could be constant without changing the above described result. For more on this see Kolb, p.56.

2 The expectations operator found in equation (4.3) is dropped in equation (4.4) with the introduction of the forecast error term, e(t,T), which, of course, is assumed to be zero, consistent with the rational expectations assumption. See MacDonald and Taylor, p. 146.

one last preparatory step we define the time-varying risk premium to be the futures price bias as a forecast of the future spot price or:

(4.5) $RP(t,T) = F(t,T) - S(T)$.

Substituting this into equation (4.4) gives:

(4.6) $F(t,T) - S(t) = (S(T) - S(t)) + F(t,T) - S(T) + e(t,T)$,

which states that the basis is equal to the change in spot price plus the time-varying risk premium and sets the stage for the empirical analysis.

In order to examine the variability of time-varying risk premiums and expected spot price changes as well as their covariability, we use Fama's (1984a) variance decomposition approach. In particular, evidence that the basis contains information about time varying risk premiums can be tested for by regressing the premium on the basis in the following manner:

(4.7) $F(t,T) - S(T) = a_1 + b_1(F(t,T) - S(t)) + e_1(t,T)$.

The coefficient b_1 tells us whether the premium component of the basis has variation that reliably shows up in F(t,T)-S(T). It is expected that b_1 will be positive and less than one indicating that the basis contains information about the risk premium.

Similarly, evidence that the basis contains information about the change in spot price from time t to T can be tested for by regressing the change in spot price on the basis in the following manner:

(4.8) $S(T) - S(t) = a_2 + b_2(F(t,T) - S(t)) + e_2(t,T)$.

The coefficient b_2 tells us whether the basis observed at t has the power to predict the future change in spot price. It is expected that b_2 will be positive and less than one indicating that the basis also contains information about the change in spot price.

In this theory the variation in the basis must be entirely allocated to the risk premium and/or the change in spot price . The complementarity of equations (4.7) and (4.8) is evident in that the stochastic regressor is the same in both equations and the sum of the dependant variables is the stochastic regressor. Therefore a_1 in equation (4.7) and a_2 in equation (4.8) must sum to zero and b_1 in equation (4.7) and b_2 in equation (4.8) must sum to one: $a_1 + a_2 = 0$ and, $b_1 + b_2 = 1$.[1]

However, a problem arises here. The allocation of basis variation to the premium and/or the expected change in spot price may be inaccurate when the two series are correlated.The faith we can place in the b-coefficient estimates may be minimal. To clearly see how this is possible we examine in detail the meaning of the coefficients b_1 and b_2 in equation (4.7) and (4.8).

Again following Fama (1984a), the coefficients b_1 and b_2 are[2]:

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1 Since regressions (4.7) and (4.8) contain identical information about the variation of the premium and the expected change in spot price components of the basis, in principle there is no need to estimate both regressions. For completeness, and as a self check, we do so.

2 For a regression of the form $Y_i = a + bX_i + e_i$ the estimated coefficient b is: b = covariance(X, Y)/variance(X). See Kmenta, p.214 and 66 for relevant statistical theory.

$$(4.9)\quad b_1 = \frac{\text{cov}(F(t,T)-S(t),\ F(t,T)-S(T))}{\text{var}(F(t,T)-S(t))}, \text{ and}$$

$$(4.10)\quad b_2 = \frac{\text{cov}(F(t,T)-S(t),\ S(T)-S(t))}{\text{var}(F(t,T)-S(t))}.$$

In words, b_1 is the ratio of the covariance between the basis and the time-varying risk premium to the variance of the basis, and b_2 is the ratio of the covariance between the basis and the change in spot price to the variance of the basis. We can get a better idea of why the regressions may fail to identify the source of variation in the basis by more closely examining the variance of the basis relative to the variance of the premium and expected change in the spot price, as well as the covariance between the premium and expected change in the spot price. To do so, we break down these components and rewrite b_1 and b_2 in greater detail. First, we invoke the rational expectations assumption and use equation (4.3) to get (see Fama,.1984a, p.321):

$$\begin{aligned}(4.11)\quad \text{var}(F(t,T)-S(t)) &= \text{var}(RP(t)+E(S(T)-S(t))) \\ &= \text{var}(RP(t))+\text{var}(E(S(T)-S(t))) + 2\text{cov}(RP(t), E(S(T)-S(t))),\end{aligned}$$

$$(4.12)\quad \text{cov}(F(t,T)-S(t), F(t,T)-S(T)) = \text{var}(RP(t)) + \text{cov}(RP(t), E(S(T)-S(t))), \text{ and}$$

$$(4.13)\quad \text{cov}(F(t,T)-S(t), S(T)-S(t)) = \text{var}(E(S(T)-S(t))) + \text{cov}(RP(t), E(S(T)-S(t))).$$

Therefore, using equations (4.11), (4.12) and (4.13), b_1 and b_2 can be written as:

$$(4.14)\quad b_1 = \frac{var(RP(t)) + cov(RP(t), E(S(T)-S(t)))}{var(RP(t)) + var(E(S(T)-S(t))) + 2cov(RP(t), E(S(T)-S(t)))}, \text{ and}$$

$$(4.15)\quad b_2 = \frac{var(E(S(T)-S(t))) + cov(RP(t), E(S(T)-S(t)))}{var(RP(t)) + var(E(S(T)-S(t))) + 2cov(RP(t), E(S(T)-S(t)))}.$$

From equation (4.14) and (4.15) we can see that if the risk premium and the expected change in spot price are uncorrelated, so their covariance equals zero, cov(RP(t),E(S(T)-S(t))) = 0, then there arises a simple interpretation of the slope coefficients for these equations. The slope coefficient b_1 is simply the proportion of the variation of the basis due to the variation in its premium component, var(RP(t)), and b_2 is the proportion of the variance of the basis due to the variance in its expected spot price change component, var(E(S(T)-S(t)) (keeping in mind that all variation in basis is allocated to one or the other or both). This simple interpretation is ideal in that we are clearly separating and identifying the independent and additive individual impact of the risk premium and expected spot price change on the basis. However, it may be that these two components of the basis are correlated. If so, then the covariance terms in (4.14) and (4.15), cov(RP(t),E(S(T)-S(t))), are non-zero and add to the independent effects that the change in spot price and the premium have on the basis thus clouding the simple interpretation of b_1 and b_2.

We now go on to present the data and select summary statistics in the following section. Next, their time series properties are examined and finally, the empirical results are presented and discussed.

4.3 Data and Summary Statistics

As in the previous chapter, the raw data used herein are daily postings including spot prices and one-month, two-month, three-month and six-month futures prices for heating oil, crude oil and unleaded gasoline as determined at the New York Mercantile Exchange.[1]

The basis, F(t,T)-S(t), the risk premium, F(t,T)-S(T), and the change in spot price, S(T)-S(t), were generated from the raw data for each maturity month futures contract for each of the three commodities. For example, a one-month basis series was generated to be used in regression analysis with a one-month risk premium and a one-month change in spot price series. A similar set of series were calculated for the two, three and six-month basis groups. For the one-month data group, T was set at t+21 (for example, twenty-one working days) as this is the time period over which the expectation takes place.[2] The two, three and six-month values of T were similarly set at t+42, t+63 and t+126 respectively.

The standard deviations of the basis group series are reported in Table 4.1. We find that the standard deviations of the basis, the premium and the spot price change are larger for crude oil than for heating oil and unleaded gasoline, the later two of which are similar in deviation. This observation is consistent across the two, three and six month basis groups of data.

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1 Section 3.3 has all the other raw data information.
2 It is assumed that the one-month futures contract, for example, matures one month from the date that the price of the contract is observed. "Twenty-one" represents the average number of working days from the observation of the price of the contract to its maturity. This generally matches the futures price with the future spot price that would prevail upon maturity of the futures contract but the alignment could be a day or two off in some cases.

TABLE 4.1

STANDARD DEVIATIONS: ALL COMMODITIES

Standard deviations of the basis, F(t,T)-S(t), the risk premium, F(t,T)-S(T), and the change in spot price, S(T)-S(t).

Basis Length & Variable	Commodity: Heating Oil	Crude Oil	Unleaded Gasoline
One-month			
F(t,T)-S(t)	.01955	.20677	.01282
F(t,T)-S(T)	.05806	1.83987	.05931
S(T)-S(t)	.06330	1.84067	.06219
Two-month			
F(t,T)-S(t)	.03560	.42538	.02242
F(t,T)-S(T)	.07509	2.78391	.08215
S(T)-S(t)	.08310	2.88426	.08943
Three-month			
F(t,T)-S(t)	.04729	.62772	.03274
F(t,T)-S(T)	.08767	3.42199	.09147
S(T)-S(t)	.10100	3.64121	.10343
Six-month			
F(t,T)-S(t)	.05967	.95329	.05152
F(t,T)-S(T)	.11053	4.55441	.12516
S(T)-S(t)	.13817	5.12313	.14581

Note: All series are daily.

A further finding for all basis groups across all commodities is that the variation in the basis is small relative to the variation in the risk premium and spot price changes. This finding, as Fama and French indicate, decreases the likelihood that regressions (4.7) and (4.8) will reliably assign basis variation to premiums and expected spot price changes (Fama and French, pp. 64-65). When the independent variable in a regression has small variation relative to the dependant variable the coefficient attached to the independent variable will often be statistically insignificant.

4.4 Time Series Properties: Univariate Tests for Unit Roots

In this section we examine the time series properties of the series to determine whether or not they are stationary. We follow the exact method as described in detail in chapter 3 using Schwarz's criterion to determine the optimal model specification for equations (3.9), (3.10) and (3.11) and then test for unit roots. The only difference between the present application and the one in the previous chapter is in the variables used. Here the unit root tests are performed on the basis, the premium, and the change in spot price of the four different basis time periods and, as before, this analysis is performed on all three petroleum commodities: heating oil, crude oil and unleaded gasoline.[1]

Tables 4.2, 4.3 and 4.4 provide unit root test results for heating oil, crude oil and unleaded gasoline respectively. In each table, column one gives the results of a test for a unit root alone, column two gives the results of a test for a unit root allowing for a possible drift in the series, and column three gives the results of a test for a unit root allowing for a possible drift and time trend in the series. The one-percent, five-percent and ten-percent level of significance critical values are the same as those used in Chapter 3.[2]

Turning to Table 4.2 we will examine all of the unit root tests for heating oil. Column one indicates that the null hypothesis of a unit root is rejected for all series across all basis periods almost entirely at the one-percent level of significance. The exception to this is that the null for the six-month premium and change in spot price series is rejected at the five-

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1 Only the results of the tests are reported here. See Section 3.4 of this thesis for a detailed description of the theory and application of unit root analysis.

2 The 1%, 5% and 10% level of significance critical t-values for the test for a unit root alone are -2.58, -1.95 and -1.62 respectively. For the test of a unit root with drift they are -3.43, -2.86 and -2.57. And for the test for a unit root with drift and trend they are -3.96, -3.41 and -3.12.

percent level of significance. Column two indicates that after allowing for a possible drift in the series we still reject the unit root null largely at the one-percent level of significance.

TABLE 4.2

UNIT ROOT ANALYSIS: HEATING OIL

Tests for unit roots alone, unit roots with drift, and unit roots with drift and trend in the Basis, F(t,T)-S(t), the Risk Premium, F(t,T)-S(T), and the Spot Price Change, S(T)-S(t).

	Type of Unit Root Test		
Basis Length	ADF	ADF(c)	ADF(c,t)
One-month			
F(t,T)-S(t)	-8.6513**(2)	-8.7362**(2)	-8.7489**(2)
F(t,T)-S(T)	-6.2891**(0)	-6.3043**(0)	-6.3023**(0)
S(T)-S(t)	-5.3753**(1)	-5.4078**(1)	-5.4054**(1)
Two-month			
F(t,T)-S(t)	-4.2776**(2)	-4.4210**(2)	-4.4164**(2)
F(t,T)-S(T)	-3.8356**(1)	-3.8419**(1)	-3.8408* (1)
S(T)-S(t)	-3.7581**(1)	-3.8098**(1)	-3.8076* (1)
Three-month			
F(t,T)-S(t)	-3.5046**(2)	-3.6596**(2)	-3.6532* (2)
F(t,T)-S(T)	-3.2000**(1)	-3.2108* (1)	-3.2063+ (1)
S(T)-S(t)	-3.1727**(1)	-3.2456* (1)	-3.2443+ (1)
Six-month			
F(t,T)-S(t)	-3.2235**(1)	-3.5130**(1)	-3.5125* (1)
F(t,T)-S(T)	-2.3597* (1)	-2.3769 (1)	-2.3782 (1)
S(T)-S(t)	-2.2142* (1)	-2.3240 (1)	-2.3280 (1)

Notes: 1) ADF - unit root alone test.
ADF(c) - unit root with drift test.
ADF(c,t) - unit root with drift and trend.
2)Reject the null of a unit root at the **1%, *5% and +10% levels of significance.
3)The numbers in brackets are the optimal lag lengths for the autoregressive processes in equations (3.9), (3.10) and (3.11).

The exceptions here are for two series the null is rejected at the five-percent level of significance and we fail to reject the null for the six-month premium and spot price change series. Column three, where we show the results of the unit root test allowing for drift and trend, also indicates that we fail to reject the null of a unit root for the six-month premium and spot price change. However, we do reject the unit root null for all other series, although at various levels of significance.

In summary then, Table 4.2 provides us with the following observations of the heating oil series. When testing for a unit root alone we overwhelmingly reject the null hypothesis. When testing for a unit root with drift, or trend and drift, we still largely reject the null hypothesis but at lower levels of significance and in two cases we fail to reject the null. Looking at the overall "picture" of results in Table 4.2 we can safely conclude that all heating oil series contain no unit roots.[1]

We now turn to the unit root analysis for the crude oil series detailed in Table 4.3. Column one indicates that we reject the null of a unit root for all series at the one-percent level of significance except for the six-month change in spot price and premium for which we reject the null at the ten-percent level of significance. We see in column two where we test the null of a unit root with drift that we reject the null in all cases except for the change in spot price and risk premium components of the six-month basis. However, the null rejection levels of significance are lower in a few cases as compared to the test for a unit root alone. Column three provides the results of the test for a unit root with drift and trend. It reveals that for more than half the series we reject this null, the exceptions being the change in spot price and risk premium components of the three and six-month basis.

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[1] The ambiguity of the unit root with drift and with drift and trend results as compared to the unit root alone results will be cleared up later in this section.

TABLE 4.3

UNIT ROOT ANALYSIS: CRUDE OIL

Tests for unit roots alone, unit roots with drift, and unit roots with drift and trend in the Basis, F(t,T)-S(t), the Risk Premium, F(t,T)-S(T), and the Spot Price Change, S(T)-S(t).

	Type of Unit Root Test		
Basis Length	ADF	ADF(c)	ADF(c,t)
One-month			
F(t,T)-S(t)	-24.2810**(0)	-24.4282**(0)	-24.4198**(0)
F(t,T)-S(T)	-5.0910**(0)	-5.1465**(0)	-5.1481**(0)
S(T)-S(t)	-5.2549**(0)	-5.3202**(0)	-5.3216**(0)
Two-month			
F(t,T)-S(t)	-5.3350**(3)	-6.0853**(3)	-6.0976**(3)
F(t,T)-S(T)	-3.3604**(0)	-3.3847 * (0)	-3.3868+ (0)
S(T)-S(t)	-3.4523**(0)	-3.5122**(0)	-3.5165+ (0)
Three-month			
F(t,T)-S(t)	-4.0030**(4)	-4.7241**(4)	-4.7310**(4)
F(t,T)-S(T)	-2.7682**(0)	-2.8016+ (0)	-2.7929 (0)
S(T)-S(t)	-2.6402**(0)	-2.7199+ (0)	-2.7141 (0)
Six-month			
F(t,T)-S(t)	-3.4879**(1)	-4.2654**(1)	-4.2626**(1)
F(t,T)-S(T)	-1.8398+(0)	-1.8558 (0)	-1.8600 (0)
S(T)-S(t)	-1.8295+(0)	-1.8833 (0)	-1.8899 (0)

Notes: 1)ADF - unit root alone test.
ADF(c) - unit root with drift test.
ADF(c,t) - unit root with drift and trend.
2)Reject the null of a unit root at the **1%, *5% and +10% levels of significance.
3)The numbers in brackets are the optimal lag lengths for the autoregressive processes in equations (3.9), (3.10) and (3.11).

Therefore, as was the case for heating oil, we clearly reject the null of a unit root alone for all basis groups in the crude oil series. We reject the null in all but two cases when testing for a unit root with drift, and in all but four cases when testing for a unit root with drift and trend. Although we fail to reject the null in a few cases, the overall evidence that Table 4.3

provides strongly suggests that we can safely conclude that all series contain no unit roots.[1]

Finally, we examine the unit root test results for the unleaded gasoline series. These are presented in Table 4.4. Column one shows that we reject the null of a unit root alone, at various levels of significance, in all cases except for the six-month change in spot price. Columns two and three show that we reject the null in half the cases when we test for a unit root with drift, as well as when we test for a unit root with drift and trend. Although these results are not as statistically strong as those for heating oil and crude oil, we can still conclude that all unleaded series contain no unit roots except for the six-month change in spot price.[2] This is the only case in all of the tests for a unit root alone where we find evidence that there may be a unit root present in the series. For completeness sake, in the final regression analysis, the six-month change in spot price will be treated as if it has no unit roots.

A consistent pattern emerges in these time series tests that is common to each of the three petroleum commodities. Except for the six-month change in spot price for unleaded gasoline there is a complete rejection of the null of a unit root alone across all three commodities (see column one in Tables 4.2, 4.3 and 4.4). We fail to reject the null hypothesis and the significance levels of those that are rejected are somewhat less in a few cases when we test for a unit root allowing for drift. Finally, when testing for a unit root allowing for drift and trend across the three commodities there are a few more cases where we fail to reject the null and more instances of rejection at the ten percent level of significance rather than at the more preferred one percent level of significance.

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[1] As in the previous footnote, the ambiguity of results will be cleared up shortly.

[2] See previous two footnotes.

TABLE 4.4

UNIT ROOT ANALYSIS: UNLEADED GASOLINE

Tests for unit roots alone, unit roots with drift, and unit roots with drift and trend in the Basis, F(t,T)-S(t), the Risk Premium, F(t,T)-S(T), and the Spot Price Change, S(T)-S(t).

	Type of Unit Root Test		
Basis Length	ADF	ADF(c)	ADF(c,t)
One-month			
F(t,T)-S(t)	-9.6339**(1)	-10.0512**(1)	-10.0700**(1)
F(t,T)-S(T)	-4.2276**(0)	-4.2569**(0)	-4.3203**(0)
S(T)-S(t)	-4.2679**(0)	-4.3334**(0)	-4.3934**(0)
Two-month			
F(t,T)-S(t)	-3.5228**(2)	-4.0295**(2)	-4.3557**(2)
F(t,T)-S(T)	-2.9240**(0)	-2.9335* (0)	-2.9946 (0)
S(T)-S(t)	-2.4482*(1)	-2.5166 (1)	-2.6033 (1)
Three-month			
F(t,T)-S(t)	-2.5752*(2)	-2.8980* (2)	-3.4305* (2)
F(t,T)-S(T)	-2.5241*(0)	-2.5537 (0)	-2.6207 (0)
S(T)-S(t)	-2.0950*(1)	-2.2131 (1)	-2.4142 (1)
Six-month			
F(t,T)-S(t)	-2.1241*(1)	-2.3272 (1)	-3.0432+ (1)
F(t,T)-S(T)	-1.7460+(0)	-1.7735 (0)	-2.0154 (0)
S(T)-S(t)	-1.4254 (1)	-1.4509 (1)	-1.8862 (1)

Notes: 1)ADF - unit root alone test.
ADF(c) - unit root with drift test.
ADF(c,t) - unit root with drift and trend.
2)Reject the null of a unit root at the **1%, *5% and +10% levels of significance.
3)The numbers in brackets are the optimal lag lengths for the autoregressive processes in equations (3.9), (3.10) and (3.11).

This trend can be described as a "clouding" of results as we add a drift variable and then a trend variable to the strict unit roots test.[1] This increasing cloudiness yielding ambiguous unit root test results can be explained by looking at the manner in which the basis, the premium, and the change in spot price variables have been generated in the first place. They

1 As can be seen by equations (3.9), (3.10) and (3.11).

all derive from a series of futures prices and a series of spot prices. It is well known that futures and spot prices of the same commodity tend to move together and the closer the futures contract is to maturity the closer will its price be correlated with the prevailing spot price. It is clear that they are series very similar in magnitude and movement. When calculating any basis, F(t,T)-S(t), or its components, the risk premium, F(t,T)-S(T), and the change in spot price, S(T)-S(t), we are doing something very similar to differencing a time series. Differencing tends to remove any trend that may be present in a time series and if the futures and spot price series have a similar drift, which is likely, then it will be removed also. Since differencing has this effect, the unit root tests which allow for drift and trend may be inappropriate in this case. Therefore, the tests for unit roots alone are the appropriate ones to consider when drawing final conclusions about the time series properties of the variables. This is the approach used and it removes any ambiguity in the unit root test results.

Therefore, on the basis of the first columns in Tables (4.2), (4.3) and (4.4), we can conclude unequivocally that all series for all commodities, except the six-month unleaded change in spot price, do not contain any unit roots. These petroleum series are integrated of order zero, I(0), and thus are stationary. Cointegration theory allows us to conclude that cointegration exists between two variables if the linear combination of the variables residual integration order is reduced by one. Since all variables are I(0), cointegration theory does not apply. This result tells us that we can go ahead with ordinary least squares analysis rather than using cointegration theory to test the basis for the existence of time-varying risk premiums and spot price forecastability for the one, two, three and six-month basis periods for each of heating oil, crude oil and unleaded gasoline.

4.5 Regressions and Empirical Results

In this section we provide the test results and discussion of the basis form of the time-varying risk premium and forecastability theory of futures markets. Unit root analysis has revealed that all series are stationary so we may use ordinary least squares analysis for testing purposes.[1] To test whether the basis has variation that significantly shows up in the risk premium and/or change in spot price we ran ordinary least squares regressions, of the form found in equations (4.7) and (4.8) , on the heating oil, crude oil and unleaded gasoline basis groups. The results of the estimated regressions of F(t,T)-S(T) and S(T)-S(t) on F(t,T)-S(t) are presented in Table 4.5.

The intercept and slope coefficients for both the risk premium and change in spot price regressions are listed for each basis group. However, since these regressions are complementary in nature as earlier described, only one set of coefficient standard errors is reported (the other set is identical). R-square values for both regressions are also reported in Table 4.5.

We see in Table 4.5 that all slope coefficients, b_1 and b_2, for all regressions are statistically significant except for that on the two and three-month heating oil risk premium. This lends strong support to the time-varying risk premium and forecast hypothesis as applied to these petroleum commodities. When we test for the existence of basis variation that is reliably evident in a time-varying risk premium we find evidence of this as shown by the significant b_1 coefficients. Similarly, we find evidence of the spot price forecast power of the basis as

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1 Note again that under unit root analysis the six-month change in spot price for unleaded gasoline did not prove to be stationary. However, the six-month basis and six-month premium did prove to be stationary, so, for completeness sake we treat the six-month change in spot price as being stationary too.

TABLE 4.5

Ordinary Least Squares Regressions of the Premium and the Change in the Spot Price on the Basis

$$F(t,T)-S(T) = a1+b1(F(t,T)-S(t))+u(t,T) \quad \text{and} \quad S(T)-S(t) = a2+b2(F(t,T)-S(t))+v(t,T)$$

	Coefficient Estimates				Standard Errors		Summary Statistics	
	a1	b1	a2	b2	s(a)	s(b)	Rsq(1)	Rsq(2)
HEATING OIL								
One-month	0.0032	-0.3311**	-0.0032	1.3311**	0.0016	0.0833	0.0124	0.1690
Two-month	0.0047	-0.0001	-0.0047	1.0001**	0.0021	0.0600	0.0001	0.1835
Three-month	0.0067	-0.0622	-0.0067	1.0622**	0.0026	0.0532	0.0011	0.2474
Six-month	0.0071	-0.4651**	-0.0071	1.4651**	0.0033	0.0529	0.0630	0.4003
CRUDE OIL								
One-month	0.2591	0.4654+	-0.2591	0.5345*	0.0520	0.2507	0.0027	0.0036
Two-month	0.1062	-1.0716**	-0.1062	2.0716**	0.0875	0.1837	0.0268	0.0933
Three-month	-0.1060	-1.4648**	0.1060	2.4648**	0.1100	0.1507	0.0721	0.1805
Six-month	-0.8061	-2.5281**	0.8061	3.5281**	0.1389	0.1194	0.2800	0.4310
UNLEADED GASOLINE								
One-month	0.0041	-0.5646**	-0.0041	1.5646**	0.0020	0.1591	0.0148	0.1040
Two-month	-0.0006	-0.7428**	0.0006	1.7428**	0.0030	0.1259	0.0411	0.1909
Three-month	0.0000	-0.5877**	0.0000	1.5877**	0.0035	0.0971	0.0442	0.2525
Six-month	0.0127	-0.5539**	-0.0127	1.5539**	0.0050	0.0876	0.0519	0.3014

NOTE: Coefficients are significant at the **1%, *5% and +10% levels of significance.
Rsq(1) and Rsq(2) are the R-squared values for the premium and change regressions, respectively.
The complete complementarity of the premium and change regressions for each commodity means that the standard errors of the estimated regression coefficients are the same.

shown by the significant b_2 coefficients.[1] The actual estimates of the coefficients are not as initially expected but this can be explained with the previously discussed theory. As mentioned, b_1 contains the proportion of the variance of the basis due to variation in its premium component and b_2 contains the proportion of the variance of the basis due to variation in the expected change in spot price. Also as explained earlier, equations (4.7) and (4.8) are subject to an adding up constraint such that $a_1 + a_2 = 0$ and $b_1 + b_2 = 1$.

Although the adding up constraints are satisfied, the estimates are rather strange in that b_2 is in all but one case greater than one, which necessarily forces b_1 to be in all but one case less than zero. Therefore, the above described simple interpretation of the b-coefficients cannot hold. We must look again at equations (4.14) and (4.15) and consider the explicit interpretation of these regression coefficients in order to explain the magnitude and sign of b_1 and b_2. Equation (4.14) and (4.15) are repeated here:

$$(4.14)\quad b_1 = \frac{var(RP(t)) + cov(RP(t), E(S(T)-S(t)))}{var(RP(t)) + var(E(S(T)-S(t))) + 2cov(RP(t), E(S(T)-S(t)))},$$

$$(4.15)\quad b_2 = \frac{var(E(S(T)-S(t))) + cov(RP(t), E(S(T)-S(t)))}{var(RP(t)) + var(E(S(T)-S(t))) + 2cov(RP(t), E(S(T)-S(t)))}.$$

The simple interpretation of b_1 and b_2 relies on an independent relationship between the risk premium, RP(t), and expected change in spot price, E(S(T)-S(t)). But the statistical interpretation of the signs of the estimated coefficients suggests that they are not independent. Consider the negative estimates of b_1 and the corresponding greater than one

1 The "a" coefficients simply capture part of the variation of the basis that is not being assigned to either the risk premium or the change in spot price, depending on which equation is being used. Since we more accurately use the actual magnitudes of the premium and change in spot price, in their respective equations, to capture their total effects on the basis, we do not bother discussing the a coefficients here.

estimates of b_2. Since the denominators in (4.14) and (4.15) are positive, the negative estimates of b_1 imply that cov(RP(t),E(S(T)-S(t))) is negative and larger in magnitude than var(RP(t)).[1] The complementary estimates of b_2 which are greater than one imply that the negative cov(RP(t), E(S(T)-S(t)) is smaller in absolute magnitude than var(E(S(T)-S(t))). Therefore, we can conclude from the statistical equations and the coefficient estimates themselves that var(E(S(T)-S(t))) is larger than var(RP(t)) or, in other words, more of the variation of the basis arises from variation in expected spot price changes than in the time-varying risk premiums.[2] In addition, the spot price change is a larger component of the basis than is the risk premium.

An important point to take note of in the above discussion is the negative covariance between the risk premium and the expected spot price change. Although it is still true that b_1 contains the proportion of the variance of the basis due to the variance in the risk premium and b_2 contains the proportion of the variance of the basis due to the variation in the expected spot price change, the coefficient estimates imply that they now both also contain the covariance between the risk premium and expected spot price change. This covariance makes it impossible to independently capture the individual effects that the risk premium and the expected change in spot price have on the basis. However, the fact that both b_1 and b_2 coefficients are in all cases statistically significant does imply that the premium and change in spot price are reliable components of the basis in support of the time-varying risk premium and forecastability hypothesis of the basis.

1 Variances are positive in sign, therefore, var(RP(t))), var(E(S(T)-S(t))) and the denominators of (4.14) and (4.15), var(RP(t)) + var(E(S(T)-S(t)) + 2cov(RP(t), E(S(T)-S(t))) = var(F(t,T)-S(t)), are all greater than zero.

2 This is confirmed in Table 4.1 where we can see that the standard deviations of the change in spot price are larger than those for the risk premium.

The slope coefficients may also be a little strange because the change in spot price used in the regressions is the actual change in spot price and not the expected change in spot price as the theory says it should be. We use the actual change in spot price as a proxy for the expected change. The closer that the expected change in spot price is to the actual change, the more accurate will the regression results be. On the contrary, the larger the unexpected component of the actual change in spot price, the less accurate will the results be

Before finding the covariance result one might have expected a positive relationship between the risk premium and the expected change in spot price. This concern is resolved in light of the discussion of actual versus expected change in spot price. A speculator may well request a larger than normal premium to compensate for greater perceived risk attached to a larger than usual expected spot price change. This suggests a positive relation between the two. However, since the basis variation is low compared to that for the risk premium and the change in spot price, and bearing in mind that the change in spot price is the actual change and it is added to the risk premium to arrive at basis value, then an increase in the actual change in spot price without much variation in the basis implies a decrease in the risk premium - actually forcing a negative relation between the premium and the change in spot price. This is one possible explanation of the negative correlation result. However, this possibility should not be taken to mean that negative correlation cannot exist. Indeed, if we are confident that the expected and actual change in spot price are very close, then this last argument turns into a support of negative correlation between the premium and the change in spot price.

Therefore, tying these last ideas together, if the ratio of expected change in spot price to the actual change in spot price is close to one, then it is the (negative) covariance between the risk premium and the expected change in spot price that makes it impossible to isolate the individual effects of these two components of the basis. Hence, b_1 and b_2 do not indicate what they "appear" to - thus our strange coefficients. On the other hand, if the ratio of the expected change in spot price to the actual change in spot price is close to zero, then the strangeness of the coefficient estimates can be attributed to the forced complementarity between the premium and actual spot price change. The complementarity condition requires that they sum to give the basis, and in effect, actually forces a negative correlation between the two. In this case the expected change in spot price and the time-varying risk premium may indeed be independent and the slope coefficients, b_1 and b_2, could well have the simple interpretation we spoke of earlier, but the estimates would be inaccurate because of the large unexpected component of the change in spot price and forced complementarity.

As a last statistical note, we consider the R-square values which are observed to be relatively small. This result, as well as the nature of the coefficient estimates described earlier are similar to what others have found in related research (Fama and French, Fama, 1984a, and French). The low R-square values may be partially due to low basis variation, relative to risk premium and spot price change variation, resulting in a relatively poor fitting regression. For all commodities the R-square values get progressively larger as the basis length increases. As Table 4.1 indicates the basis variation increases with term to maturity which may "cause" the better fit as indicated by these progressively larger R-square values. Further, the R-square values are larger for equation (4.8) than equation (4.7). This is consistent with the conclusion drawn earlier that most of the variation in the basis is due to variation in the expected change in the spot price. The variation in the change in spot price, as is evident in Table 4.1 as well as from the interpretation of the b_2 estimate and equation, is larger than that of the risk premium providing a better chance of a good regression fit for the change in spot price regression as compared to the risk premium regression.

In summary we repeat that we do find evidence in support of the time-varying risk premium and forecastability theory of futures markets in the petroleum industry. The spot price forecast coefficients for all regressions across all petroleum commodities are statistically significant. The risk premium coefficients are also significant in all cases except for the two and three month heating oil basis. Although the possibility of non-zero correlation clouds the interpretation of the individual effects of these coefficients, their statistical significance does lend support to the forecastability/risk premium theory of the basis in petroleum markets. Based on the size of the coefficients and variability of the components, it is also evident that the risk premium has less effect on the basis than does the change in spot price.

4.6 Conclusion

The objective of this chapter was to examine the petroleum futures market from a different viewpoint than in the previous chapter for the purpose of adding strength and completeness to any conclusions drawn herein. The approach in this chapter differs from the previous one in that it allows for time-varying risk premiums and the theory is proposed in the context of the basis. However, we still look for evidence of forecastability of future spot prices and risk premiums in petroleum futures prices.

Before testing this theory we examined the time series properties of the heating oil, crude oil and unleaded gasoline basis groups. It was found that all series were integrated of order zero and hence, were already stationary. Therefore, cointegration tests were not applied. Instead, simple ordinary least squares regression analysis was performed to determine if the basis for these petroleum products varied with a time-varying risk premium and a forecast of the future spot price.

It was found that the basis does indeed vary significantly with the premium and spot price forecast components. However, either forced or actual negative correlation between these two components renders the quest for isolation of their individual effects a no-win pursuit. The simple interpretation of individual and additive effects of the premium and spot price forecast on the basis is lost. But the fact does remain that the basis for heating oil, crude oil and unleaded gasoline for all maturities considered does vary significantly with these two components. The absolute size of these components and their variability suggests that, overall, the change in spot price is a more significant component of the basis than is the time-varying risk premium. Perhaps accurate detection of the individual effects is an area for further research.

CHAPTER 5: CONCLUSIONS AND DISCUSSION

5.1 Summary and Conclusions

The purpose of writing this thesis was twofold. One goal was to present a description of futures markets in general, with specific focus on the petroleum industry and how its futures market operates and functions. This insight is the content of Chapter 2. Chapter 3 and Chapter 4 were more specific in focus. Their aim was to perform rigorous technical analysis of the risk transference and price discovery mechanisms in the petroleum futures market. Specifically, the focus here was on detection of spot price forecastability of petroleum futures prices as well as discerning if there exists a risk premium bias in these same futures prices. The relatively new statistical techniques of cointegration and unit root analysis were employed in the testing procedure thus distinguishing these chapters as being somewhat unique from more traditional methods of analysis. Little applied research has been done on the petroleum futures market so this thesis contributes original and hopefully useful material to the growing body of literature in this dynamic field of study.

Chapter 2 introduced futures markets and presented the overall operations and functions of the New York Mercantile Exchange (NYMEX), which houses the largest petroleum futures market in the world. It was noted that futures contracts are traded in centrally organized exchanges like NYMEX, where many knowledgeable buyers and sellers focus their trading activity and much information, including prices, is immediately disseminated world wide. The financial integrity of the exchange provides traders and their customers with the secure knowledge that all trades will be honored. For these reasons it is the author's opinion that futures markets are as close as the "real world" can get to the economic ideal of a "perfect market".

Several factors were listed as desirable industry conditions for the longevity of any futures contract. Most importantly, the industry should be relatively decentralized, have a competitively determined price, and there must be a viable delivery mechanism to ensure the economic link between the futures contract and the physical commodity. Based on these and other criteria, the petroleum industry stacks up well, and of course, it certainly meets the principle condition of price volatility with unparalleled success. All evidence points to a successful futures market. The volume and open interest statistics (see Section 2.5) provide further support that the futures market in the petroleum industry is, in fact, functioning well and continues to do so.

Part of the reason for this success stems from the mix of participants in this market. Simple examples of the often overlapping activities of hedging, speculation and arbitrage were presented. All three types of activity are complementary because each ones existence depends for its success on the existence of the others. The active involvement of all three agents helps to ensure a smoothly functioning and financially liquid petroleum futures market. The theoretical and empirical thrust of this thesis stems, in a practical sense, from the general awareness provided in Chapter 2, but the heart of the rigor is found in Chapter 3 and Chapter 4.

In Chapters 3 and 4 we examined the influence that the risk transference and price discovery mechanisms have on a range of futures prices for heating oil, crude oil and unleaded gasoline. A very extensive spot and futures price data set was analyzed. The futures price series for all three commodities represent a one-month, two-month, three-month and six-month term to maturity. Chapter 3 examined the levels of the series while Chapter 4 used for its empirical work, the basis - a time relationship defined as the difference between any maturity length futures price and its associated spot price, at a given moment in time. In both cases we tested for evidence of forecastability and risk premiums. A primary theoretical difference between the two approaches is that the "basis" theory in Chapter 4 allows for a risk premium that is time-varying, while Chapter 3 is less complex, allowing only for a constant premium.

Chapter 3 began by developing and applying the efficient markets hypothesis to the petroleum futures market. This simple theory states that the petroleum futures price should be an unbiased forecast of the future spot price to prevail upon the maturity of that futures contract. The theory was then expanded to accommodate a risk adjustment factor that might be present in the futures price. This factor was accounted for by building a constant term into the efficient markets criterion. The theory could now explain a futures price that had predictive power but was biased by a constant risk premium. Thus we were able to examine whether futures prices, in levels, are either "risk biased" or efficient predictors of the future spot price.

To test whether these two theories could hold in the petroleum futures market we used relatively recent advances in econometrics - that of cointegration theory and unit root analysis. Unit root analysis, which examines the time-series properties of the individual series, indicated that they are all integrated of the same order (I(1), in particular). This meant that cointegration tests could now tell us whether particular spot and futures prices were related in a long run fashion as described by the economic theory. A finding of cointegration would reveal that the prices did move together through time and hence supported either one of the economic relationships posited above.

The regression coefficients attached to the potentially cointegrating functions suggests that the one-month futures prices reflect very little, if any, risk adjustment and have strong predictive power of the future spot price. The two, three and six-month contract prices contain progressively less predictive information but are adjusted by a relatively greater premium component. These results make sound economic sense based on two simple observations. The first is that arbitrage opportunities and speculative wisdom force the price of a contract with a short term to maturity into line with actual market conditions to a far greater extent than a futures contract with a long term to maturity. Therefore, a nearby contract price is a better reflection of the future spot price than the price of a contract with a long time to maturity could ever be. This conclusion is supported by the high R-square values for the one-month contracts and the progressively lower R-square values for the equations as the futures term to maturity increases. In this case the lower R-square values can be interpreted as meaning that there is less spot price predictive power. The other side to this explanation is that greater uncertainty motivates a larger risk adjustment on a contract of relatively longer term to maturity. Therefore, the more distant contract prices will be biased by a relatively large risk premium as compared to the nearbys.

While cointegration was found for all of the nearby contract prices and some of the two and three-month prices, the cointegration results did not support the six-month contract prices and the remaining two and three-month prices. We could not conclude that these later futures prices moved together with their spot price. Even though the coefficients make sense standing alone, they got little technical support. Therefore, motivation in hand, we turned to the alternative approach, found in Chapter 4, to examine the same concepts of price discovery and risk transference in the petroleum futures market.

The theory in Chapter 4 is posed in the context of the basis, as defined earlier. The other major fundamental change is the allowance for a risk premium which can vary with time. A time-varying risk premium may be a more realistic analytical variable given the volatile nature of the petroleum industry. Unit root analysis, as a prerequisite to cointegration tests, was performed on the various basis groups. In this case, all series were found to be integrated of order zero, I(0), or perhaps in more familiar terms, they are stationary. Since they were already stationary, it was not necessary to employ cointegration analysis. We simply went ahead with ordinary least squares regression analysis and favorable results unfolded.

The equations used to test specifically for spot price predictiveness, yield statistically significant coefficients for all commodities in all basis groups. Similarly, the equations testing for time-varying risk premiums also yield statistically significant coefficients for all commodities in all basis groups. This is compelling evidence that the time-varying risk premium and spot price forecast theory of the basis is prevalent in the petroleum futures market.

However, the coefficients attached to the risk premium and forecast components on their relevant regressions are somewhat strange. In particular, although the "adding up" constraint is satisfied, the coefficients do not quite make intuitive sense.[1] But this result can be explained by close examination of the statistical formulas for the relevant b_1 and b_2 coefficients. It was found that the strange coefficients can be attributed to either forced, through the complementarity condition, or actual negative correlation between the time-varying risk premium and the expected change in spot price. The simple interpretation of the coefficients focuses on the independent effect of the two variables. But because they are correlated, the simple interpretation becomes inappropriate.

However, the size of the coefficients and the variability of the series (as derived from the coefficient formulas and series standard deviations, as well as the relative sizes of the R-

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[1] Specifically, all but one "forecast" coefficient was greater than one, which in effect, forced all but one "premium" coefficient to be negative. Other researchers have had similar results. See Table 4.5 and the discussion thereof.

square values) provide important insight into the relative effects that the spot price change and the premium have on the basis. The combination of these factors lead us to conclude that for all basis groups, the expected change in spot price (the forecast of the future spot price) is clearly a more pronounced component of the basis and causes more of its variability than does the risk premium.

Chapter 3 and 4 approached the same problem of identifying forecastability and risk adjustment in the petroleum futures market but used different methodology. The purpose of this was to add overall completeness and gravity to conclusions drawn from this work. Based on the detailed empirical analysis and results of Chapter 3 and Chapter 4 as well as the intuitive understanding grasped from Chapter 2, we make the following general conclusions about the heating oil, crude oil and unleaded gasoline futures markets.

The closer a petroleum futures contract is to maturity, the more accurate will its price be as a forecast of the future spot price. Speculative and arbitrage activity will be based on more immediate information sets. Since potential loss or gain is not too far off into the future, the large number of agents trading these nearby contracts have strong motivation to be very accurate in their market assessments. Hence, nearby contract prices, as spot price forecasts, will be in error less than more distant contract prices. Since the time to maturity is relatively short, there is less uncertainty. From this it follows that risk premiums may be non-existent for nearby contracts, or if they are evident, they will be small, causing little bias in the futures price and accounting for little of the variation in the basis. Almost all of the basis variation will arise from changes in the expected spot price.

Contracts with a longer term to maturity will also contain a large variation in the basis due to changes in spot price forecasts, and the spot price forecast will still be the largest component of the basis, but to less extent than for the nearby contracts. Since the futures maturity date is not as near, there is less concern as to whether or not the futures price is an exact future spot price forecast. The time factor allows traders to adjust and act on their expectations as new information is realized. Traders realize that it is much more difficult to predict events, say, six months into the future than, for example, one month hence. Those speculators that do trade these distant contracts know that their price forecasts are likely to be inaccurate, and therefore, they will demand a large risk premium for their efforts. Hence, the distant contract prices still reflect a forecast of the future spot price, but the futures price itself is biased by a relatively large (time-varying) risk premium adjustment.

These results of this thesis, when stated in their simplest form as in the last two paragraphs, are intuitively appealing and make sound economic sense. The detailed analytical rigor (unit root analysis and cointegration tests) behind these observations provides substantial and persuasive empirical analysis in support of an otherwise logical and straightforward understanding of the petroleum futures market and futures markets in general. The work in this thesis was complex but the final conclusions are simple and support the economic theory.

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