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World Oil Markets:
Changing Structure and Greater Price Volatility
Causing the Third Petro-Recession

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Oil markets have been extraordinarily volatile for the last three years. Prices first plunged from the mid-20s in late 1997 to less than $10 per barrel in early 1999. Prices then rose in the following two years to almost $40 per barrel. This paper examines the causes of the increased price volatility. The most recent upsurge in petroleum prices has created an economic environment that will drive the world into recession in 2001 and 2002.

The recession will occur because the price of oil, like the price of any commodity, can achieve equilibrium over a wide range for an identical level of supply and demand. The key determinant of the observed price is the amount of inventories held by processors and consumers.

OPEC has noticed the linkage between inventories and prices. Since March 1999, the cartel has acted much more cohesively, with the primary goal of working off the high inventories held by consuming countries. OPEC succeeded beyond its members' wildest expectations. Much of the achievement rests with Venezuela. A new government there abandoned that country's disdain for OPEC and became the cartel's champion. Its decisions have dramatically strengthened OPEC's market power.

Mergers in the oil industry also changed market dynamics over the last two years. The joining companies have sought to reduce costs and investments, liquidating inventories as part of this process. In this paper, I show that their stock reduction has contributed to increased price volatility and inadvertently aided OPEC.

Markets have also been made more volatile by the transfer of assets from large integrated companies to smaller firms. Over the last decade, the integrated companies have sold a large number of refineries to smaller companies. These smaller firms generally must operate with reduced stocks. Their liquidation of inventories has also contributed to market volatility.

Lastly, the oil industry is suffering from sclerosis. Pipelines are old and tend to break. Refineries are old and experience more interruptions. The shipping fleet has shrunk as regulators have prohibited older ships from traveling to OECD nations. This sclerosis implies that any sudden

change in demand cannot be easily met by increased production. Instead, prices must rise because firms do not hold inventories.

The trend of increasing price volatility will continue unless steps are taken to build greater buffers between producers and consumers. These buffers are called inventories. One proposal calls for the governments of consuming countries to make greater use of strategic stocks to reduce price instability. Many European governments have embraced this idea.

The organization of this paper is as follows. Section I briefly discusses background events that have increased price volatility. Section II describes the role played by inventories in determining petroleum prices. This is an important issue that most economists have ignored. Consequently, the world is now facing its third "petro-recession" in 30 years.

Section III discusses the specific decisions taken by OPEC that have caused recent price increases. Section IV then examines the changing structure of the world petroleum industry, which has worked to support OPEC. The combined impacts of these two actions are behind the worldwide slowdown.

Surprisingly, governments of consuming countries could restrain price increases. As Section V discusses, these nations hold more than 1.2 billion barrels of oil reserves, which they can use to offset OPEC's attempts to drive prices higher. Properly deployed, these stocks could moderate the economic slowdown of 2001 and 2002. To date, however, they have not been used (except for one event where the Clinton Administration released oil at a time of high heating oil prices in the United States).

I. Background

Officials from oil-exporting countries, consuming countries, OPEC, and the International Energy Agency met in Riyadh, Saudi Arabia, in mid-November 2000 for a "Producer–Consumer Dialogue." The meeting received little note in the general press or even in the petroleum press because it occurred while all eyes were on the vote recounting in Florida for the US presidential election. The meeting was also ignored because the participants deliberately refused to address the only issues that intrigue investors: oil prices and OPEC production.

However, the gathering was important because what was said, and more significantly, what was not said, highlighted the fundamental incompatibility between the policy goals of major participants in world energy markets. Speakers at the conference (all officials of governments or international organizations) expressed a desire for price stability. Those who did not talk (officials of energy companies) would obviously have spoken of the need for good shareholder returns.

Saudi Crown Prince Abdullah kicked the meeting off with this pronouncement: "Price stability is the path that the Kingdom of Saudi Arabia wants to maintain, while stressing the importance of dialogue between producing and consuming nations to the benefit of all."[1] Robert Priddle, executive director of the International Energy Agency, warned, "We think the price should not be so high but the market is adjusting to the reality of the price." He also explained that today "the world has a slight surplus of crude oil, but because stocks are so low the market is tense."[2]

Separately, Priddle's agency offered a prescription for an ideal oil market in its November *Oil Market Report:*

> Supply should be relatively transparent and predictable. Producers can of course exert control over it should they choose to do so. Demand cannot be directly observed; it responds to climatic and economic events and is beyond collective control. What keeps the two ends of the fuel cycle connected is the ebb and flow of adequate stocks in producing countries, tankers, ports, pipelines, generating facilities, distribution, and gasoline stations. Market stability requires a longer view. Demand growth and the impact of timing, infrastructure, and processing requirements all need to be taken into account. Stocks need to build in advance of demand if instability is to be avoided. This is a formidable agenda for any "market planner."[3]

Unfortunately, Priddle, Crown Prince Abdullah, and the others at the meeting failed to seek the advice of another oil market participant: the private sector. Had they done so, they would have learned that executives of the world's largest companies had less concern for stable prices than for good shareholder returns. They also would have learned that these firms had concluded that good shareholder returns were more easily achieved if marginal refining assets were sold to smaller companies.

More significantly, the participants in the Riyadh meetings would have found that the supermajors, as well as smaller oil companies, all possess a laser-tight focus on cost

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[1] "Saudis Propose Permanent Producer/Consumer Secretariat," *Platts Global Alert*, November 17, 2000.
[2] "IEA Sees Sufficient Supplies, Tense Market," *Platts Global Alert*, November 16, 2000.
[3] *IEA Monthly Oil Market Report*, November 2000, p. 4.

minimization. Every executive, every manager, and every new hire would have explained to those attending the meeting that the most successful industry executives were those who achieved the greatest cost reductions. These representatives of private enterprise would also have told the gathered officials that such a finding should not be surprising: profitability in commodity businesses such as the petroleum industry can only be improved by achieving greater efficiencies. The punch line from the discussion would be quite simple:

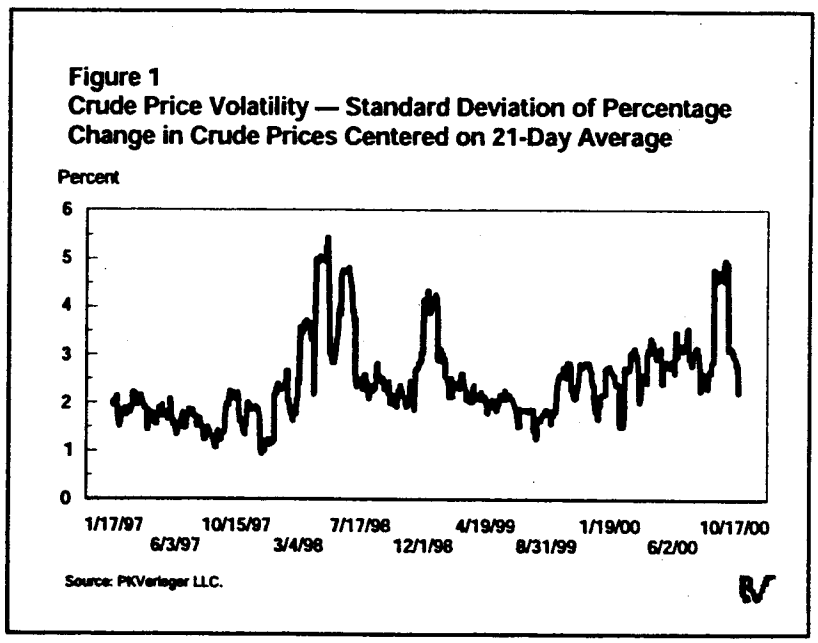
> Those companies that achieve the greatest reduction in inventories produce the best financial returns.[4]

In other words, the IEA recommendation that market participants hold larger inventories is utopian in today's deregulated market. The private sector will not do the bidding of OPEC or consuming governments on its own.

The Increase in Oil Price Volatility

In "Subterranean Homesick Blues," Bob Dylan sings, "You don't need a weatherman to know which way the wind blows." Today, one does not need a computer to know that oil price volatility has increased. Figure 1 traces one measure of the change. This figure shows the 21-day centered standard deviation in the percentage change of WTI crude prices. The data were derived by first computing the day-to-day change in the spot WTI price and then computing a 21-day average centered on a specific day.[5] Not surprisingly, the data themselves show substantial variance. However, two distinct trends can be observed. From January 1997 to May 1999, the average daily standard deviation is 2 percent. From May 1999 to the present, the average standard deviation is 3 percent. By this measure, price volatility has increased 50 percent.

Volatility has also increased according to a second measure: the number of days in which cash prices have increased or decreased by more than 1 percent. Between January 1997 and May 1999, prices rose or fell more than 1 percent in six days out of ten. This number rose to seven days in ten in the last eighteen months.



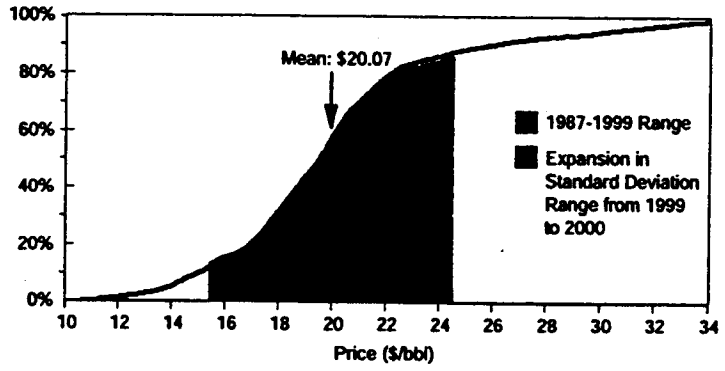
The increase in volatility has affected the cumulative distribution of oil prices. A year ago, this report found

[4] Imaginary advice from the private sector to those attending the Riyadh conference.
[5] For example, observations from October 13 to November 10 were used to compute the October 27 data point.

that the average WTI price was $19.36 per barrel and that the one-standard-deviation range above and below the mean (described as the "two-thirds" range) encompassed prices as low as $15.50 per barrel and as high as $23 per barrel. Over the last year, this range has increased, as can be observed from Figure 2. Today, the average is $20.07 per barrel, while the upper end of the range has risen to $24.68. The lower end of the range has remained unchanged.

The increase in prices and the increased volatility have affected economic activity across the globe. One year ago, economic forecasts polled by Consensus Economics Limited, a London-based consultancy, predicted that worldwide GDP would rise by 3.1 percent in 2001. A year later, their forecasts had been trimmed to 2.5 percent and were being marked down daily.[6] In many countries, higher energy prices caused in part by OPEC are credited for bringing about the slowdown.

Figure 2
Cumulative WTI Distribution — 1987 to 2000



Note: Shaded area represents the two-standard-deviation range of prices.
Source: PKVerleger LLC.

Two explanations can be offered for the increase in price volatility. First, oil-exporting countries have engaged in a concerted effort to squeeze inventory levels to minimum possible levels. Second, the oil industry has developed an allergy to stocks. In particular, merging companies seeking cost savings and synergies have aggressively sought to reduce inventory levels.

The next three sections examine the role of commodity markets, the role of OPEC, and the structural changes in the petroleum industry that have contributed to the current state of affairs.

[6] *Consensus Economics Forecasts*, March 2000 and March 2001, p. 28.

II. The Role of Inventories in Determining Oil Prices

Many competent studies have described the relationship between commodity inventories and the determination of commodity prices. Many high-quality analyses have also illustrated the fluctuation in petroleum inventories at both the national and the international levels. However, there have been few attempts, and no successful ones, to link stock levels and the fluctuations of petroleum prices to the economic factors that clearly determine them. Indeed, aside from the essentially accounting studies done by Roland[7] and the National Petroleum Council[8], no real analyses of petroleum inventories have been done.

This section attempts to fill the gap by applying the results presented in the literature on commodity markets to the petroleum market. This literature, which dates back more than 60 years, has not developed without controversy. Indeed, even today the debate rages on over why firms hold physical inventories at times when it is irrational to do so. The studies by Wright and Williams[9] and Brennan, Williams, and Wright[10] help clarify the seemingly illogical behavior of profit-maximizing firms. The results of their research provide the basis for the analysis of petroleum inventories presented in this paper.

Unfortunately, studies of inventories are devilishly complicated. Indeed, some of the papers attempting to describe inventory behavior make the mathematics used to put a rocket in orbit or to express the performance of a petroleum reservoir look simple. The complications occur because of two characteristics that make the storage of a physical commodity different from other assets. These are 1) the non-negativity condition, and 2) the apparent similarity between physical commodities and other financial assets.

The non-negativity condition can be stated quite simply. It is possible to lend physical commodities to the future, but it is impossible to borrow against future production if inventories are exhausted. Whereas societies can borrow money from the future (for example, the US Social Security system), society cannot borrow food from the future. If the grain elevators are empty, consumers must eat something else or starve. The non-negativity condition introduces discontinuities into the behavior of physical markets that are not observed in financial markets. The discontinuities occur at particularly awkward times, usually when storage is filled to capacity or empty.

The apparent similarity between physical commodities and financial assets has led many economists and some misguided corporations to predict the behavior of markets for physical commodities as if they were markets for other assets. This approach is incorrect. The problem occurs because the arbitrage process can be time-consuming. Physical commodities stored at location "A" cannot always be moved instantaneously to location "B." Indeed, transportation is

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[7] Heather Roland, *How Much Oil Inventory Is Enough?* (New York: Energy Intelligence Group, 1997).
[8] National Petroleum Council, *Petroleum Storage & Transportation* (Washington: National Petroleum Council, 1989), and "Draft Report Prepared for the National Petroleum Council's Committee on Petroleum Supply" (Washington: National Petroleum Council (mimeo), 1998).
[9] Brian Wright and Jeffrey C. Williams, "A Theory of the Negative Prices for Storage." *Journal of Futures Markets* 9, No. 1 (February 1989): 1–13.
[10] Donna Brennan, Jeffrey Williams, and Brian D. Wright, "Convenience Yield without the Convenience: A Spatial-Temporal Interpretation of Storage under Backwardation," *Economic Journal* 107, No. 443 (July 1997): 1009–1022.

often quite slow. Arbitrage is further complicated by differences in the types of commodities. In this report, this situation is referred to as the "imperfect arbitrage" condition.

The non-negativity and imperfect arbitrage conditions play very important roles in determining all commodity prices. The works by various academics noted here strive to elucidate these roles, and this paper attempts to extend them to petroleum.

Section I.1 briefly discusses the role of inventories in determining prices. This analysis is drawn from a number of academic papers extending from 1930 to the present. Section I.2 demonstrates how the analyses developed for other commodity markets (presented in Section I.1) apply to the oil market.

In Section I.3, the results presented in Section I.2 are compared to studies of the petroleum inventories developed by the National Petroleum Council and Roland. These studies, generally considered to represent the best information available to the public, contain kernels of information that support the basic conclusions regarding petroleum markets developed in Section I.2. Section I.4 concludes.

II.1 The Economic Role of Inventories

The business practice of holding inventories of physical commodities has created problems for economists for centuries. Under the conventional economic model, profit-making firms should not act in any way that deliberately leads to losing money. Yet, businesses regularly store inventories of physical stocks, even when it is apparent that far greater profits could be earned from the immediate sale of goods. This practice is observed in the manufacture of physical goods such as automobiles, grains, other foodstuffs, and petroleum.

Often, the action of holding stocks is explained by the need to ensure a continued flow of product and avoid disruptions. Difficulties in obtaining physical supplies of raw materials have created a need for inventories in many industries. This explanation has been accepted for ages. Even so, inventory-holding practices continue to puzzle theorists.

The commodity receiving the greatest attention has been cash. Theory suggests that no economic agent should hold deposits in a bank account if the bank charges the agent a significant amount to be the custodian. The rationality of this conclusion has strengthened as the speed at which funds can be transferred has increased. Yet, economic agents do hold bank deposits, even though this action costs them money. In fact, *Financial Times* recently reported that Japanese firms are depositing funds with banks that are charging them negative rates of interest.[11]

Sixty years ago, John Maynard Keynes[12] attempted to explain this phenomenon in *The General Theory of Employment, Interest, and Money.* In this study, Keynes identified three types of currency demand: transactional, precautionary, and speculative. According to his theory, economic agents hold transactional balances to meet the day-to-day requirements to pay bills,

[11] *Financial Times*, November 6, 1998, p. 1.

[12] John Maynard Keynes, *The General Theory on Employment, Interest, and Money* (1936). In Austin Robinson and Donald Moggridge (eds.), *The Collected Writings of John Maynard Keynes.* Cambridge: The Cambridge University Press, 1970.

salaries, etc. In addition, agents hold precautionary cash balances, despite the fact they earn no interest, out of caution or to avoid risk. These balances can be used to meet unexpected emergencies. Finally, agents hold speculative balances when the economic incentive (i.e., interest rates) makes it worthwhile to do so.[13]

The Keynesian explanation survived for several decades. Indeed, many textbooks on monetary economics still refer to the three classifications of cash balances.

Williams extended this explanation to physical commodities.[14] In *The Economic Function of Futures Markets*, he offered three specific explanations for holding inventories when the financial incentive for this action is absent. These are the *transactions demand* for inventories, the *precautionary demand* for inventories, and the *speculative demand* for inventories. Precautionary demand is created by uncertainties associated with production, deliveries, and other operational considerations. The transactions demand for stocks is analogous to the transactions demand for cash, that is, stocks are necessary to conduct operations and maintain production. Another term for transactions demand could be "minimum operating levels." Speculative demand is an opportunistic demand: stocks are held to be sold at a profit.[15]

Williams also introduced the concept of "demand for accessibility." He explained as follows:

> In the case of commodities, the costs of converting other assets into the desired one are substantial. A miller in an isolated location whose regular flow of receipts is interrupted has few and imperfect substitutes for wheat in his own warehouse.[16]

Williams continued, "Because of the trouble getting money or wheat quickly, people and firms make sure they have a ready supply."[17] Ready supply is created by stocks.

Williams postulated that the price of access is a declining function of the amount stored. In other words, the marginal value of stocks as a palliative for risks associated with access declines as stocks increase. This relationship contributes, in his view, to the shape of the supply-of-storage function.

Williams also catalogued the ways in which a firm can acquire access. Among these are 1) obtain a line of credit at a nearby warehouse, or 2) borrow the commodity. The line of credit allows the company to acquire the commodity from the warehouse at the prevailing price. Alternatively, a firm borrowing the commodity takes possession of the good and agrees to return it later at a fixed price. (This is also called "short hedging."[18])

In applying Keynes' explanation for the holding of physical stocks using Keynes' theory of the demand for money, Williams in effect refined an incomplete theory put forward earlier by Keynes. In 1930, Keynes introduced his inventory demand theory to explain the behavior of manufacturers and processors who, he observed, held inventories of raw materials when it was

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[13] Keynes (1936), p. 195.
[14] Jeffrey Williams, *The Economic Function of Futures Markets* (Cambridge: Cambridge University Press, 1986).
[15] Williams (1986), p. 112–123.
[16] Williams (1986), p. 127.
[17] Williams (1986), p. 128.
[18] Williams (1986), p. 129.

not profitable to do this. In that study, Keynes advanced several explanations for why firms might take this action absent a financial incentive. First, he suggested that companies needed to pay speculators to take long positions in markets. Noting that inventories of commodities were held when markets were in "backwardation" (a condition where the cash price exceeds the futures price), he stated the following:

> But it is not necessary that there should be an abnormal shortage of supply in order that a backwardation should be established. If supply and demand are balanced, the spot price must exceed the forward price by the amount which the producer is ready to sacrifice in order to "hedge" himself, i.e., to avoid the risk of price fluctuations during his production period. Thus in normal conditions, the spot price exceeds the forward price, i.e., there is a backwardation. In other words, the normal supply price on the spot includes remuneration for the risk of price fluctuations during the period of production, whilst the forward price excludes this. The statistics on organized markets show that 10 percent per annum is a modest estimate of the amount of this backwardation in the case of seasonal crops which have a production period approaching a year in length and are exposed to all the chances of weather.[19]

This paragraph has led to the term "normal backwardation," a phrase that one finds discussed frequently in texts and articles on futures markets.

However, backwardation cannot exist in markets at all times. Indeed, in instances where inventories rise to excessive levels, Keynes concluded that stocks would be sold if spot prices exceeded futures prices. Consequently, Keynes reasoned, the market would have to shift into contango (a condition where cash prices are less than futures prices). However, even in this case Keynes suggested that producers would still need to pay speculators to take a long position.

> But the existence of a contango does not mean that a producer can hedge himself without paying the usual insurance against price changes. On the contrary, the additional element of uncertainty introduced by the existence of stocks and the additional supply of risk bearing which they require mean that he must pay more than usual. In other words, the quoted forward price, though above the present spot price, must fall below the anticipated future spot price by at least the amount of normal backwardation, and the present spot price, since it is lower than the quoted forward price, must be much lower than the anticipated future spot price. If the stocks are expected to be absorbed within a year, the present spot price must fall (say) 20 percent below the anticipated future spot price, but if the stocks look like lasting for two years, then the present spot price must fall (say) 40 percent.[20]

The concept of commercials having to pay to hedge has led economists to coin the term "convenience yield." Working discussed this concept in his analysis of industry practices of holding inventories.[21] Noting that the relationship between two futures provides a useful instrument for deterring costs, Working wrote the following:

> In any case, the known relation between prices of two futures gives the hedger a basis for anticipating his return for storage which is far superior to any estimate which could be

[19] Keynes (1930), p. 128.
[20] Keynes (1930), p. 129.
[21] Holbrook Working, "The Theory of the Price of Storage," *American Economic Review* 48 (1949): 1254–1262.

> made in the absence of a good hedge in a futures market or an outright forward sale of the actual wheat.[22]

This relationship is referred to as the cost of storage.

> A known return for storage is, in essentials, a price of storage. The fact that the price of storage is not quoted directly, but must be derived by taking the difference between quoted prices of wheat for two different dates of delivery is immaterial for the economic reasoning.[23]

The problem for Working was the negative spread, or "when the price for delivery is below the 'nearer' price."[24] Negative spreads bothered Working as much as the holding of bank balances troubled Keynes.

Working suggested several explanations for the practice of holding inventories. One of the answers offered was that storage is an enterprise where operating costs are fixed. Furthermore, Working noted that the costs are joint because "owners of large storage facilities are mostly engaged either in merchandising or in processing, and maintain storage facilities largely as a necessary adjunct to the merchandising or processing business."[25] In this case, costs of storage may be charged against other operations. "For any such potential supplier of storage, stocks of a commodity below some fairly well recognized level carry what Kaldor has aptly called a *convenience yield.*"[26] As used here, the term "convenience" refers to the convenience or support provided to processing businesses by inventories.

On Convenience Yields

The study of convenience yields *has* dominated one portion of the literature on the relationship between cash and futures markets for thirty years. Every issue of the *Journal of Futures Markets* (which appears six times per year) seems to contain at least one article on the subject, and countless other writings on it have appeared in various journals of finance.

In a classic article on the supply of storage, Brennen[27] used the term "convenience yield" to explain the decision to hold stocks:

> The convenience yield is attributed to the advantage (in terms of less delay and lower costs) of being able to keep regular customers satisfied or of being able to take advantage of a rise in demand and price without resorting to a revision of the production schedule.[28]

He went on to note the following: "The smaller the level of stocks on hand the greater will be the convenience yield of an additional unit. It is assumed that there is some quantity of stocks so large as the marginal convenience yield is zero."[29]

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[22] Working (1949), p. 1257.
[23] Working (1949), p. 1258.
[24] Working (1949), p. 1259.
[25] Working (1949), p. 1260.
[26] Working (1949), p. 1260.
[27] Michael J. Brennen, "The Supply of Storage," *American Economic Review* 47, No. 1 (1958): 50–72.
[28] Brennen 1958, pp. 53–54.

Brennen used changes in convenience yields to explain the holding of inventories. Specifically, he correlated changes in convenience yields with changes in inventory levels.

Years later, Larson used more elegant econometric techniques in an attempt to find convenience yields.[30] In a World Bank study, he investigated the persistent and continuous backwardation in copper, noting, "These market conditions are in direct violation of frequently used price arbitrage conditions which maintain that storage only occurs when the price of storage is positive." His investigation was conducted using a generalized price-arbitrage condition related to the value of inventories in the future. As a result of his analysis, Larson suggested that inventories can be held even when returns are negative because they produce a *convenience yield* and because market responses to demand shocks are asymmetric when inventories are low.

Larson found little evidence, however, of a convenience yield for copper. Instead, he found strong evidence for the asymmetric effect.

> Just as the price of a call option contains a premium based on the underlying variability of prices, the shadow price of copper inventories contains a premium based on the variability of the unplanned component of inventories. When inventory levels are low, the value of the premium increases to the point where certain levels of inventories will be held even in the face of a fully anticipated fall in price.[31]

The asymmetric effect is further explained by Larson, who noted that when inventories are low, an unanticipated positive shift in the demand schedule causes large price increases.

> While a negative shift may be just as likely, the effect on price is not symmetric. This skews the distribution of potential price outcomes toward higher prices and generates a dispersion premium.[32]

In other words, inventories are not held because they offer the potential of a flow of services but because they may provide speculative profit. This conclusion might be seen as a confirmation of Williams' theory of the "speculative" holding of stocks.

In their earlier study, Fama and French[33] took the issue a step further, attempting to determine whether expected future prices or convenience yields explain the holding of stocks.

> There are two popular views of commodity futures prices. The theory of storage of Kaldor (1939), Working (1948), Brennen (1958), and Telser (1958) explains the difference between contemporaneous spot and futures prices in terms of interest foregone in storing a commodity, warehousing costs, and a convenience yield alternative. The

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[29] Brennen (1958), p. 54.
[30] Donald F. Larson, "Copper and the Negative Price of Storage," *Policy Research Working Paper 1282* (Washington: The World Bank, 1994).
[31] Larson (1994), p. 59.
[32] Larson (1994), p. 60.
[33] Eugene F. Fama and Kenneth R. French, "Business Cycles and the Behavior of Metals Prices." *Journal of Finance* 43, No. 5 (December 1988): 1075-1093.

alternative view splits a futures price into an expected risk premium and a future spot price.[34]

The results of this statistical analysis are mixed. For precious metals, such as gold and silver, the alternative specification works well. For physical models, the convenience yield appears to fit better.

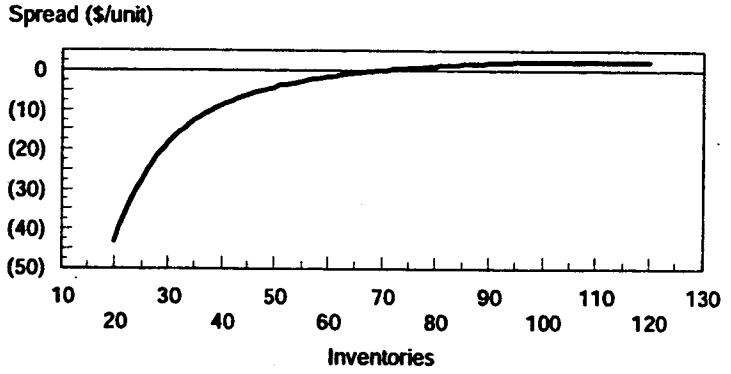
Other analytical attempts had similar results. The bottom line is that there is a linkage between inventories and spreads for physical commodities such as oil and precious metals. However, the idea of a convenience yield does not seem to apply to physical commodities.

The Inverse Relationship between Stocks and Spreads

Whether businesses hold stocks when it would pay to dispose of them because the stocks offer a convenience yield or for some other reason, the empirical evidence is clear — there is a negative relationship between inventories and spreads. The basic relationship, first introduced in Working's 1949 paper, is shown in Figure 3.

Figure 3 shows an inverse relationship between inventories (shown on the horizontal axis) and the spread (futures prices less cash prices and costs) shown on the vertical axis. When done correctly, the spread is calculated as the price that would be received in a future period less the cash price of the commodity *plus* all the factors related to the activity of storing the commodity from one period to the next. These factors include the following:

Figure 3
Theoretical Supply-of-Storage Curve —
Relationship between Inventories and Price Spreads



Source: Jeffrey C. Williams, The Economic Function of Futures Markets (Cambridge: Cambridge University Press, 1986).

- The time value of money (interest on the money invested in the inventory that could have been earned if the stocks had not been purchased)
- Storage costs (monies spent on physically holding the commodity, moving the commodity into and out of storage, insurance costs, and other out-of-pocket expenditures)
- Shrinkage (expected losses from deterioration, spoilage, or other factors affecting the quality of the commodity being held)

[34] Fama and French (1987), p. 55.

Working demonstrated the linkage for a few agricultural commodities. Brennen provided more evidence for a group of 15 commodities, mostly agricultural. Results published by Fama and French provide similar confirmation for a group of commodities. Finally, Cho and McDougal[35] produced results for petroleum that confirm the existence of a supply of storage in this industry.

In the last ten years, Williams and Wright published two papers that question the entire concept of convenience yields as an explanation for holding stocks at apparent financial losses. In a paper entitled "A Theory of the Negative Prices for Storage," they belittled the theory by noting the following: "Convenience yield as the explanation of storage at inverse carrying charges has not been analyzed beyond demonstration of its plausibility with brief examples related to the behavior of individual processors."[36] The authors then demonstrated that it is rational for producers to hold stocks of intermediate goods such as crude oil under certain conditions.

The basis of the Williams and Wright findings has to do with geographical aggregation. As they noted, "Observation of storage under backwardation is an aggregation phenomenon. As disaggregation proceeds, the expected rate of change of the price of each subaggregate with positive stocks tends towards full carrying charges."[37]

Wright and Williams continued by showing that it is also rational to hold intermediate stocks used to produce finished goods if the cost of transformation of the intermediate good increases with the amount transformed. This increased cost can be explained by technologies or by the fact that one mode of transportation is less costly than another.

> Very often it is cheaper to transform a particular amount if the transformation is done more slowly. An obvious example is shipping by water instead of by airfreight. Another example is the lower transactions cost associated with a seller's less hurried search for a buyer. Such lower costs to slower transformation can lead to the appearance of continuous storage whenever the subaggregate of goods in process is included in the stocks of the aggregated commodity, as when goods in transit are included in visible supply.[38]

Finally, Wright and Williams noted that trade or competition is essential for storage to occur. They explained that an assumption in Telser[39] of nonlinear transformation costs is not sufficient to justify storage of an intermediate good with backwardation in the finished good market. In addition, there must be an expected supply of the intermediate good from other sources, such as imports.

Wright and Williams offered three conclusions from their analysis concerning the holding of inventories when markets are in backwardation.

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[35] Dong W. Cho and Gerald S. McDougal, "The Supply of Storage in Energy Futures Markets," *Journal of Futures Markets* 10, No. 6 (December 1990): 611- 621.
[36] Wright and Williams (1989), p. 1.
[37] Wright and Williams (1989), p. 2.
[38] Wright and Williams (1989), p. 6.
[39] Lester G. Telser, "Futures Trading and the Storage of Cotton and Wheat," *Journal of Political Economics* 66 (1958): 541–65.

> The first is the importance of nonlinearities or intertemporal shifts in technology whether the technology concerns transporting, processing, or merchandising commodities. The phenomenon of storage at an apparent opportunity cost can arise because the activities are more inflexible in the short run than in the long run, or are unusually costly in the short run.[40]

> The second lesson is that storage at an apparent opportunity cost can arise because commodities normally lumped together are actually different and are held apart by the cost and timing of transforming them into one another. This is true even in a world with perfect foresight; uncertainty, let alone risk aversion, is not necessary for observing aggregate storage at inverse carrying charges.[41]

> A third lesson is that distortions in commodity markets, such as export subsidies or strategic petroleum reserves, change the relationship between the amount stored and backwardation.... Public stockpiles distort not only the total quantity of private storage but also the location and grades of private stocks.[42]

In another paper, Brennan, Williams, and Wright offered empirical evidence to validate Williams and Wright by showing that the relationship is not the result of a financial factor but rather, fundamentally, the result of the fact that conducting instantaneous arbitrage with physical commodities is impossible. In a short paper with a terribly long title ("Convenience Yield without the Convenience: A Spatial-Temporal Interpretation of Storage under Backwardation"), the authors demonstrated that logistical considerations associated with moving grain inventories from various regional elevators to the port of exportation generate a supply-of-storage relationship without the financial incentive associated with the convenience yield.

Brennan, Williams, and Wright (BWW) began by noting that economists were perplexed by two phenomena. These were first that nationwide stocks were held even when the intertemporal spread for delivery at Chicago was negative, and second, that the amount held was sensitive to the spread. They suggested that the concept of the convenience yield was created to resolve the problem and quote Telser as the explanation:

> [Why is it] necessary to introduce the concept of convenience yield to explain the holding of stocks? Why is it not sufficient to consider only the marginal cost of storage? The answer lies in the fact that stocks are held even when prices are expected to fall.[43]

BWW noted that discussions of yield other than the possible gains from appreciation in the value of the stock have been traced to "opportunity yield," "accessibility," "liquidity," "option value," or "option profit." Two assumptions are necessary for these opportunities to be available. They are the presence of risk and nonlinearity in the individual firm's marketing or processing. The authors cited suggestions by Ramey[44], who postulated that inventories provide a flow of service,

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[40] Wright and Williams (1989), p. 12.
[41] Wright and Williams (1989), p. 12.
[42] Wright and Williams (1989), p. 12.
[43] Telser (1958), p. 23, as quoted in Brennan, Williams, and Wright (1997), p. 1009.
[44] Valery A. Ramey, "Inventories as Factors of Production and Economic Fluctuations," *American Economic Review* 79 (1989): 338–54.

and Pindyck[45], who concluded that "the convenience yield that accrues to the owner of a commodity is directly analogous to a dividend" on an equity.[46]

BWW showed that these two assumptions are not required. The authors used a spatially dispersed model of shipments and storage by location to model shipments of grain from elevators located near farmers to grain elevators located at ports. With this model, they derived a relationship that duplicates the relationship observed by Working. "The mystery of the supply-of storage curve," they suggested, "can be explained as a phenomenon of aggregation over space, quality, or form without recourse to conjecture that it derives from customers' good will, uncertainty, risk aversion, or nonlinearities in costs other than those implied by system-wide capacity constraints."[47]

In their model, BWW described how firms will hold inventories of raw materials such as wheat or oats under those circumstances where markets for products such as bread are in contango and the costs of converting the products are nonlinear. These nonlinearities can occur because costs of production rise (for example, overtime must be paid or productivity declines) or because the costs of transportation rise with increased shipments.

BWW described another situation where inventories of wheat are held in elevators located in rural areas of Australia where the production is first stored, as well as in coastal facilities where they are exported. Operators of many rural storage facilities will have two or more ways to move wheat to the export locations — for example, either via a slow, narrow-gauge train or a fast, standard-gauge train. It is less expensive to transport by slow train than by fast train. Furthermore, costs will differ by location, with the operators of the most distant elevators paying higher transportation costs than operators of elevators located closer to the point of exportation.

BWW showed that elevator operators would use the lower-cost transport modes when markets are in contango or modest backwardation. However, as backwardation increases, operators would shift to fast trains so that they could obtain the higher spot price. First, the elevators located close to the export point would shift. Then, as backwardation increases, those with larger and larger transportation differentials would shift.[48] The effect is to generate a supply-of-storage curve without any consideration of convenience yield.

A Missing Element

Up to this point, the analysis of commodity markets has ignored changes in either contemporaneous or future supply and demand. Indeed, when one thinks about it, the analysis of the role of futures prices in determining demand today compared to demand tomorrow is

[45] Robert Pindyck, "Inventories and the Short-Run Dynamics of Commodity Prices," *RAND Journal of Economics* 25, No. 1 (Spring 1994): 141–159.
[46] Pindyck (1994), p. 512.
[47] Brennan, Williams, and Wright (1997), p. 1011.
[48] An example may help here. Consider the situation of two elevators. The first elevator operator pays $1 per bushel to move grain by slow train and $2 to move grain by fast train. The second operator, located further from the market, pays $4 for the slow train and $8 for the fast train. If the market is in contango, both operators will use the slow train. If the backwardation increases to $3 per bushel, the first operator will use the fast train, while the second operator will use the slow train. If the backwardation exceeds $8 per bushel, both operators will use the fast train. If inventories are examined at a point of time, one will observe a supply-of-storage curve with inventories held in the field declining as backwardation increases.

curiously absent, as is the analysis of contemporaneous supply versus future supply. While the models are extraordinarily elegant and dynamic regarding the determinants of spreads, there apparently is no place for either a *ceterus paribus* (other things being equal) change in either supply or demand. Yet, such shifts do occur and do have consequences.

Consider, for example, the market for a single petroleum product — distillate fuel oil. At every instant, there is demand for product today and a demand for product to be delivered in the future. Demand today is determined by such factors as income (GDP), prices, and weather. Current demand for the future is determined by expectations regarding future income, future prices, weather, and other factors. Contemporaneous supply is determined by the price, raw material (crude oil) costs, production possibilities, etc. Supply for the future today is determined by expectations of these factors for the years to come.

Now suppose there is an exogenous increase in future demand for distillate fuel oil today. Such an increase might occur because a group of disinterested investors (speculators or hedge funds) has decided to reallocate portfolios, increasing their purchases of distillate fuel oil. Alternatively, a large consumer (a railroad or an airline) may have decided to make a large purchase of distillate for future delivery, effectively locking in the cost of the raw material.

In either event, the exogenous shift in demand for product to be delivered in the future *today* will have a number of effects on the market. Among the potential changes are the following:

- Initially, the increased demand will push up prices in the future. Because future supply does not change, forward prices will rise.

- The rise in forward prices will be reflected in an increase in the spread between cash and futures prices. The increase in the spread could have several impacts.

    1. First, firms holding inventories of distillate fuel oil today may decide to defer sales from inventories, *transferring* product from the current period to the future period. Presumably, such a decision will be reflected in increased sales in the future. Such an action will cause spot prices to increase, while causing prices quoted today for delivery in the future (future prices) to decrease.

    2. Alternatively, the increased spread may spur firms to boost output in the current period, with the incremental production being stored. This production would presumably be sold in the forward market, depressing the price for future product quoted today, which would decline back toward but not to the initial level.

    However, the story does not end with either of these actions. Whether production is shifted or increased, the action will affect other decisions regarding contemporaneous supply and demand for crude oil and products.

        Under the first alternative, the rise in the spot price of distillate fuel oil would presumably lead to increased production by other parties. The increased production would be reflected in an increased demand for crude oil and higher contemporaneous crude oil prices.

The increased demand for crude oil could be met from inventories (because the spread between spot and futures crude prices had changed) or from increased purchases. Prices of crude for future delivery would be expected to increase if the demand were met from inventories.

Under the second alternative, the story is essentially the same. Increased processing would require increased purchases of crude oil and crude markets would respond.

- As complicated as this one simple change in *ceterus paribus* demand seems, there are many other alternatives. For example, the rise in prices for distillate quoted today for future delivery could prompt some firms to sell distillate for future delivery. The shift in the supply curve would offset the rise in the demand curve. These firms could then either

  Enter contracts for the delivery of crude oil in the future, effectively increasing the spread between spot and futures prices for crude, or

  Purchase crude oil supplies in the market, adding them to inventories for future processing.

  Either transaction changes the supply-and-demand balance in both the contemporaneous crude market, where supplies are traded for delivery today, and in the futures crude market, where supplies to be delivered in the future are traded today.

  The purchase of crude oil today for future processing removes supply from the market today and causes prices charged for cash supplies to rise.

  The purchase of oil to be delivered in the future raises the spread between futures and cash prices, causing one or more parties to increase inventories, thereby reducing deliveries today and causing cash prices to rise.

Without belaboring the point further, random exogenous shifts in either contemporaneous supply or demand for products will affect cash prices for products delivered today, prices quoted today for the future supply of product, cash prices for crude oil today, and prices quoted today for the future delivery of crude oil.

These linkages work their way through the Williams and Wright analysis in a number of subtle ways. For example, Williams and Wright demonstrated that firms might hold inventories of a raw material in some geographical locations when markets are in backwardation because it is less expensive to hold stocks near the point of processing. Their analysis also predicted that some stocks of finished products might be held at distant locations under certain conditions. Inventory levels change when spreads between cash and futures prices change. Thus, a *ceterus paribus* increase in contemporaneous demand may result in cuts of product inventories held at the point of consumption or at a more distant point, as well as changes in crude inventories.

Application to Petroleum

The theoretical models developed by Williams and Wright, and Brennan, Williams, and Wright have a number of direct applications to the petroleum industry. In particular, their conclusions

that firms will hold inventories of raw materials even when raw materials markets are in backwardation and the transformation process is nonlinear is directly applicable to crude oil. For example,

- Crude oil inventories will be held at refineries despite backwardation in crude markets because the costs associated with a stockout are extremely nonlinear.[49]

- Crude oil inventories will be held at terminals near refineries and distant from the point of production because the costs of moving inventories at a regular rate by ship or pipeline are much lower than the costs of moving them by a faster mode of transportation (such as trucks, fast ship, or barge) if the faster mode of transportation is available.

On the other hand, the amount of crude inventories held at refineries or at terminals such as Cushing or Rotterdam will decline as backwardation increases because the costs of alternative modes of operation or shipping are fixed. Thus, as backwardation increases, the economic justification for holding stocks either at terminals or at refineries declines. Indeed, one can imagine a situation where the market might offer a financial incentive of sufficient magnitude that a refiner would maximize throughput and take the risk that it would exhaust stocks, thereby necessitating a shutdown before additional crude arrived.

The situation that would create the incentive to risk a stockout would most likely occur when product markets are in extreme backwardation. For example, some refiners might risk running out of crude inventories if prompt heating oil were selling for $40 per barrel, while one-month-forward product could only be sold for $20 per barrel. Under these circumstances, some refiners might maximize throughputs despite the risk that they could be forced to shut down in the next week or month. Such circumstances may have occurred in the US market in December 1989.

The circumstances regarding product markets appear different. There is essentially no financial incentive for a firm to hold inventories of products when markets are in backwardation. However, this does not imply that a firm should instantaneously liquidate its inventories because costs are again nonlinear. A Gulf Coast refiner holding distillate stocks intended for distribution in the East Coast heating market would not, for example, normally pay extra fees to move these stocks to the East Coast if the market shifted into backwardation. Instead, the product would be moved as rapidly as possible by pipeline, barge, or ship. However, under certain circumstances, such as an extreme period of cold weather or the disruption of production at a critical refinery, firms would be willing to consider using modes of transportation that move the product from the Gulf to the East Coast more quickly.

Conclusions Regarding Theory

The relationship between the shape of the forward price curve and inventories has been a subject of debate in the economic literature for more than six decades. Economists have advanced a number of theories to explicate the phenomenon. Many of these studies have attempted to explain and justify the "convenience yield" first attributed by Kaldor to inventories. Convenience

[49] A refiner running out of crude would be confronted with the large fixed costs of shutting facilities down in a hurry. The costs of such unanticipated and unplanned shutdowns are much greater than the costs of continuing to operate on a scheduled basis.

yield is the amount a firm would theoretically be willing to pay to hold a unit of inventory when financial markets would dictate that no stocks be held.

An explanation offered by Wright and Williams is implicitly more satisfactory. Convenience yield is, according to these authors, an artificial phenomenon that results from aggregation over regions and over time. In the absence of this aggregation, Williams and Wright suggested that convenience yields would not be observed. Brennan, Williams, and Wright demonstrated that a supply-of-storage curve and convenience yields can be generated in a model of spatial storage with differential transportation costs, where there is no such thing as a convenience yield.

All the analyses, however, are incomplete in a sense because they do not incorporate changes in the demand for or supply of commodities in either the present or the future. Spreads and inventories are linked together, but the effects of sudden changes in demand or supply are not accommodated.

II.2 Empirical Evidence for Petroleum

The theoretical analysis presented above offers certain predictions for petroleum markets. The first is that price spreads will be more closely correlated in the market where delivery occurs. The second prediction is that inventories should generally be higher when markets are in contango than when they are in backwardation. The third prediction is that inventories should tend to increase when markets are in contango, while decreasing when markets are in backwardation.

The first prediction is relatively obvious. In markets such as petroleum where geographic arbitrage requires time, the risk of holding stocks in locations removed from the point where transactions occur is greater than the risk associated with holding stocks at the point where delivery can occur.[50] Data for crude oil inventories and distillate inventories held in or near the delivery location do show a greater correlation with spreads on these products than do data for products stored at locations that are more distant.

Table 1 shows the correlation of four spreads, labeled second through fifth, with weekly inventories as reported by the API. The table is divided into sections for crude oil, distillate fuel oil, and gasoline. The columns show the result for the correlation between the inventories shown on a specific row and the spread between the futures prices. For example, the correlation between national crude oil inventories and the second crude spread (second futures less cash) is 0.128, while the correlation between crude inventories held in PADD V and the fifth spread (fifth future less cash) is 0.037.

Examining Table 1 reveals that the correlation for crude oil inventories and spreads is greatest in PADD II, the location where delivery occurs for crude oil. The results for products are more ambiguous.

[50] In the case of the petroleum markets, delivery of light intermediate crude under the New York Mercantile Exchange contract occurs in Cushing, Oklahoma, while gasoline and distillate are delivered in New York. Delivery on Brent forward contracts occurs in the North Sea, while delivery under the International Petroleum Exchange's gasoil contract occurs in Rotterdam.

Table 1. Correlation between Inventories and Price Spreads for Four Contracts

Crude Oil, 1988 to 1998

Region	Second	Third	Fourth	Fifth
USA	0.128	0.127	0.117	0.105
PADD I	0.023	0.020	0.020	0.020
PADD II	0.294	0.315	0.309	0.296
PADD III	0.180	0.188	0.175	0.160
PADD IV	0.087	0.089	0.084	0.079
PADD V	0.021	0.030	0.034	0.037

Distillate Fuel Oil, 1988 to 1998

Region	Second	Third	Fourth	Fifth
USA	0.135	0.096	0.042	0.009
PADD I	0.141	0.104	0.046	0.010
Post 1990				
USA	0.208	0.141	0.058	0.011
PADD I	0.207	0.144	0.060	0.011

Gasoline, 1988 to 1998

Region	Second	Third	Fourth	Fifth
USA	0.249	0.224	0.172	0.118
USA (Unleaded)	0.255	0.258	0.227	0.191
PADD I	0.237	0.179	0.122	0.081

Source: PKVerleger LLC.

In particular, the results for gasoline are poor. The correlation between spreads and stocks is low, with no apparent advantage in New York. The change in specifications of gasoline may explain the lower correlation. Specifically, the introduction of reformulated gasoline at the end of 1994 may have distorted statistical relationships. Limiting the correlation period to the last three years (1996 to 1998) improves the correlation and confirms the first proposition (see Table 2).

Table 2. Correlation between Gasoline Inventories and Price Spreads for Four Contracts, 1996 to 1998

Region	Second	Third	Fourth	Fifth
USA	0.494	0.464	0.379	0.300
USA (Unleaded)	0.453	0.431	0.357	0.286
PADD I	0.340	0.301	0.226	0.175

Source: PKVerleger LLC.

The second proposition is that inventories should be positively correlated with spreads. The statistical results shown in Tables 1 and 2 confirm this hypothesis. Spreads and inventories always have the expected relationship. This may seem surprising in the case of fuels such as distillate, which experience a strong seasonal pattern of demand. In such instances, one might expect to observe an increase in inventories in the summer even if spreads are negative.

In fact, the expected relationship holds. In the months before peak demand, markets shift into contango and inventories increase. In the months following periods of peak demand, markets shift into backwardation and stocks decline.

Table 3 shows the frequency with which the observed relationship occurred. For example, one can note that inventories of distillate increased 77 percent of the time when spreads were increasing, while decreasing in 54 percent of the cases where spreads fell. This table provides an empirical test of the proposition advanced by Brennan, Williams, and Wright. It may be recalled that these three authors demonstrated that elevator operators in Australia would move inventories more rapidly to the seacoast as spreads increased. In a similar ways, one should expect that refiners and oil companies would do the same, reducing stocks more aggressively as spreads expanded.

The empirical analysis of markets for petroleum products and crude oil confirms the results put forward by the academics. A regular relationship between inventories and price spreads can be observed. Furthermore, this relationship works better in the markets were delivery is required, i.e., New York and Cushing.

Table 3. Frequency of Inventory Increases when Markets are in Contango and Inventory Decreases when Markets are in Backwardation

	Crude	Distillate	Gasoline
Contangos	244	358	229
Stock Increase in Contango	140	191	132
Stock Increases	293	247	267
Frequency of Stock Increases with Contango (%)	47.8	77.3	49.4
Backwardations	271	191	320
Stock Decrease in Backwardation	164	133	183
Stock Decreases	271	244	280
Frequency of Stock Decreases with Backwardation (%)	60.5	54.5	65.4

Source: PKVerleger LLC.

A similar analysis cannot be performed at this point for either the European gasoil market or the Brent market because data on inventories are not available. Such an analysis may be performed in the future if this situation changes.

However, it should be noted that the structure of the Brent market complicates the analysis. The complication occurs because contracts for delivery in the Brent market require that the buyer or the seller take or make delivery at Sullom Voe, where storage is unavailable. This absence of storage makes it possible for market participants to squeeze the Brent market in just the way electricity markets in the United States were squeezed last summer.[51]

Statistical estimates of supply-of-storage curves for WTI, distillate, and gasoline are provided in Table 4.

[51] In a way, the Brent market is identical to an electricity market because neither market has storage. In June, spot electricity prices rose twenty fold ("New Rules Blamed for Power Shortages," *The Wall Street Journal*, July 24, 1998, p. 2) when some suppliers were unable to perform on their contracts. In the same way, the Brent market will periodically rise when one or more buyers obtains control over a large number of forward delivery contracts and demands delivery, forcing prices up sharply. Because there is no storage at Sullom Voe, there are no inventories to be drawn down and accordingly there would be no upper limit to prices.

Table 4. Results of Econometric Estimation of Supply-of-Storage Relationship

	Inventory Variable	Coefficient of Multiple Correlation (R^2)	Standard Error of Estimate	Notes
Crude Oil				
Coefficient	9.96	0.644	0.643	Dummy variable included for Gulf War
Standard Error	0.5			
(t-stat)	19.9			
Heating Oil				
Coefficient	117,447	0.374	9,475	Certain extreme data points censored in data
Standard Error	6,009			
(t-stat)	19.5			
Gasoline				
Coefficient	-1,971	0.326	2.87	RFG period only; dependent variable is inverse of inventories
Standard Error	207			
(t-stat)	-9.5			

Summary on Empirical Evidence

Data drawn from petroleum markets support the conclusions developed by economic theorists who have examined commodity markets. Inventories are linked to spreads. Inventories rise when spreads rise and decline when spreads fall. Furthermore, there is a linkage between contemporaneous or forward unexpected demand or supply. Such unexpected economic behavior causes *ceterus paribus* changes in demand or supply that are reflected first in spreads, then in prices, and ultimately in stocks.

II.3 Other Studies of Petroleum Inventories

It is fair to conclude that petroleum inventories have not been the subject of economic analysis. The few studies that have been completed (for example, those by the National Petroleum Council and Roland) must be viewed at best as accounting descriptions of inventory systems or more truthfully, long apologies for industry behavior deemed by some to be undesirable.

Roland prepared a detailed study that examines, among other things, the structure of industry inventories. In an introduction and eleven chapters, the author explains

- The structure of the supply system
- The problems encountered in measuring supplies
- The linkage between inventories and prices
- The dramatic decline in inventories between 1996 and 1997
- The impact of structural shifts and, in particular, the decline in minimum operating levels
- The appearance of a new, lower optimum level of inventories
- The impact of government inventories and the role of governments
- Stocks of crude at sea (and presumably in transit)

- The way in which taxes can affect inventories
- The seasonal fluctuations in inventories

Roland concluded that the dramatic decline in world inventories observed in 1996 occurred among discretionary stocks.

> Thus, it is clear which was the chicken and which was the egg in the second half of 1995 and in 1996. Global demand was strong, global production failed to keep up, and the only way to balance the market was for stocks — discretionary stocks in the consuming areas, of course — to be drawn, and this needed a price signal. Therefore, price came first, and the stock draw followed — a perfect example of the free market at work.[52]

Roland also noted the following:

> ...there is no evidence of a calculated policy by oil companies to initiate stock cuts in order to manipulate the market in their favor. Such a policy could only be the underlying cause of unusually low stocks in one region or segment of the oil market for one or two reasons: if there were an unusual industry-instigated build in another segment or region, or if supply were cut back to allow the barrels eliminated from storage to be absorbed. Neither happened in 1996.[53]

> The gap between supply and demand was so great in 1996 that the market's stock cushion was almost eliminated, leading directly to the increased price volatility. The market could no longer call on relatively high-priced elastic stocks to fill for any further shock in the shape of either an unexpected demand increase or sudden supply loss.[54]

Roland's study, unfortunately, is unconvincing because the author is unfamiliar with the economic literature on inventories. The absence of this familiarity leads to a number of mistakes that effectively vitiate the study's conclusions. Two examples illustrate the problems with the Roland report.

The first obvious problem concerns the author's assumption that the industry only began to respond to financial incentives to hold inventories when financial markets were introduced. As Roland stated,

> This inventory accumulation is a child of the era of oil market financial instruments. If the discount at the front of the market is sufficient to cover working capital costs in the forward months, then a company with long-term access to appropriately located storage can accumulate stocks and lock in a guaranteed profit by selling forward.[55]

Roland implied that companies did not engage in such transactions before the introduction of financial markets. This view conflicts with almost 100 years of economic research. Keynes[56]

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[52] Roland (1997), p. 79.
[53] Roland (1997), p. 79.
[54] Roland (1997), p. 79.
[55] Roland (1997), p. 63.
[56] John Maynard Keynes, *A Treatise on Money: The Applied Theory of Money* (1930). In Austin Robinson and Donald Moggridge (eds.), *The Collected Writings of John Maynard Keynes* (Cambridge: The Cambridge University Press, 1970).

noted that firms build inventories when they expect prices to rise. Brennen later demonstrated that expected prices created as moving averages of spot prices had a very similar relationship to inventories as futures prices.

Such behavior has been noted in the oil industry over the last 25 years. Indeed, the world industry was strongly criticized in the early 1980s by Saudi Arabia's oil minister Sheik Yamani for liquidating stocks. Yet, this liquidation is explainable by the change in price expectations. As Keynes and Brennen explain, companies adjust inventories when expectations regarding future prices change. The decline in inventories from 1980 to 1984 is consistent with a change in expectation regarding the ability of OPEC to sustain higher price levels. As expectations change, companies reduce inventories.

One measure of these expectations is the difference between netback and product prices. The author noted that netbacks provided a measure of expectations of future crude prices because official oil prices tended to adjust to netbacks with a lag.[57] Thus, the spread between expectations and actual prices gave a signal to companies regarding the decision to build or liquidate inventories. A letter by the author to *The Economist* in December 1980 contained a simple explanation for the observed phenomenon and explained that companies were following a rational approach.

Roland's failure to recognize the role of expectations in determining inventories is troublesome because there are relatively few financial instruments and relatively few financial markets. This is not a unique situation for petroleum. There are also few financial markets for grains, metals, or other commodities. Yet firms in most industries and most locations manage to adjust their inventories as expectations of future prices change. The process is one that has occurred for centuries and will continue for centuries to come.

Roland's study is also incomplete because it fails to consider the role of demand. To quote a former Aramco economist, "Roland provides only half a pair of scissors." The missing actor in Roland's study is the customer who buys oil in forward markets. Yet, as noted above, forward prices play an important role in determining inventory holdings and forward prices are determined in large part by consumers of petroleum products. An increase in forward demand for products (effectively a shift in the demand curve for future deliveries) will, *ceterus paribus*, lead to an increase in forward prices. This increase, in the absence of other changes, will lead to an increase in the spread between forward and cash prices and a shift of products or crude from the present to the future. The shift could be accomplished by any of the following:

- Increased production of products that are then held to meet future demand
- A reduction in the sale of existing products so that the product can be delivered in the future (however, such action would involve a *ceterus paribus* shift in the current supply curve and rise in the spot price)
- Increased purchases of crude oil in either the cash or the futures market by the suppliers who contemplate future production of the products required to meet the new demand

[57] Philip K. Verleger, Jr., *Oil Markets in Turmoil* (Cambridge, MA: Ballinger Press, 1983).

Where a *ceterus paribus* increase in the demand for products results in the purchase of future supplies (for example, futures) of raw material by a party that contemplates manufacturing the product at a later date, that purchase will change the spread between cash and futures prices, providing an incentive for some other party to build crude inventories.

The point to be emphasized (and the point missed by Roland) is that the level of stocks is determined simultaneously by buyers and sellers in *both* the cash market and the market for forward delivery. Consumers in the cash market by themselves cannot cause inventories to be drawn down. Their increased demand must be accompanied by passivity of consumers in the forward market or, alternatively, an increase in forward supplies from producers who respond to high contemporaneous prices by increasing supply. Roland missed these nuances of the market.

In summary, Roland provided a very thorough discussion of the accounting concepts and the physical or structural facets of the world's petroleum storage system. Regrettably, though, the study is so incomplete and lacking in economic analysis that it provides no useful insights into the factors that determine petroleum stocks.

The National Petroleum Council has prepared two studies of the petroleum storage system. The first study, completed in 1989, carefully reviewed the storage system and included estimates of inventories held by consumers, typically information neither collected nor reported. The NPC recently updated this study. Both studies presented detailed analysis of levels and trends in inventories as well as information on reported trends in stocks. However, neither study attempted to examine the factors that determine stock levels. Instead, both reports offered innocuous assurances that firms did not adjust inventories in response to market forces, assurances that were tempered with notes that companies would occasionally delay inventory accumulations if they expected future increases in supply. Such explanations ignore the role of the market.

II.4 Conclusions

This section has examined the detriments of inventories and the relationship between inventories, contemporaneous supply and demand conditions, and forward supply and demand conditions. The discussion began by describing the results presented in a number of papers devoted to the subject. Then, in Section II.2, it was shown that petroleum markets behaved as expected. Finally, in Section III.3, research by others was examined.

The basic conclusion of the discussion can be stated as follows. The level of inventories is determined in the long run by the spread between futures and cash prices. Positive spreads (contango) will lead to higher stocks than negative spreads (backwardation). Positive spreads will occur when there is strong demand for future delivery of products caused either by end-user demand or by speculation. Negative spreads will occur when contemporaneous demand is strong or speculators temporarily boost supply. It is a market that is very dynamic and quite complicated.

III. OPEC Actions Contributing to Price Increases

Oil-exporting countries implicitly recognized the role of inventories when they agreed to cut production sharply in March 1999. In the two years since then, they have demonstrated their increasing understanding of how stocks influence oil prices.

The initial market reaction to the March 1999 production cut of 2 million barrels per day (MBD) was astounding. The decision by the world's oil producers (OPEC plus Norway and Mexico) was treated as a ho-hum matter with little relevance to the world economy.

The complacency might have been correct. However, in retrospect, the OPEC action represented a watershed event, one that changed the direction of energy prices and economic growth for several years.[58] The shift in the market environment transformed world energy markets, boosted the average price above levels that might otherwise have prevailed, and utterly altered the relationship between energy-consuming nations and energy-producing nations.

The Price Collapse and the Events of March 1999

The 1998 collapse in oil prices coincided with the Asian economic crisis. Growth in the Far East had been projected to stimulate the long-run expansion in energy demand, particularly for petroleum. However, the depression in Thailand, Indonesia, and South Korea, combined with recession in Japan, removed this prop from the energy market, creating the conditions for declines in all commodity prices.

Oil-exporting countries could have prevented the collapse of energy prices had they acted early in 1998. However, producers dallied, failing to realize the magnitude of the loss in demand. When they did act in June, the cuts imposed were insufficient. Supply was reduced to match the diminished consumption, but no effort was made to reduce output enough to force liquidation of inventories that had built during the first six months of 1998. These stocks were the cancers that ultimately forced prices into single digits.[59] A subsequent attempt to limit production in September failed to resolve the problem.

By the end of February 1999, editors at *The Economist* were preparing a long article. The piece suggested that the world might be on the verge of a prolonged period of very low oil prices. The feature, published on March 6, 1999[60], noted that Saudi Arabia had the reserves and the capacity to meet the world's oil requirements, while holding prices down to $5 per barrel. The concluding paragraph cautioned those firms considering investment in oil and gas exploration:

> In the medium term, however, the Gulf States will find that their revenues recover and even increase with cheaper oil. So once they have made the transition to higher production, a $5 world should not hold any terrors for them. But it may hold more terrors for the rest of the world — for just as in 1973, it will find that it is increasingly dependent

[58] Note: I wrote these words originally in my publication *The Petroleum Economics Monthly* in March 1999.
[59] The role of inventories in determining commodity prices is not well understood. Seven years ago, President Clinton ran for the presidency using the phrase, "It's the economy, stupid." In oil, the phrase should be "It's the stocks, stupid." As economists from Keynes to Kaldor to Samuelson have known for almost 100 years, the stock levels of a commodity determine the price. This apparently complex idea does not seem to have penetrated the thinking of those who comment frequently on oil markets.
[60] "Cheap Oil: The Next Shock?," *The Economist*, March 6, 1999, pp. 23–25.

> on a few unstable and unreliable Gulf countries, notably Saudi Arabia, Iran, and Iraq, for its energy. Cheap oil may not look quite so wonderful, after all.[61]

The article also pointed out that new technological breakthroughs would lower the average price level. Statements from executives at Shell and other companies to the effect that many profitable projects could be started if prices rose above $12 per barrel were cited as facts that would hold down prices.

Within weeks of *The Economist* article, Saudi Arabia inaugurated operations at its new Shaybah oil field. Completion of this new field boosted its productive capacity to 11 MBD and, more importantly, increased the volume of light, low-sulfur crude — the most desirable to the market — by 33 percent.

Saudi Arabia used the kickoff of the Shaybah field as an occasion for celebration. Oil ministers and senior officials from other oil-exporting countries were invited to mark the affair. In retrospect, the event was more of a demonstration than celebration. The Saudis took the opportunity to warn other producers that the Kingdom's patience had been exhausted. According to press reports, Crown Prince Abdullah ushered each of the key visitors from other oil-producing countries aside and explained very carefully that it was time for joint action to restrict oil output. He also indicated that Saudi Arabia would have no choice but to flood the world market with oil, thereby validating *The Economist*'s forecast, if the Kingdom's proposal were not accepted.[62]

Less than a week later, senior officials from the major oil-exporting nations met informally in Amsterdam. Two days afterward, the group announced that producers would collectively cut oil production by more than 2 MBD — approximately 2.6 percent of world production. Ten days later, the ministers of OPEC gathered in Vienna and agreed to reduce output by 1.7 MBD for one year. Other producers (Mexico, Norway, and Russia) agreed to cut production by 300 to 400 thousand barrels per day (kbd), bringing the total to 2.1 MBD.

Common Wisdom

The accepted view of this agreement was captured in an article published in *Financial Times* on March 23, 1999. In the article, the author, Robert Corzine, suggested that oil-exporting countries wanted to move prices back into "the comfort zone."

> The recent rise in oil prices will reassure the ministers, many of whom no doubt hope it will continue until prices are back in their "comfort zone" of around $18–$20 a barrel, the level at which many Gulf Arab economies seem to be structurally geared to.[63]

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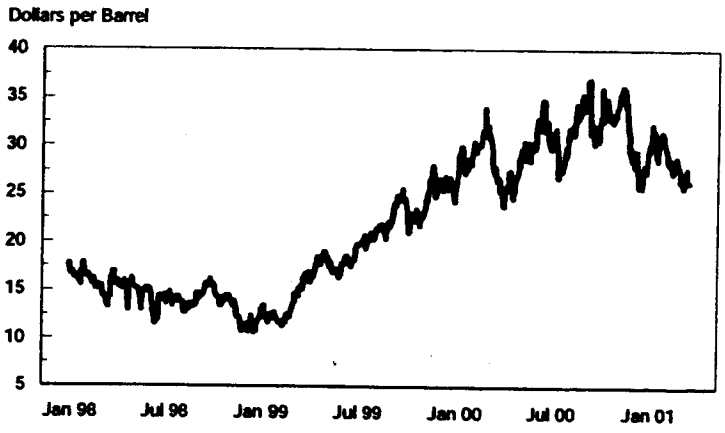
[61] "Cheap Oil: The Next Shock?," p. 25.

[62] See "Saudis Offer Big Carrot — And Wield Big Stick," *Energy Intelligence Briefing*, Energy Intelligence Group, May 11, 1999.

[63] Robert Corzine, "OPEC Determined to Reach the Oil Price 'Comfort Zone,'" *Financial Times*, March 23, 1999, p. 3.

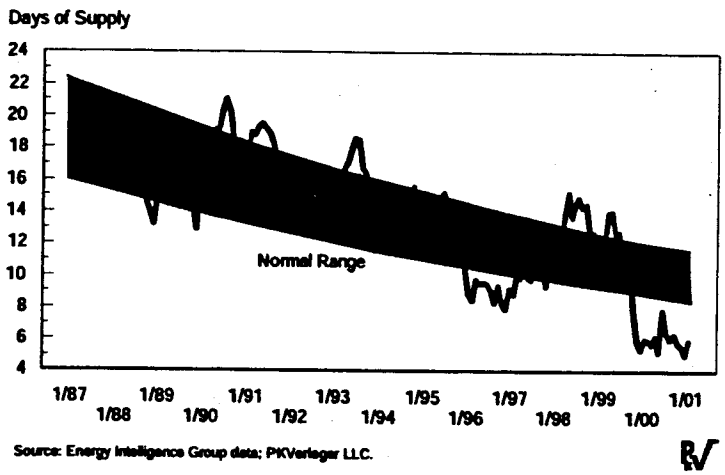
Once prices moved back into the "comfort zone," Corzine and others expected that OPEC's agreement would break down. They were wrong. Instead, prices continued to rise from the low teens to the mid-30s, as can be seen from Figure 4.

Figure 4
WTI Spot Prices — 1998 to Present



OPEC succeeded because producers cut output aggressively and caused a dramatic decline in stocks by the end of the first quarter of 2000. Inventories, measured in terms of days of supply, were pulled below the very low levels observed in 1997, as can be seen from Figure 5. Oil producers emphasized their desire to bring stock levels down in order to sustain higher prices. In pursuing this policy the ministers were often explicit with regard to their wish to keep inventories low.

Figure 5
Usable Commercial Stocks in OECD Countries



OPEC's management of the world oil market from March 1999 to March 2001 illustrates the organization's focus on stock levels. The organization met in March 1999 at a time when oil prices were hovering around $10 per barrel. In the March 6 *Economist*, a long article headlined "Drowning in Oil" heralded the arrival of single-digit oil prices.[64] OPEC members met three weeks later to institute a production cut of more than 2 million barrels per day. The reduction was introduced as a measure designed to remove "surplus oil" from the world market. Nowhere can one find a specific focus on the linkage of stock levels to prices, although some articles refer to an inventory overhang of 400 million barrels.

[64] "Drowning in Oil," *The Economist*, March 6, 1999. See especially p. 19 and pp. 23–25.

In a report published on March 11, *The Wall Street Journal* noted that rumors of the production cut sent prices up. The piece cites a joint statement by the oil ministers of Saudi Arabia, Kuwait, Qatar, and Oman in which the countries agreed to work with other exporters "to take all measures, most importantly, effective reduction of output, in order to withdraw excess supplies from the market and boost oil prices."[65] Statements printed in the financial and petroleum press describing the March 1999 action note the desire to cut production but make almost no mention of inventories.

Six months later, OPEC members met to review the market situation. By the time of the September 19, 1999 meeting, oil prices had more than doubled and consuming nations had begun pressuring OPEC to increase output. The members refused, citing high inventory levels. *Platts* reported that OPEC's Economic Commission Board (ECB), which included marketing experts from each country, had expressed concerns that stocks were too high.

> The ECB report says that if OPEC continues to pump around 26.2 mil b/d through March next year, the first quarter could see global stocks reduced by 4 mil b/d. Nevertheless, the ECB discussions, which happened over three days, threw up concern that stocks remained on the high side. And while it was generally felt that stocks would eventually return to "normal" levels, it could not be predicted when this would happen because of a number of uncertainties.[66]

The ECB report went on to note that stocks were still too high. Other publications reported similar comments from OPEC members. In an interview with *Petroleum Argus*, OPEC Secretary General Lukman was asked about stocks. He responded, "I don't want to get embroiled in figures and statistics. What we're referring to is the general level of stocks, which is higher than would normally be considered reasonable."[67]

Through 1999 and 2000, oil-exporting countries maintained their focus on inventory levels. For example, in a detailed review of market behavior published a year after the March 1999 meeting, writers for *The Wall Street Journal* noted the ministers' perspective:

> Oil ministers from the Mexico-Venezuela-Saudi Arabia troika got together in November in what many thought would be a first step to loosen restrictions on output. But the data the ministers had to guide them suggested that oil stocks were resilient, so they took no action on the cutbacks.[68]

This concern with inventory levels has continued. OPEC's March 2001 production cut was dictated by expectations of stock increases. *Financial Times* reported that OPEC made the cut to "give oil-consuming countries less leeway to build up stocks in periods of slack demand."[69]

The increase in prices and decline in inventories, combined with statements issued by OPEC members, indicate that oil-exporting countries are clearly attempting to keep stocks low.

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[65] "Oil Prices Surge as OPEC Weighs Cuts," *The Wall Street Journal*, March 11, 1999, p. A2.
[66] "OPEC Sees Need for Further Stock Draw," *Platts Oilgram News*, September 20, 1999, p.1.
[67] "Lukman Sees No 'Danger' in High Prices," *Weekly Petroleum Argus*, September 27, 1999, p. 9.
[68] "Barrel Roll: Why Oil Price Tripled Even as Nations Strove to Limit Its Gyration," *The Wall Street Journal*, March 27, 2000, p. A1.
[69] "Oil Production Cut Likely to Boost Oil Prices," *Financial Times*, March 19, 2001.

Producing nations have taken this action because they have discovered the linkage between inventories and prices.

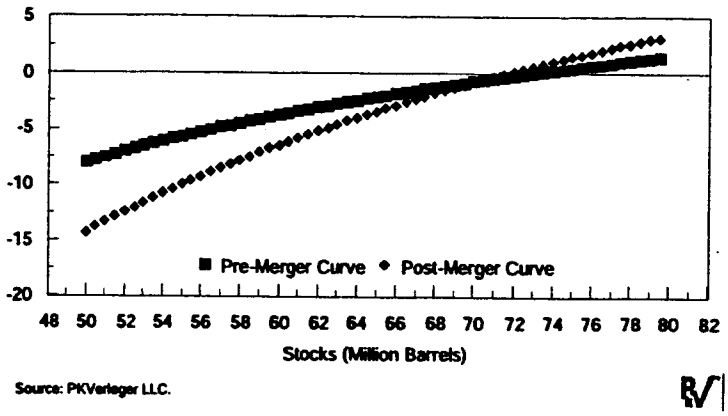
IV. The Contributions of Structural Change in the Petroleum Market to Oil Price Increases

The supply-of-storage relationship hypothesized by Working *et al* noted above has generally been thought to be static. However, there appear to be no studies that examine whether the relationship changes over time. (There are really very few studies of the subject at all.) It does appear, though, that the relationship has been altered. In fact, the supply of storage seems to have become less elastic.

The shift in the supply-of-storage curve can be observed from Figure 6, which shows two estimated relationships. The first, labeled "Pre-Merger," is calculated for the period 1992 to 1997. The second curve, labeled "Post-Merger," is computed for the period 1998 to 2000. The post-merger supply-of-storage curve is much less elastic than the pre-merger curve. Both relationships are statistically significant and the statistics confirm that the relationships are different.

What does the decreased elasticity of the supply-of-storage curve mean? Basically, the steeper (less elastic) curve implies that firms are willing to pay or insist on charging a higher rental rate for crude in 2000 than they did in 1998. The results suggest that prices would have been more volatile in 2000 even if OPEC had done nothing. The differences in rental rates can be seen from Table 5, which shows calculated spreads for various inventory levels.

Figure 6
The Merger Impact: Change in the Observed Supply-of-Storage Curve for Crude



The change in the supply-of-storage curve is attributed to three factors: investor disenchantment with petroleum equities, the transfer of refining assets from big oil to little oil, and mergers in the industry. Start with investor disenchantment.

During the recent technology boom, oil equities languished with other "bricks-and-mortar" stocks. Executives naturally sought to boost profits and shareholder returns. Firms repurchased shares, disposed of assets, looked for ways to differentiate their product, and aggressively sought to cut costs. Because oil companies generally could not differentiate their product (gasoline is regrettably gasoline to most buyers), much of the effort had to be focused on cutting costs. Inventories were one of the obvious targets. Companies began to accept that they should occasionally run out of stocks (recall Mobil's KILL program — Keep Inventories Low and Lean). Companies installed better monitoring equipment to closely track stocks. Companies

installed new "drain dry" tanks that enabled them to reduce minimum operating levels. Every possible step was taken to cut inventory.

A 1998 National Petroleum Council study on inventories summarized the effects of these changes. The report showed that minimum operating levels had been reduced substantially despite increases in consumption.[70]

Table 5. Rental Rates for Crude Oil: Amount a Borrower Would Have to Pay a Supplier to Rent a Barrel per Year (Dollars per Barrel)

Stocks (000 Barrels)	Old Supply-of-Storage Curve	New Supply-of-Storage Curve
50,000	7.96	14.30
55,000	5.65	10.01
60,000	3.73	6.44
65,000	2.11	3.42
70,000	0.72	0.83
75,000	-0.49	-1.42
80,000	-1.55	-3.38
85,000	-2.48	-5.12
90,000	-3.31	-6.66

Source: PKVerleger LLC.

The second change affecting the supply-of-storage relationship has been the transfer of ownership of refining capacity from "big oil" to "little oil." This shift has been chronicled often, but the numbers keep changing as big oil companies sell refining capacity to little oil companies. In November, BP announced that it would sell four additional refineries. Table 6 shows the distribution of refinery ownership by size of firm in 1990 and in 2001, assuming BP completes its most recently announced asset sales. From the table, one can observe that the share of US refinery capacity owned by little oil has increased from 29 percent to 38 percent.

The transfer of refining capacity from the well-capitalized firms that make up the big oil category to the small companies defined as little oil must alter the supply-of-storage relationship. Firms in the big oil category could afford to hold excess stocks occasionally or even build stocks in anticipation of a prospective market opportunity. Some large oil companies even have organizations that are permitted to speculate. Little oil companies do not have this luxury. The smaller companies acquiring refining capacity from the supermajors must generally keep inventories to a minimum. The lenders to these firms prevent them from building stocks even when the urge to accumulate occurs. This shift of assets from big oil to little oil clearly contributes to the supply-of-storage curve's increased inelasticity.

Table 6. Distribution of US Refining Capacity by Size of Firm following BP's Proposed Refinery Sales (Percentage of Capacity Owned)

Market Capitalization	1990	2001
Large Integrated	52.3	35.1
Moderate Size	18.4	26.8
Small Firms	29.3	38.0
Total Capacity (Barrels per Day)	15,675,627	16,261,290

Note: Large integrated firms have capitalization in excess of $60 billion; moderate firms have market capitalization in excess of $5 billion.
Source: US DOE and PKVerleger LLC.

The merging of major oil companies to create supermajors is third cause of the increased inelasticity. The last two years have witnessed five significant mergers. BP purchased Amoco. Total acquired Fina. Exxon acquired Mobil.

[70] National Petroleum Council, *US Petroleum Product Supply Inventory Dynamics*, 1998.

BP-Amoco acquired Arco. Total-Fina acquired Elf. Separately, Shell and Texaco merged their US refining and marketing activities. Each of these mergers has been undertaken primarily to boost shareholder value. While proponents of the supermajors (including the author) have asserted that larger firms were necessary to maintain the diversified exploration programs required to stay in the business, the basic reason to merge has clearly been shareholder value. Every merged firm has sought to improve margins. Improving margins is synonymous with cutting costs. In most cases, the merged firms have sought to achieve these synergies by reducing inventories. In fact, one of the merged companies sought to lower its worldwide stocks by between 30 and 50 million barrels.

The pursuit of minimum stocks by the merged companies must have increased the inelasticity of the supply-of-storage function. As companies chose to operate with lower stocks, they implicitly accepted the fact that they would be forced to pay a greater premium for incremental supplies. In the process, they abrogated a traditional role. In the past, integrated companies provided a pseudo price insurance program for consumers by holding stocks. Today, financial markets and responsibility to shareholders make it impossible for these firms to perform such a role.

V. Economic Impacts and Policy Alternatives

The restructuring of the oil industry, deregulation of markets, and increased emphasis on company financial performance, combined with the greater focus of oil-exporting countries on worldwide inventories, provide the ingredients for a permanently volatile oil market. The editor of the *IEA Monthly Oil Market Report*, Klaus Rehaag, commented on the problem in the November 2000 issue, noting that the world oil market has been squeezed by growing demand and fluctuating supply. In 1999, cuts in supply depleted world stocks as demand surged. As Rehaag eloquently noted, "The combined effect has tightened the supply/demand balance by 4 billion barrels, generating physical restocking on a massive scale, leading to price volatility."[71]

Rehaag went on to state that as OPEC belatedly attempts to prevent further price increases, producers are confronted with constraints in refining, shipping, and distribution:

> Lead times are long. Unless stocks are built in advance of peak demand, regional supply imbalances are inevitable, as was the case with gasoline last summer and heating oil this winter.[72]

Today, no solution to this problem is in the offing. At their November 2000 meeting, oil ministers expressed their inclination to cut production in January because demand for crude would decline in the spring. Their assessment was probably correct, and OPEC reduced output in January 2001. The oil industry cut refining runs in January and February as companies rushed to undertake maintenance programs deferred from the fall. Crude purchases were cut to keep inventories in line. A sharp decline in backwardation occurred as expected, given the observed relationship between stocks and spreads. OPEC repeated this process in March 2001, announcing further production cuts at that time because demand was again projected to decline.

Annual repetition of the recent upward spirals in oil prices could have several possible effects. Ultimately, higher oil prices could trigger a worldwide recession. The recession would undoubtedly cause a decline in crude prices and lead to a temporary reduction in price volatility.

However, other, more certain steps can be taken to reduce price volatility. The IEA hints at a possible solution in its utopian plea for maintaining adequate stocks. The IEA members have at their fingertips the very tools needed to achieve price stability: the strategic stocks held in Europe, the United States, and Japan. These reserves could be used to stabilize markets.

Consuming countries own or control 1.2 billion barrels of crude oil and products. These volumes are stored in government and private facilities. The US government alone owns 568 million barrels of oil. Introducing some of this crude into the market would quickly moderate price volatility. Prices would have never reached $30 per barrel had the reserves been used last fall as proposed by Senator Charles Schumer of New York.

Proposals to use strategic stocks have received a very cold response from official sources and from energy security analysts. These opponents assert that such reserves were created to meet "shortages" rather than address market problems.

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[71] *IEA Monthly Oil Market Report*, November 2000, p. 4.
[72] *IEA Monthly Oil Market Report*, November 2000, p. 4.

Such views overlook a policy that, if implemented, could allow government officials to expand the size of the reserves at no cost to the taxpayer. The policy would involve the use of "swaps." Under a swap, firms taking oil from the reserve now would agree to return more oil in the future. For example, a buyer could agree to take 100 barrels in February 2000 and return 120 barrels in February 2001.

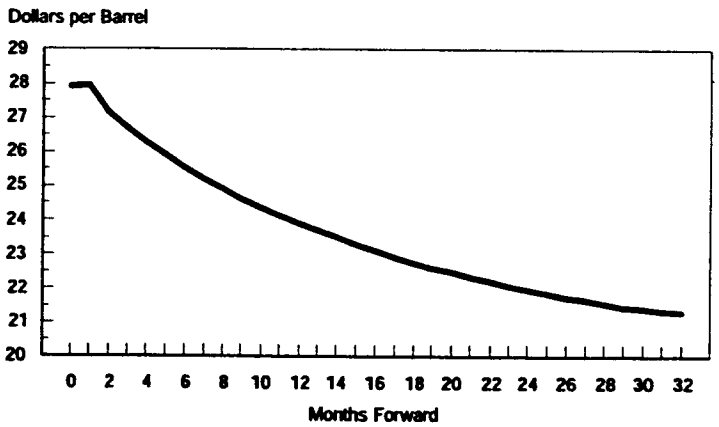
This strategy would have three immediate benefits. First, in the long run, strategic stocks would increase as the government took back 120 barrels for every 100 barrels released through swaps. Second, the expansion would be costless. Third, releasing oil would provide much needed liquidity to the market.

Many individuals may ask why any firm would be willing to take delivery of 100 barrels of oil now and agree to return 120 barrels later. The answer to this question lies in the forward price curve (see Figure 7). A buyer would take delivery of 100 barrels and promise to give back 120 barrels if the economic value of the 100 barrels today exceeded today's cost of obtaining 120 barrels for delivery in twelve months. On February 25, 2000, for example, the economics of the transaction worked as follows:

Value of 100 barrels in February 2000	$3,013.00
Cost of 120 barrels of oil to be delivered in February 2001	$2,731.20
Difference	$681.80

This calculation illustrates the effect of a steeply backwardated price curve. Under certain conditions, firms will trade a large volume of a commodity in the future for a small volume today. Most of the buyers presumably would hedge their positions, selling the oil quickly while buying futures to cover their future obligation. This action tends to depress the front of the price curve (causing lower spot prices), while lifting the back part.

Figure 7
Forward Price Curve for WTI — 1/05/01

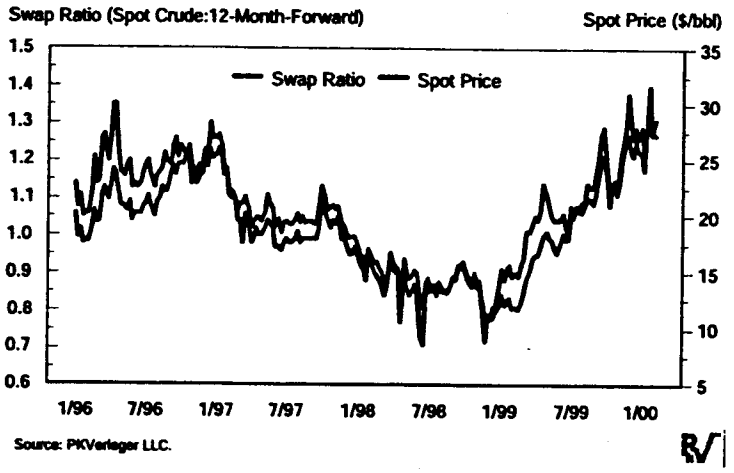


No one has attempted to estimate the impact of an oil swap yet. However, comparing the ratio of cash oil prices to twelve-month-forward prices indicates a close correlation between the "swap ratio" (the ratio of the cash price to the forward price) and the spot price of oil. This empirical relationship can be seen from Figure 8. A literal reading of this graph suggests that an exchange ratio of 1.1:1 would cap prices at around $23 per barrel, while an exchange ratio of 1.2:1 would cap prices at $25 per barrel. While it is wrong to

accept such ratios at face value, they do imply that a swaps policy could stabilize markets. In other words, swapping strategic stocks seems to represent a good use of the taxpayer's oil when markets are excessively backwardated, as they are today.

This view will be challenged by some. One valid argument against this strategy is that it might provoke oil exporters into cutting production or at least not increasing output. This response is obviously possible. Such an action would boost the price of oil. However, it would not create the liquidity problems experienced recently in markets because ongoing swaps would promote a better allocation of oil over time. Current and future consumption would be depressed by larger amounts. Investment in new production would be increased because forward prices are boosted by firms hedging their swap positions. Consequently, oil exporters would be marginalized more rapidly and OPEC's ability to control the market would be reduced. While this adjustment would take several years, it would ultimately squeeze producers from the market permanently. The prospects of such an outcome should deter OPEC from attempting any manipulation.

Figure 8
Spot WTI Prices v. Ratio of Spot to Forward Prices



Others argue that such a policy attempts to pick a price for oil. This view is incorrect. Prices are determined by the amount of oil put into the market. OPEC has primary control over these volumes in the short run and thus has control over spot prices. Swaps only fix the slope of the price curve. By offering swaps, consuming nations would be using oil purchased by taxpayers to prevent markets from being excessively distorted.

Another objection to swaps is that they would anger the world's largest oil-exporting country, Saudi Arabia. This may happen. However, Saudi Arabia has enormous sums invested in the industrialized world. Excessively large price increases and disorderly markets threaten the value of these investments. Swaps moderate the disorderly markets and lend an element of stability to the market.