Review

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Treasury Bill Futures—

Opportunities and Pitfalls

By Wallace H. Duncan

A year and a half ago, on January 6, 1976, futures contracts in U.S. Treasury bills began trading on the floor of the International Monetary Market (IMM) of the Chicago Mercantile Exchange. Their debut followed by only 2½ months the start of trading in "Ginnie Mae" futures contracts on the Chicago Board of Trade.[1] Interest rate futures were an idea whose time had come.

Futures markets tend to develop in commodities that are subject to relatively volatile price movements. Such conditions create an incentive for businesses that are involved with these commodities to seek shelter from the buffeting of continual price changes; and simultaneously, speculators are attracted to the potential for large trading profits.

During and shortly after World War II, a futures market in Treasury bills would have been totally unviable because, at the time, the Federal Reserve was pegging three-month bill rates at three-eighths of 1 percent. By contrast, during the 1970's, interest rates hit levels unprecedented in this century, accompanied by an increase in volatility. From 1973 through 1975, money managers experienced especially large and unexpected changes in the value of their asset portfolios or their liability costs. The time was propitious for the beginning of a futures market in short-term interest rates.[2]

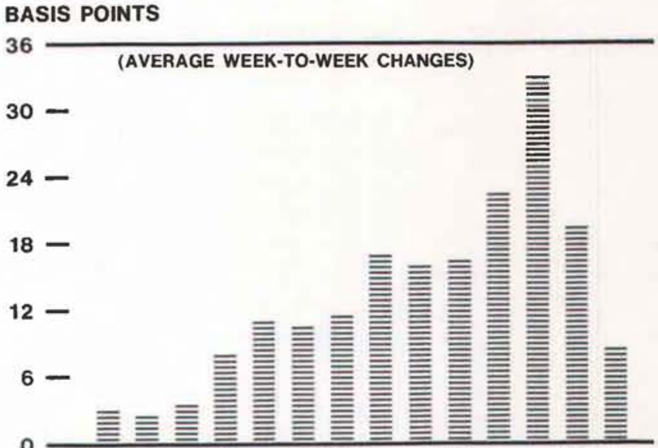
The new market in three-month Treasury bill futures offers money managers an opportunity to reduce their risk exposure to unexpected changes in short-term interest rates. However, various pitfalls await the uninitiated, as hedging is considerably more complex in practice than in theory. This article considers some of these complexities as they apply to the futures market in Treasury bills.

Characteristics of T-bill futures market

Futures contracts in Treasury bills are traded in units of $1 million of three-month bills. Currently, contract months for trading are March, June, September, and December. A contract month actually refers to the bill that is auctioned by the Treasury in the third weekly auction of the specified month. For example, the September 1977 futures contract refers to the three-month Treasury bill to be auctioned on Monday, September 19, 1977. Futures trading in an expiring month continues until two days after the Treasury auction. Any futures contracts still open at the end of the second day are settled by actual delivery of the newly issued Treasury bills and payment in cash on the following day. This is also the day on which the Treasury settles with successful auction bidders, delivering newly auctioned bills in exchange for cash.

As with other commodity futures, most T-bill contracts are terminated by offsetting; that is, one

Auction prices of three-month Treasury bills have become more volatile in recent years



SOURCE: Board of Governors, Federal Reserve System.

1. "Ginnie Mae" is the trade name for certificates issued by the Government National Mortgage Association and represents a pool of home mortgages insured by the Federal Housing Administration or guaranteed by the Veterans' Administration.
2. Futures markets in still other interest-bearing instruments may be on the horizon. The Chicago Board of Trade has asked the Commodity Futures Trading Commission for approval to establish futures markets in 90-day commercial paper and in long-term U.S. Treasury bonds. The Chicago Mercantile Exchange is seeking approval to begin futures trading in four-year U.S. Treasury notes and in one-year Treasury bills to complement its present trading in three-month bills.

enters into another contract in the same month for the same amount but on the opposite side of the market. Entering a new contract to buy $1 million of September T-bills cancels a previously held contract to sell the same amount of September T-bills and leaves no remaining position.

Prices of Treasury bill futures are quoted according to the IMM index. The index is the difference between 100.00 and the actual T-bill yield on a discount basis at an annual rate. For example, an IMM price quotation of 94.57 is equivalent to a Treasury bill discount rate of 5.43 percent. Prices are quoted in increments of .01, or 1 basis point of yield, which is equivalent to a change of $25 in the value of the entire $1 million contract. There is a daily price-range trading limit of 50 points above and below the previous day's closing price.

Individuals and institutions that are not members of the IMM must pay a brokerage commission and deposit a specified amount of margin, or good faith money. Though individual brokerage houses may require higher amounts, the Chicago Mercantile Exchange currently requires a minimum commission of $60 per contract on a round-turn basis (both a purchase and a sale) and $1,500 of margin deposit.

Reason for hedging

Most businesses are subjected to price risk in the course of normal operations. Prices of inventories may change, causing an unexpected gain or loss, or prices of materials that must be purchased in the future may change, causing an unexpected increase or decrease in costs of production. In most cases, businessmen would prefer to be rid of the risks associated with unexpected price change.[3] Futures markets offer a means for businesses to offset much of the price risk among themselves and to shift a portion of it to speculators, who willingly assume the risks in hopes of making a profit on price changes.

The basic principle of hedging is to enter into an obligation involving a commodity whose price moves closely with the price of a commodity that is subject to price risk in the normal conduct of business. One enters into such an obligation on the opposite side of the market from the obligation incurred in the course of business. Then, if there are similar changes in the prices of the two commodities, losses in one are offset by gains in the other, and price risk is thereby eliminated. If price risk is completely eliminated, the arrangement is called a perfect hedge.

3. Such risks also tend to raise prices paid by consumers, since risk-averse business owners require an additional return on capital for assuming the additional risks associated with price fluctuations of materials.

In hedging with futures contracts, the futures contract serves as a commodity that is similar to though slightly different from the commodity creating a price risk in the normal course of business. For example, a commercial bank that buys $1 million, face value, of newly issued three-month Treasury bills in, say, August faces a price risk if the bills are not held to maturity. But this bank with a "long" position in T-bills can gain some protection from changes in market value caused by fluctuating interest rates if it simultaneously sells an appropriate amount of September T-bill futures contracts to create an offsetting "short" position.[4]

If the market price of actual Treasury bills and the price of T-bill futures move exactly together, a 25-basis-point increase in interest rates causes a $625 loss in the value of the Treasury bills, of three-month maturity, and a $625 gain in the value of the futures contract. Similarly, a 25-basis-point decline in interest rates causes a gain and a loss, respectively, in opposite directions, again offsetting each other.

This example has been that of a perfect hedge. The bank has eliminated the price risk due to interest rate fluctuations. The cost of eliminating the risk has been the transactions cost of the futures contract position—specifically, the brokerage commission and the forgone interest on the margin deposit.

In the above example, it was not necessary for the hedging bank to have any opinion as to the probable future course of interest rates. In pure hedging, the decision to hedge does not require any expectations regarding the probable course of prices in the future. However, in practice, hedgers typically do consider their own expectations as to future price changes, hedging when they estimate the risk of loss is great and not hedging when they view the risk as small or likely to be in their favor.

The T-bill futures market can also be used to hedge other money market instruments, such as commercial paper, bankers' acceptances, and negotiable certificates of deposit. This is known as cross-hedging. However, as an instrument's price move-

4. Usually, the nearest futures contract month will provide the best hedge for current bills, since the market forces of supply and demand for the two are likely to be the most closely related. More distant futures months would be less influenced by current market conditions. In some instances, a hedged position may entail rolling over a futures contract in the nearest month to a contract in the next succeeding month as the former approaches expiration. "Rolling over" constitutes the simultaneous purchase and sale of contracts in two different futures months for the purpose of substituting the more distant month.

ments become less closely correlated with those of T-bill futures, the hedge will become less effective.

The basic hedging principle that price movements in opposite positions provide offsetting gains and losses, thus eliminating risk, is simple in concept yet complex in practice. For the novice hedger, armed only with this amount of knowledge, there are various pitfalls.

Imperfect hedging

In practice, hedging usually does not completely eliminate price risk. To achieve a perfect hedge, the hedger must know exactly the date and amount of his expected cash market transaction or the holding period of his current bills. An appropriate futures contract must also be available, specifying the amount, delivery date, and term to maturity needed by the hedger. And, in addition, the market price of the futures contract must accurately reflect true market expectations.

The closest hedge vehicle may be for an inaccurate quantity, with an inaccurate term to maturity and an inaccurate delivery date—all these imperfections tending to reduce the correlation between the prices of Treasury bills and Treasury bill futures.

These conditions might best be illustrated by an example. Suppose a money manager knows he will be buying $1.25 million, face value, of newly issued three-month T-bills on July 28 and that he will be holding them for four weeks, selling them in the market on August 25. To hedge the position perfectly, he must sell on July 28 a futures contract that will be deliverable on August 25 for $1.25 million, face value, of 9-week Treasury bills—equal to the remaining term to maturity on his 13-week bills. The futures contract and the bills in his portfolio would then represent identical commodities. Furthermore, the interest rate implied by the futures contract price on July 28 must be the same as the corresponding forward rate implicit in the term structure, including any liquidity premium.

Any deviation from these conditions will introduce imperfections into the hedge. For example, the money manager may not know the precise amounts and dates of expected future cash market transactions. And even if he does have such information, some uncertainty usually remains.

Our hypothetical hedger also has a problem in obtaining a suitable futures contract. Contracts are not traded in units as small as a quarter of a million dollars, and there is no contract calling for delivery of nine-week bills; nor are any contracts traded for delivery on August 25. The nearest alternative would be the September contract specifying $1 million of three-month bills for delivery on September 22.

Thus, the closest hedge vehicle may be for an inaccurate quantity, with an inaccurate term to maturity and an inaccurate delivery date—all these imperfections tending to reduce the correlation between the prices of Treasury bills and Treasury bill futures. And for other money market instruments, the correlation with T-bill futures prices will be even less, since an additional element of inaccuracy in risk matching is introduced.

Another reason for imperfect hedging is market imperfection. Interest rates of futures contracts may differ from the rates actually expected to exist in the Treasury bill market. For example, futures contract rates may not be equal to the forward spot rates implied in the term structure.

Money managers should be relatively indifferent between (1) the purchase in September of a newly issued six-month Treasury bill and (2) the purchase in September of a newly issued three-month bill and a December futures contract for another three-month bill. Arbitrage should keep the effective yield on the three-month bill/futures contract combination approximately equal to the yield on the six-month bill. Thus, the yield implicit in the December futures contract should equal the forward rate implied by the difference between the yields on the three-month and six-month bills in September. However, to the extent that either market is imperfect in reflecting the consensus of expectations, futures market and forward spot rates will differ, introducing yet another obstacle to the achievement of a perfect hedge.

Hedge adjustment

The underlying principle of hedging requires that price risk in the cash, or spot, position be matched as closely as possible with an offsetting price risk in the futures position. If the cash and futures commodities are identical except for their time characteristic, this generally requires matching quantities. Thus, a business with an inventory of 2,000 bales of cotton hedges by being short 2,000 bales in a nearby futures contract. By analogy, one would expect to hedge $2 million, face value, of Treasury bills in a portfolio by being short two futures contracts, each with a $1 million face value. If the portfolio position is $1.5 million, there is of course the problem of not being able to achieve a good match between offsetting price risks. Should one futures contract, or two, be sold in order to hedge $1.5 million of face value?

However, with Treasury bills the problem is even more complicated than simply achieving an initial match. Suppose a money manager hedges $2 million of newly issued bills by selling two futures contracts. After 1½ months, if no further changes in his portfolio or in his futures position have occurred, he will find that he is exposed to twice as much risk in his futures position as in his portfolio. A decline of 50 basis points in interest rates on both bills and futures would result in a net loss of $1,250 instead of leaving his net worth unchanged, as would have been expected at the beginning of the hedge.

This mismatching of risks exists because the price risk of Treasury bills is a function of term to maturity, declining continuously as the bill approaches maturity. At 1½ months to maturity, a change of 1 basis point in T-bill interest rates causes a change of only $12.50 in the value of $1 million of bills—half as much as that associated with bills having three months to maturity.

On the other hand, a 1-basis-point change in a three-month T-bill futures contract is associated with a constant $25 change in value during its entire lifetime of trading, equal to the change in value of a three-month T-bill. The value of a T-bill futures contract does not vary automatically over time, as does that of a T-bill moving toward maturity. Only at the expiration of trading in a given futures month when any outstanding contracts become transformed into Treasury bills can they start on a path to maturity.

A 1-basis-point price risk retains a constant dollar value in a T-bill futures contract, but it has a continually declining dollar value in actual Treasury bills. This dissimilarity makes the hedging of Treasury bills in a portfolio all the more difficult for the money manager. Balancing price risk in portfolio and futures positions requires continual adjustment, even in the absence of portfolio additions or deletions.

For a large portfolio containing Treasury bills of many different maturities, the portfolio manager should calculate at frequent intervals the total risk in terms of futures contract equivalents, taking into account the different terms to maturity. The futures position should then be adjusted frequently to keep price risks matched as closely as possible with those of the portfolio.

In some portfolios, the average term to maturity of Treasury bills, and perhaps other money market instruments, may be kept relatively constant as a management objective. In such circumstances, the problem of frequent adjustment in order to maintain matched risks will be reduced.

Further opportunities and problems

Locking in. Money managers who expect to receive funds to lend at some future date may wish to "lock in" the rate of interest to be earned on the funds. This can be done by buying a futures contract in the delivery month nearest the date of expected receipt of the funds. If the investment is to be in Treasury bills and coincides with the delivery date of a futures contract month, the manager can use the futures market as if it were a forward market by taking delivery on the futures contract.

However, an effective hedge can also be realized without actually taking delivery. By buying a futures contract, selling it when the funds are to be invested, and then applying any gain or loss on the futures position to the purchase price of the investment security, interest rate declines that occurred prior to the investment will have been hedged. The degree of effectiveness of the hedge will, of course, depend on how closely the implied interest rate of the futures contract has tracked the change in the spot market yield on the security.

If expectations of the market are for rising interest rates, the effectiveness of a strategy to lock in lower borrowing costs well in advance is nil.

The practice of using the futures market to lock in an interest rate for some future date is legitimately a hedge only if the cash transaction to be made in the future is known with a relatively high degree of certainty. If a money manager enters into a futures contract to hedge a relatively uncertain future cash transaction, he may actually be increasing his risk exposure; for if the cash transaction does not materialize, the portfolio will be subject to gains or losses on the futures position without any offset in the cash (spot) position.

Hedging for borrowers. Besides lenders, who hedge current or anticipated ownership of short-term securities, borrowers also may use the futures market to hedge against unexpected interest rate fluctuations. For example, a finance company, making fixed-interest loans for periods of a year or more, will be adversely affected by an increase in its borrowing cost in the finance paper market. By selling T-bill futures contracts, it may be able to avoid the classic squeeze caused by rising interest rates on institutions that lend at long maturities and borrow at short ones. Since futures contracts begin trading two years before their delivery date, hedging against unfavorable interest rate changes can be accomplished out to a time horizon of 24 months.

However, if expectations of the market are for rising interest rates, the effectiveness of a strategy to lock in lower borrowing costs well in advance is nil. At this writing, for example, Treasury bill futures for delivery 13 months hence are trading at an implied discount rate about 230 basis points above the rate on current bills. If the market expectations embodied in futures prices are correct, no gain or loss would be made on the futures contract, while the finance company would still have to borrow at a rate 230 basis points higher in the future, as well as pay the commission on the futures contract and absorb forgone interest on the margin deposit.

Summary and conclusions

The market in Treasury bill futures provides a new and potentially useful instrument with which the money manager may be able to reduce the risks associated with unexpected changes in short-term interest rates. However, hedging is considerably more complex than it first appears, and money managers should become thoroughly familiar with its intricacies in advance so that various pitfalls may be avoided.

Hedging operations attempt to match offsetting price risks and thereby reduce or eliminate net risk. In practice, some price risk remains, since price movements in futures are usually not perfectly correlated with price movements in spot markets.

The primary causes of imperfect hedging are the unknown or uncertain expectations regarding cash market transactions; the unavailability of an appropriate futures contract in terms of a specific face value, term to maturity, and delivery date; and market imperfections, which give rise to differences between the yield implied by the futures contract price and the corresponding forward rate implicit in the term structure. Cross-hedging of other money market instruments involves yet an additional source of imperfection, since price movements of instruments other than T-bills should be even less closely correlated with the price movements of T-bill futures.

Matching price risks between futures and existing Treasury bills or other money market assets often requires continual adjustment of the futures position. A 1-basis-point price change in a futures contract has a constant value. For actual bills, it is a function of the term to maturity and, therefore, continually declines over time.

In addition to hedging existing portfolio assets, futures contracts may be used to hedge expected future transactions in money market instruments. Money managers intending to purchase short-term assets or to borrow in the money market can use T-bill futures to lock in the interest rate to be earned or paid. However, such actions create speculative positions when the expected cash transactions do not materialize. So, use of the futures market as a hedge to lock in future interest rates should be undertaken only if the expected cash market transaction is relatively certain.

New member bank

Western National Bank, Odessa, Texas, a newly organized institution located in the territory served by the El Paso Branch of the Federal Reserve Bank of Dallas, opened for business June 15, 1977, as a member of the Federal Reserve System. The new member bank opened with capital of $1,000,000, surplus of $1,000,000, and undivided profits of $500,000. The officers are: Neil L. Grape, President and Chief Executive Officer; Thomas W. Anderson, Vice President and Cashier; Warren A. Cornil, Vice President; and Denzil Hartless, Vice President.

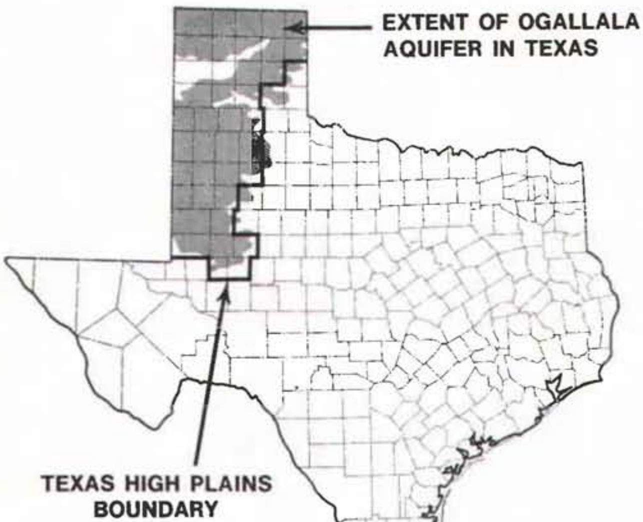
Irrigated Agriculture—

Higher Costs Dampen Economy of Texas High Plains

By Alan M. Young

Until recently, natural gas has been a relatively cheap source of power for pumping water to irrigate crops in the Texas High Plains. Cheap energy had led to phenomenal expansion of irrigated farming in the area. Since 1948 the number of irrigation wells in the High Plains has increased from fewer than 10,000 to about 71,000. During the same period, irrigated acreage there has risen from about 1.2 million acres to 6.3 million.

Water for irrigation in that area is supplied by the Ogallala aquifer, an underground formation that also extends northward into parts of Oklahoma, New Mexico, Colorado, Kansas, and Nebraska. Irrigation costs had gradually increased until 1974 as the pumping caused the water table to decline. The sharp escalation of natural gas and other energy prices since 1974, however, has accelerated the increase in irrigation costs. This sharp increase is speeding up the reversion to dryland production on a sizable acreage in the area.



SOURCES: Texas Department of Agriculture.
Texas Water Development Board.
U.S. Department of Agriculture.

Before the emergence of the energy crisis and double-digit inflation in 1974, irrigation costs in the High Plains were rising moderately, about 6 percent per year. However, with considerably higher fuel costs as well as increased costs of labor and equipment, irrigation costs per acre have about doubled in the past three years.

According to some estimates, the recent increase in fuel costs may cause the value of annual farm output in 21 counties of the High Plains to be reduced by as much as $280 million. And because of major indirect effects, total economic activity in the region would be reduced about four times as much.

The hastening of the shift to dryland farming will reduce crop production, farm income, and overall economic activity in the Texas High Plains relative to what they would have been if irrigation costs had not risen sharply. According to some estimates, the recent increase in fuel costs may cause the value of annual farm output in 21 counties of the High Plains to be reduced by as much as $280 million. And because of major indirect effects, total economic activity in the region would be reduced about four times as much. The estimated decline in annual crop value is about 34 percent of the $824 million aggregate cash receipts from crop production for these counties in 1975.

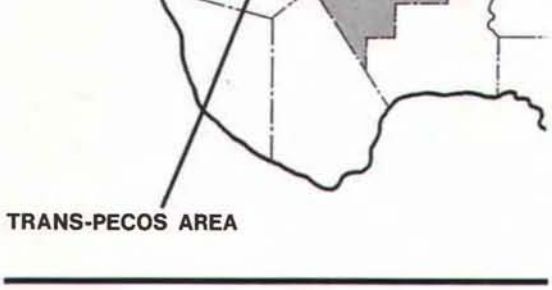
Impact of higher pumping costs

Irrigation in the Texas High Plains is used to supplement natural rainfall during periods of plant growth and fruitage. It removes variations in output caused by varying amounts of rainfall and, thus, can increase crop yields considerably. The larger yields from irrigation, on average, account for about three-

Effects of higher irrigation costs in the Trans-Pecos area

The effect of the recent surge in irrigation costs has been even more damaging for the Trans-Pecos area of Texas—consisting of Culberson, Pecos, and Reeves counties—than for the Texas High Plains. Natural gas prices in the Trans-Pecos area, where crop production is almost totally dependent on irrigation, rose from about 40 cents per 1,000 cubic feet to $1.85 and higher in a relatively short time, dramatically increasing pumping costs. The almost fivefold jump in prices caused irrigation costs to rise sharply, from around $2.12 per acre-inch to about $3.40.

The rise in irrigation expenses has moved break-even costs of production for most Trans-Pecos farmers well above market prices and resulted in a sharp downturn in farming activity. Land, farming equipment, and irrigation machinery have been idled, and some cropland has been converted to pasture. In addition, agribusiness and marketing activities—cotton ginning, farm machinery sales, and sales of other inputs—are nearly at a standstill. In fact, some supply firms have relocated elsewhere.



TRANS-PECOS AREA

With fields unplanted and farm incomes reduced, irrigated land values have plummeted as much as $150 per acre in the past two years from about $350 per acre. And declines in income and land values have caused defaults on farm mortgage loans. A number of farmers have been declared bankrupt, either voluntarily or involuntarily.

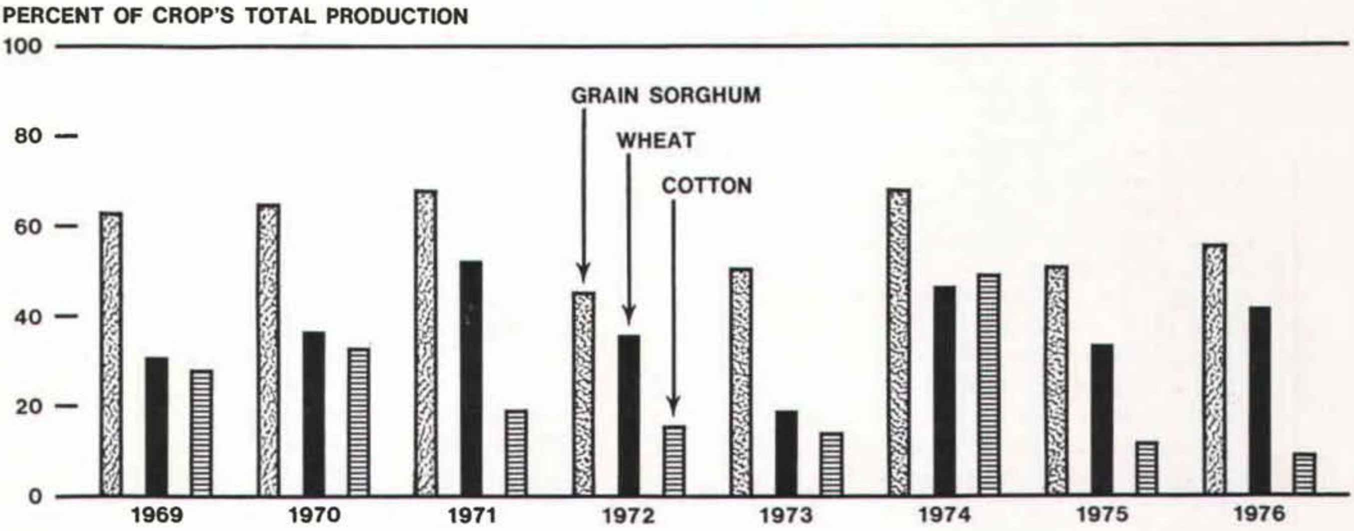
While the escalation in natural gas prices served a severe blow to the Trans-Pecos economy, major adjustments in cultivation practices and water use could support some continued crop production in the area. The application of more efficient water management practices will be required.

Early this year, the Texas Agricultural Extension Service published a study—by a team that included an entomologist, agronomist, agricultural economist, county agent, and irrigation specialist—of the Trans-Pecos area.[1] The general objective was to demonstrate how more efficient use of water and other resources could reduce costs and provide a basis for profitable agriculture there.

Where irrigation on cotton in the area had typically been ranging from 40 to 80 acre-inches of water, applications were reduced to as low as 15 acre-inches and the amount of fertilizer applied was reduced a third. Because of reduced plant foliage from less water, pest damage was negligible and insect control applications were eliminated. Moreover, yields for the lower irrigation levels averaged about the same as for the higher irrigation levels that had been common. As total costs per unit of output were reduced sharply, a significant net profit per acre—instead of a loss—was realized. While these results were obtained on small acreages under careful and expert management, the findings are nevertheless indicative that there are important opportunities to adapt to the new circumstances.

1. Kenneth E. Lindsey et al., *Texas Econocot System Upland Cotton Demonstration in Pecos County, 1976* (College Station: Texas A&M University System, Texas Agricultural Extension Service, 1977).

Portion of Major Crops in Texas High Plains Attributable to Higher Yields from Irrigation



SOURCES: Texas Department of Agriculture.
U.S. Department of Agriculture.

fifths of the grain sorghum, two-fifths of the wheat, and slightly less than a fourth of the cotton harvested in the High Plains.

This area contributes significantly to overall crop production and farm income in Texas. A large portion of the state's major crops—cotton, grain sorghum, wheat—is produced in the High Plains. The area grows more than half the cotton and wheat and over two-fifths of the grain sorghum produced in Texas. It also accounts for over two-thirds of the total irrigated acreage in Texas.

The major source of irrigation water in the High Plains—the Ogallala aquifer—is a relatively fixed supply of water, and economic depletion of the resource is inevitable at current rates of pumpage. Withdrawal for irrigation and other uses greatly exceeds natural renewal, which is limited to percolation from rainfall and irrigation. In 1976 alone, the water table declined about 2.22 feet, on average, in the 15 central counties of the Texas High Plains.[1]

As the groundwater level declines, pumping costs increase because more energy is required to pump water from greater depths. For example, for a 300-gallon-per-minute turbine well powered by natural gas costing $1.50 per 1,000 cubic feet, estimated fuel costs for furrow irrigation rise from 98 cents per acre-inch to $1.20 as pumping lift increases from 225 feet to 275 feet. In addition, a decline in the water table eventually leads to a reduction in pump yields. To compensate for lower well capacities, farmers have been drilling additional wells, but this further increases total irrigation costs.

Natural gas is the fuel used to power 64 percent of the irrigation motors in the High Plains. Prices paid by farmers for natural gas in the area have more than tripled since 1974, whereas prices paid for other production items have risen about 80 percent. And by the end of 1977, fuel costs for operating the motors may be up almost fourfold. Natural gas prices in the High Plains were about 40 cents per 1,000 cubic feet in 1974; rates currently average around $1.30. In some areas, rates are as high as $1.85 to $2.00 per 1,000 cubic feet. But prices of other energy sources—electricity, diesel fuel, and propane—have also risen dramatically, making natural gas still the cheapest fuel for deep, large-capacity wells.

Fuel costs now account for as much as a third of the total costs of irrigation. Irrigation costs, in turn, make up a like proportion of total production expenses. While energy shortages and rising fuel prices set the stage for a serious loss of output and income in agriculture, many farmers still have opportunities to adjust production practices to help alleviate the impact.

1. Don Smith, "Depth-to-Water Measured in District Observation Wells," *The Cross Section*, High Plains Underground Water Conservation District No. 1, March 1977, p. 4.

Costs of alternative irrigation techniques

With furrow irrigation, the estimated fuel cost for running a 500-gallon-per-minute well with a 250-foot lift is about $1.09 per acre-inch at a natural gas price of $1.50 per 1,000 cubic feet, with the irrigation costs totaling about $3.74 per acre-inch. Using a similar well to run a sprinkler system pumping at 40 pounds of pressure per square inch would incur a fuel cost of about $1.50 per acre-inch and total irrigation costs of about $4.19 per acre-inch. However, for one preplant plus three postplant applications, the furrow method requires 22 acre-inches of water, bringing total irrigation costs to $82.28 per acre; the sprinkler method uses only about 13 acre-inches, resulting in total costs of $54.47 per acre. But while irrigation costs are lower with sprinkler systems, yields are often somewhat lower too.

A limiting factor in replacing traditional furrow irrigation with sprinkler systems is the large initial capital investment. Costs of new sideroll and center pivot sprinkler systems, a fourth of a mile long and installed in the field, range as high as $4,000 to $5,000 and $30,000 to $35,000, respectively. A 1,320-foot sideroll system is adequate for about 80 acres, while the center pivot system will cover 160 acres. So, investment per acre ranges from around $50 to $60 for the sideroll and from $188 to $220 for the center pivot. Reflecting the lower initial costs, there are more sideroll systems in the High Plains even though center pivots are more efficient.

The initial cost of installing a new well in the center of a field for a center pivot system may also be restrictive. The drilling cost and outlays for pump, motor, gearhead, column pipe, and casing currently total close to $21,000 for a 600-gallon-per-minute, 225-foot well powered by natural gas. On a quarter section, a new well of this size would increase investment in irrigation facilities by about $131 per acre.

ESTIMATED IMPACT OF HIGHER NATURAL GAS PRICES ON FUEL COSTS PER ACRE-INCH FOR ALTERNATIVE IRRIGATION SITUATIONS IN TEXAS HIGH PLAINS, MID-1977

Irrigation method	Well capacity (Gallons per minute)	Lift (Feet)	Fuel consumption (1,000 cubic feet per acre-inch)	Natural gas prices per 1,000 cubic feet					
				$0.42	$0.75	$1.28	$1.50	$1.85	$2.50
Furrow	300	225	.652	$0.27	$0.49	$0.83	$0.98	$1.21	$1.63
	500	250	.725	.30	.54	.93	1.09	1.34	1.81
	500	350	1.015	.43	.76	1.30	1.52	1.88	2.54
	700	300	.870	.37	.65	1.11	1.30	1.61	2.17
	700	400	1.159	.49	.87	1.48	1.74	2.14	2.90
Sprinkler									
Sideroll[1]	300	225	.920	.39	.69	1.18	1.38	1.70	2.30
	500	250	.993	.42	.74	1.27	1.49	1.84	2.48
	500	350	1.282	.54	.96	1.64	1.92	2.37	3.21
	700	300	1.138	.48	.85	1.46	1.71	2.10	2.84
	700	400	1.428	.60	1.07	1.83	2.14	2.64	3.57
Center pivot[2]	500	250	1.193	.50	.90	1.53	1.79	2.21	2.98
	500	350	1.483	.62	1.11	1.90	2.22	2.74	3.71
	700	300	1.338	.56	1.00	1.71	2.01	2.48	3.35
	700	400	1.628	.68	1.22	2.08	2.44	3.01	4.07

1. Operated at 40 pounds of pressure per square inch.
2. Operated at 70 pounds of pressure per square inch.

For one thing, many farmers often irrigate in excess of actual requirements. In most cases, applying water at the rate that best fits crop and soil characteristics would mean less water would have to be pumped to produce an expected yield. Water meters may be attached to aboveground outlet pipe to measure the amount of water pumped per unit of time. Instead of attempting to maximize yields, a farmer should employ water and other inputs to produce a yield that will maximize returns per dollar of input.

Where furrow irrigation is used, significant water and cost savings are frequently possible by irrigating alternate rows and/or shortening row lengths. Although some reduction in yields is generally to be expected, shifting to skip-row watering patterns for row crops can reduce pumping costs per unit of output. And shortening row lengths can reduce seepage waste and lead to more even distribution of water.

Other savings may be had by repairing or replacing old pumping units. The efficiency of many gas-powered turbine units is as low as 10 percent. The efficiency of such units could easily be increased to 20 percent, lowering consumption and costs of fuel by as much as a half.

Many farmers have been adjusting to the declining water supply in the Texas High Plains by changing from furrow to sprinkler irrigation. When water seepage and evaporation losses are taken into account, sprinkler systems are approximately 50 percent more efficient in use of water than is furrow irrigation. Moreover, sprinkler systems require less labor per acre. These savings are partially offset, however, by the fact that irrigation costs per acre-inch of water applied are somewhat higher for sprinkler systems because of the larger energy requirements for pumping water under pressure. Repair, maintenance, and overhead costs per acre-inch are also higher for sprinkler systems.

Implications for regional economy

Rising irrigation costs in the Texas High Plains point to a sharper downtrend in irrigation and economic adjustment to increased dryland production. The reversion to dryland production would otherwise have been more gradual as the water in the Ogallala aquifer was depleted.

Prior to the sharp rise in irrigation costs, forecasts had placed the end of the economic life of the water supply at about 1990 in the southern tip and 2010 to 2020 on the northern edge of the High Plains. But the timetable for economic depletion of the irrigation water may have been speeded up as much as 20 years in most areas.

Isolated areas in the Texas High Plains have already experienced declines in irrigated acreage as wells have gone dry or well capacities have fallen below economical levels. And at current natural gas prices and irrigation costs, a large number of areas with shallow water and low well capacities, such as in the southern High Plains, are likely to shift to dryland production within the next few years. In the northern High Plains and areas with deeper water supplies and larger well capacities, the timetable for economic depletion may have shifted to as early as 1990—even assuming that future irrigation costs rise at a moderate annual rate.

The projected decline in the direct value of agricultural output would be a significant proportion of total cash receipts. Using data for cash receipts in 1975, the decline would be equal to a third of the $824 million in crop sales that year.

The Texas Water Resources Institute has completed a study measuring the effects of higher natural gas prices on the average amount of irrigation, production, and net returns to farmers in the Texas High Plains.[2] On the basis of 1971-74 average prices for corn, grain sorghum, cotton, wheat, and soybeans, the study concludes that when the price of natural gas is $0.80 to $2.12 per 1,000 cubic feet, marked declines in income tend to occur but there is little reduction in irrigated acreage or production. Sharp reductions in net returns, irrigated acreage, and production would take place at natural gas prices above $2.12 per 1,000 cubic feet. Currently, the average price of natural gas in the area is about $1.30.

Eventual reversion to increased dryland farming in the Texas High Plains will cause yields to decrease, lowering total crop production and farm income. And reduced farm income will cause land values to decline. Farmers will likely attempt to maintain income levels by enlarging their farms. But farm enlargement by purchase will likely be limited, as the capital generated internally at reduced income levels may be insufficient to cover family living expenses and finance land purchases.

2. Ronald D. Lacewell and Gary D. Condra, *The Effect of Changing Input and Product Prices on the Demand for Irrigation Water in Texas,* Texas A&M University, Texas Water Resources Institute Technical Report no. 75 (College Station, 1976).

Alternatives to purchasing land for expansion would be cash-leasing additional land and crop share-renting. While providing the opportunity to spread fixed costs over more acreage, farm enlargement by leasing or share-renting may also be restricted by the inability to finance acquisition of additional capital assets—machinery and equipment—when returns per acre are low.

The less intensive production under dryland conditions will reduce the demand for fertilizer, machinery, equipment, and supplies. Fewer firms will be required to provide farm supplies and services. And the volume and revenues of agricultural marketing and processing firms will be diminished. With incomes of agricultural producers, suppliers, and marketing firms declining, purchases of nonagricultural goods and services will be curtailed, lowering overall trade activity in the region. Consequently, agricultural employment will be adversely affected. Labor released from agriculture could possibly be used in business and manufacturing, however.

Economic depletion of the aquifer for farming should not have a significant impact on water consumption by nonagricultural users. The aquifer will not be physically exhausted, and these users should be able to pay the higher prices for water. Moreover, water consumption by most nonagricultural users in the area is generally negligible compared with that of agriculture. But the indirect effects of declining irrigation on the nonagricultural sector of the economy could be quite severe.

The impact on the area's economy of reductions in irrigated crop production can be estimated with multipliers developed by Osborn and Harris.[3] In their analysis, direct effects are defined as the change in the value of crop production derived from changes in the amount of irrigation. Indirect effects include changes in purchases of supplies associated with the production of irrigated crops. And "stemming-from" effects are changes in the output of all processing sectors resulting from the interdependence of industries in the region.

3. J. E. Osborn and T. R. Harris, *Economic Analysis—Interindustry Effects of a Declining Groundwater Supply, Southern High Plains of Texas,* Texas A&M University, Texas Agricultural Experiment Station B-1134 (College Station, 1973), pp. 10-11.

On the basis of 1967 prices, Osborn and Harris estimated that for a direct change of $1.00 in irrigation output, there will be indirect and stemming-from effects of $1.75 and $1.50, respectively. The total impact of a dollar's worth of reduction in irrigated crop production, then, comes to $4.25, according to these estimates.

Adjusting the Osborn-Harris estimates for price changes and assuming current technology, even before the recent increase in energy costs the value of agricultural output in the Texas High Plains could have fallen at least $280 million per year, in 1977 dollars, from 1980 to 2000 as a result of the declining water table.[4] The increase in irrigation costs due to more expensive energy may produce a decrease in annual farm output about equal to what otherwise would have occurred over this 20-year period.

Therefore, the higher fuel costs for irrigation could have a total impact on the economy of the Texas High Plains that is at least 4.25 times this figure—or about $1.2 billion per year. This estimate assumes that the unutilized resources either remain unemployed or move to other areas. But the projected decline in the direct value of agricultural output would be a significant proportion of total cash receipts. Using data for cash receipts in 1975, the decline would be equal to a third of the $824 million in crop sales that year.

4. This estimated dollar impact is for a 21-county area accounting for the major portion of irrigation activities in the Texas High Plains.