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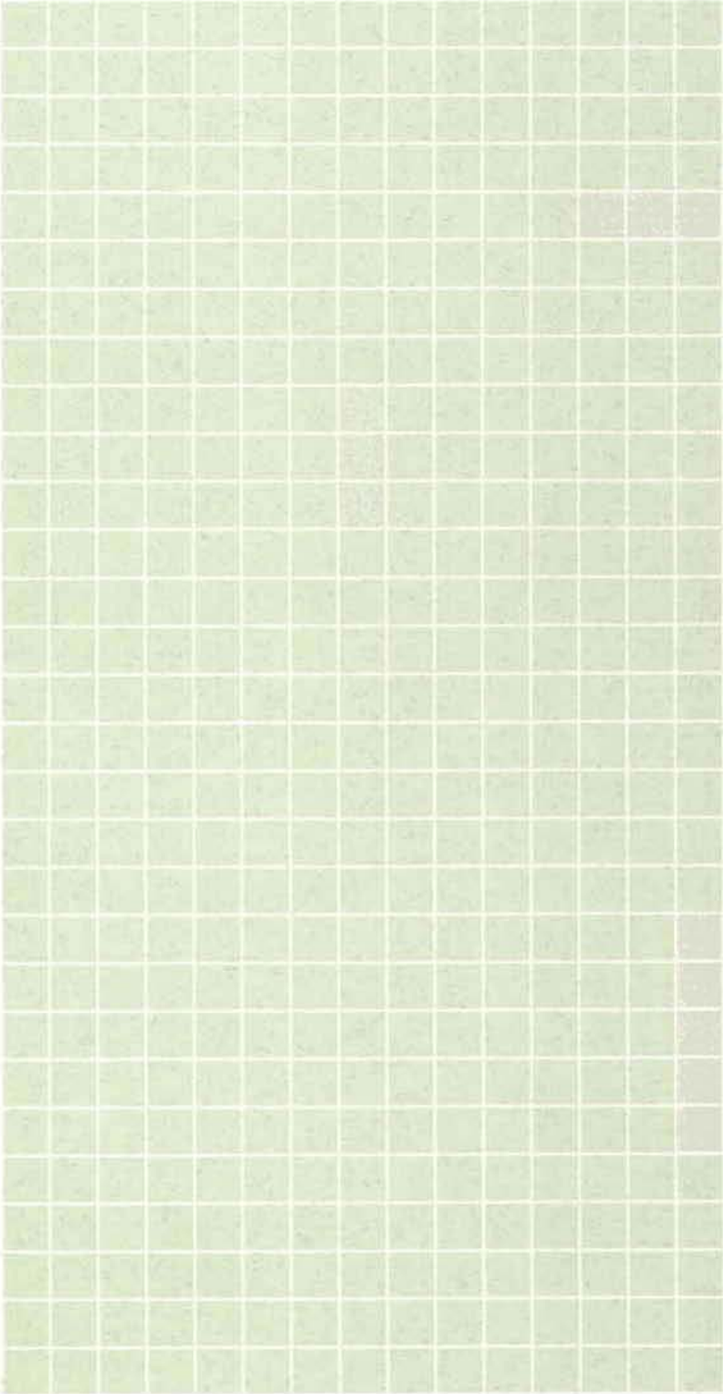
January 1989

# Economic Review



## *Oil Demand and Prices in the 1990s*

Stephen P. A. Brown and
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## *Texas in Transition: Dependence on Oil and the National Economy*

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Current oil prices are too low to be sustained in the 1990s. Stephen Brown and Keith Phillips forecast that by the year 2000, the price of oil (in 1988 dollars) could reach $30 to $40 per barrel. Adjusted for inflation, these prices are about 60 to 80 percent of the peak price established in early 1981.

Brown and Phillips find that during the 1980s a slow adjustment process, encouraged by OPEC actions, reduced oil demand and put downward pressure on prices. They expect reversal of that process in the 1990s will work with world economic expansion to boost oil demand and prices.

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## *Texas in Transition: Dependence on Oil and the National Economy*

**Thomas B. Fomby and Joseph G. Hirschberg**

Although Texas may once have appeared immune to national business cycles, the state's economy no longer has such immunity. Thomas Fomby and Joseph Hirschberg quantify the degree to which the Texas economy's responsiveness to oil prices and the national economy has changed. They find that Texas nonagricultural employment is 62 percent *less* sensitive to unexpected changes in real oil prices and 338 percent *more* responsive to unexpected changes in national employment.

Fomby and Hirschberg also develop measures of the degree of dissimilarity between the Texas and national economies. They find that these dissimilarity measures, which reflect differences in economic structure between Texas and the nation, bear a closer relation to real oil prices than does state employment.

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# Oil Demand and Prices in the 1990s

Despite excess capacity in OPEC, current oil prices are too low to be sustained through the 1990s. Surprisingly, a forecast of renewed OPEC solidarity has little to do with this outlook. Rather, increasing demand will gradually push OPEC to full capacity and prices to higher levels during the next decade.

In fact, OPEC is only part of the explanation for falling oil prices during the 1980s. Though OPEC has dominated the news about the subject, falling oil demand better explains the more than 70-percent decline in inflation-adjusted oil prices from early 1981 to late 1988. Over much of the 1980s, world oil consumption declined. Only a decrease in demand—not a change in supply conditions—can explain both lower prices *and* lower consumption.

The simplest explanation for the decrease in demand is what might be called "non-price conservation"—that is, technological change that shifted demand inward independently of the influence of prices. But this simple explanation is not supported by the facts. In our recent econometric analysis of U.S. oil demand, we found no evidence of non-price conservation.[1]

Instead, we found that a slow adjustment process, encouraged by OPEC, shifted oil demand inward during the 1980s—despite world economic expansion. During the 1990s, a reversal of that adjustment process will work with world economic expansion to boost oil demand. Our forecast of rising demand and prices in the 1990s rests on an understanding of that adjustment process.

## Oil demand and prices in the 1980s

Oil demand in the late 1980s contrasts sharply with that in the beginning of the decade. In the first quarter of 1981, world oil consumption was about 56 million barrels per day and the price of oil was $48.64 per barrel. (All prices cited are the composite refiner acquisition cost for crude oil in 1988 dollars per barrel). In the first quarter of 1988, world oil consumption was again about 56 million barrels per day. Yet the price of oil had dropped to $15.47 per barrel despite worldwide economic expansion. A series of events contributed to this development.

The Iranian revolution and the onset of the Iran-Iraq war reduced world oil production between 1979 and 1981, pushing prices up. Because short-run oil demand is very inelastic, the reduction in supply pushed prices sharply higher.

The oil consumption and price combination that prevailed in the first quarter of 1981 could not be sustained in the long run. In the absence of economic growth, a sustained price of $48.64 per barrel would have eventually reduced U.S. oil consumption, for example, by about 40 percent—from 16.5 to 10.2 million barrels per day. On the other hand, for U.S. consumers to continue to absorb 16.5 million barrels per day without economic growth eventually would have required an estimated price of only $20.61 per barrel (*See Chart 1*).

We estimate that U.S. consumers require nearly a decade to adjust fully to changes in oil prices (*See box, page 7*). Oil consumption responds slowly to price changes because substan-

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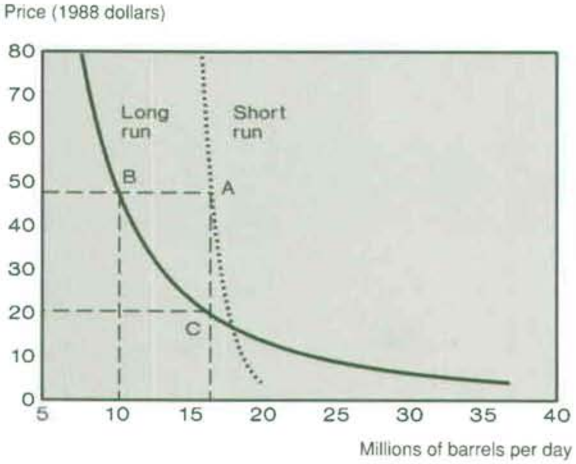
*The authors would like to thank Phil Trostel, Ken Robinson, Linda Hunter and Jerry O'Driscoll for helpful comments without implicating them in our conclusions.*

[1] *See Brown and Phillips (1989).*

Chart 1
U.S. Oil Demand in First Quarter 1981



*In the first quarter of 1981, the price of oil was $48.64 per barrel (in 1988 dollars) and U.S. oil consumption was 16.5 million barrels per day (shown as point A). At this price, consumers would have reduced consumption to 10.2 million barrels per day (point B) over the long run in the absence of economic growth. On the other hand, for consumers to continue to absorb 16.5 million barrels per day would have required an estimated price of $20.61 per barrel (point C) over the long run without economic growth.*

*The figure represents actual model estimates.*

tial changes in the ratio of oil consumption to output require new capital investment.

As short-run demand adjusted to prices during the 1980s, the market price and quantity of oil consumed were pushed down. Non-OPEC oil producers added to the downward pressure on price as their production increased. Beginning in 1981, however, OPEC moderated downward pressure on prices by reducing its own production (*See Chart 2*).

Nonetheless, short-run demand continued to decline and non-OPEC oil production continued to rise. OPEC's continued attempts to support prices reduced its production to about 14 million barrels per day by mid-1985, less than 50 percent of its total capacity.

OPEC's attempts to support prices ended in a well-publicized failure. Excess capacity and the incentive for OPEC members to cheat on quotas led to a surge in OPEC production. With demand being very inelastic in the short run, that surge in production caused a price break in late 1985 and early 1986. Thereafter, OPEC was unable to restrain its production sufficiently to drive prices back up to earlier levels.

Given our evidence that consumption responds symmetrically to rising and falling oil prices, the current price and quantity combination is too low to be sustained in the long run.[2] Even in the absence of economic growth, the first quarter price of $15.47 per barrel would eventually increase U.S. oil consumption, for example, by an estimated 35 percent—from 17 to 23 million barrels per day. On the other hand, for U.S. consumption to remain at 17 million barrels per day in the long run, prices must rise to an estimated $26.63, even without economic growth (*See Chart 3*).

## Oil demand and prices in the 1990s

In the 1990s, short-run demand can be expected to rise from the unsustainable combination of oil consumption and price that characterizes the late 1980s. Adjustment will be slow. Nevertheless, together with a growing world economy, the adjustment will contribute to strong growth in oil demand during the 1990s.

Using the estimated coefficients from our model of U.S. oil demand, we constructed 21

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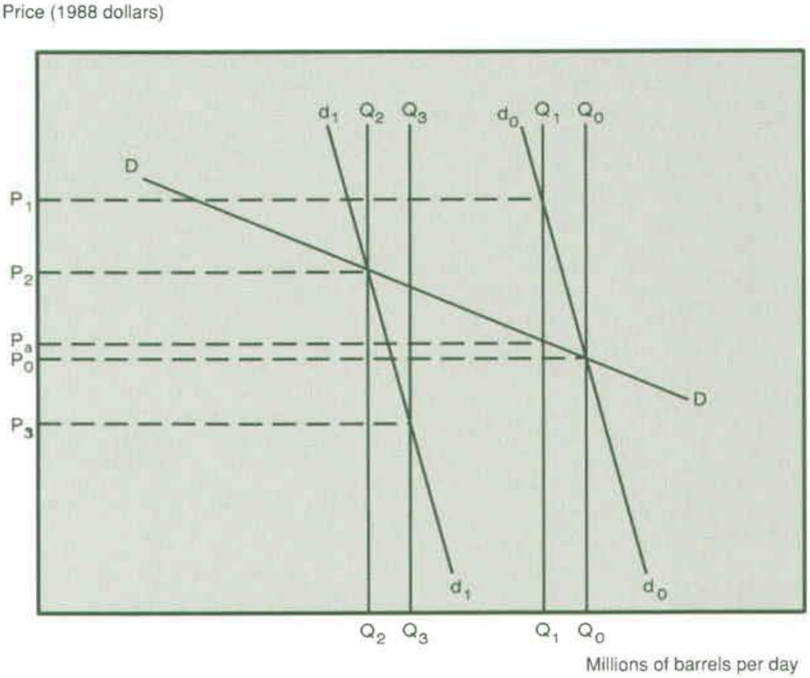
[2] *See Brown and Phillips (1989).*

## Chart 2
## A Graphical Analysis of Price and Quantity Movements in the 1980s

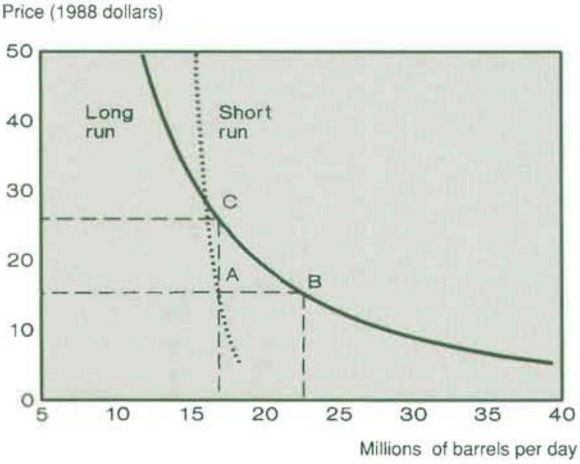
*In early 1979, both OPEC and non-OPEC producers were producing at close to full capacity. The Iranian revolution and the onset of the Iran-Iraq war reduced oil production from $Q_0$ to $Q_1$, initially pushing the price up along the short-run demand curve, $d_0d_0$, from $P_0$ to $P_1$. So long as the market price and quantity lies above the long-run demand curve, DD, the short-run demand curve shifts inward. As the short-run demand curve shifts inward, the price falls from $P_1$. Without further changes in production, short-run demand would have shifted inward until a price of $P_a$ was established.*

*In an attempt to sustain high prices, OPEC gradually reduced output to $Q_2$. Consequently, short-run demand shifted inward along the long-run demand curve to $d_1d_1$, establishing a price of $P_2$. When OPEC increased production from $Q_2$ to $Q_3$, it drove the price down to $P_3$. Because the market price and quantity lie below the long-run demand curve, the short-run demand curve will shift outward.*

*This analysis represents an abstraction of price and quantity movements in the 1980s. As such, it does not consider the long-run profit implications for OPEC behavior. Nor does the analysis reflect the increase in long-run demand that occurred during the period.*



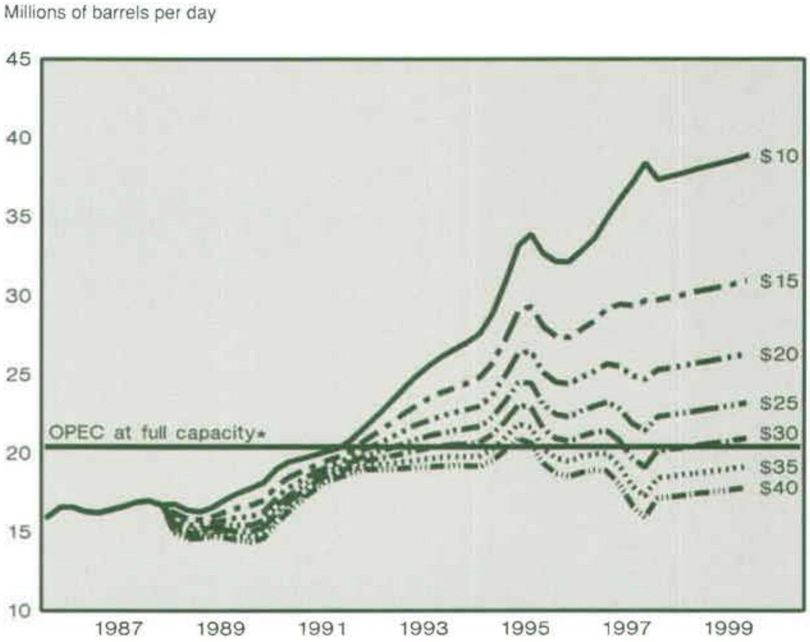
## Chart 3
## U.S. Oil Demand in First Quarter 1988



*In the first quarter of 1988, the price of oil was $15.47 per barrel and U.S. oil consumption was 17 million barrels per day (shown as point A). At this price, consumers would increase consumption to 23 million barrels per day (point B) over the long run, even without economic growth. On the other hand, consumers would absorb 17 million barrels a day at an estimated price of $26.63 per barrel (point C) over the long run, even without economic growth.*

*The figure represents actual model estimates.*

Chart 4
U.S. Oil Consumption with 2.0-Percent Annual GNP Growth



* U.S. consumption that pushes OPEC to full capacity (*See text*).

scenarios for U.S. oil consumption under a variety of assumptions about oil prices and GNP growth. We examined the effects of oil prices from $10 to $40 per barrel and of real-GNP growth from 2 percent to 3 percent annually. We assumed no changes in energy taxation and no recessions. The scenarios show relatively little evidence of consumption growth through 1989 (*See Charts 4 through 6*). We project much stronger consumption growth in the early 1990s than in previous years, as demand shifts outward. For the 1990s, we project potential growth rates of U.S. oil consumption ranging from a low of 2.1 percent to 9.5 percent annually (*See Table 1*).

If other countries behave similarly to the United States, many of our consumption projections will prove too high to be sustained throughout the 1990s; oil consumption cannot rise above world capacity to produce oil. And little capacity is likely to be added with the low oil prices that will bring about rapid growth in oil consumption. Clearly, some of the prices we used to project oil consumption in the 1990s are too low to survive the decade.

Previous studies have shown that, as OPEC is pushed to full capacity, oil prices rise.[3] Because nearly all excess capacity to produce oil is in OPEC, we take "pushing OPEC to full capacity" to mean "pushing world oil production to full capacity." To assess what oil prices might prevail by the end of the century, we assumed that world oil consumption will grow at the same rate as U.S. consumption.[4] Given this assumption, world oil production will be pushed to full capacity when U.S. oil consumption rises to 20.4 million barrels per day.

Under nearly all of our scenarios, the growth in oil consumption pushes OPEC close to full capacity between late 1992 and early 1995 (*See Charts 4 through 6*). At or below a price of $25 dollars per barrel, OPEC could reach full capacity

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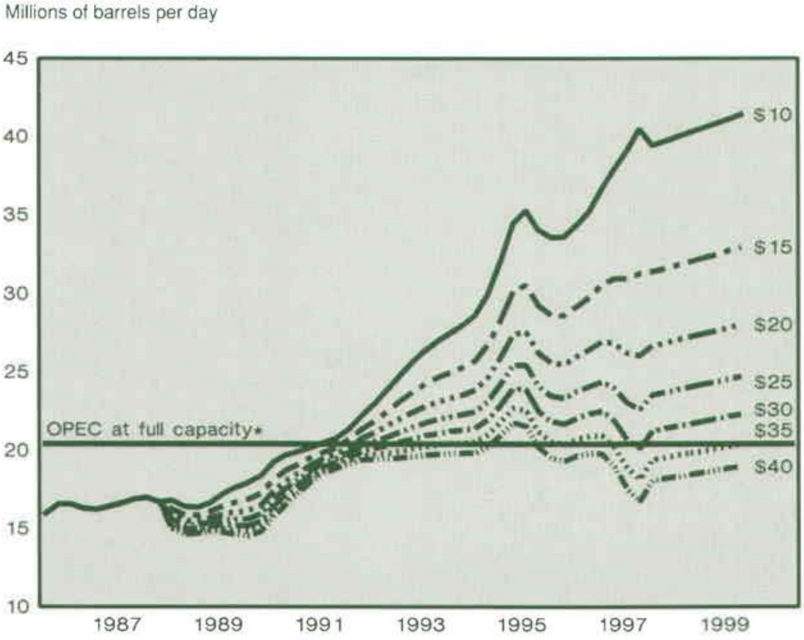
[3] *See Gately (1984).*

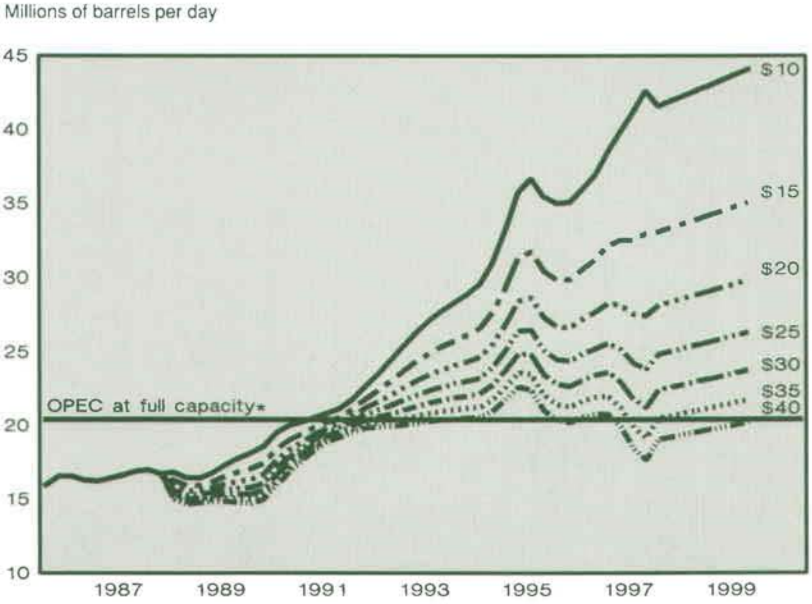
[4] *Higher energy taxes outside the United States undoubtedly mute the effect of changing crude oil prices on world oil consumption. Nevertheless, our previous research shows that the long-run crude oil demand elasticities for the other six major free-world countries are similar to that for the United States. See Brown and Phillips (1984).*

Chart 5
U.S. Oil Consumption with 2.5-Percent Annual GNP Growth



* U.S. consumption that pushes OPEC to full capacity (*See text*).

Chart 6
U.S. Oil Consumption with 3.0-Percent Annual GNP Growth



* U.S. consumption that pushes OPEC to full capacity (*See text*).

Table 1

**Projected Growth Rate of U.S. Oil Consumption During the 1990s (Annual average percent)**

| | Annual GNP Growth Rate | | |
|---|---|---|---|
| Price* | 2.0% | 2.5% | 3.0% |
| $10 | 8.3 | 8.9 | 9.5 |
| $15 | 6.5 | 7.1 | 7.6 |
| $20 | 5.2 | 5.7 | 6.3 |
| $25 | 4.2 | 4.7 | 5.3 |
| $30 | 3.4 | 3.9 | 4.5 |
| $35 | 2.7 | 3.2 | 3.8 |
| $40 | 2.1 | 2.7 | 3.2 |

* Composite refiner acquisition cost for crude oil in 1988 dollars

no later than the first quarter of 1993. By that year, a price of $25 per barrel could prove too low—if world oil capacity does not rise. Similarly, with world economic growth rates between 2.0 percent and 3.0 percent, oil prices will reach $30 to $40 per barrel by the year 2000.[5]

## Summary and conclusion

Current oil consumption and prices are unsustainably low—the result of a decrease in short-run demand brought about by adjustment to unsustainably high oil prices in the late 1970s and early 1980s. Just as long-run adjustments in demand put downward pressure on oil prices and consumption from 1981 to the present, long-run adjustments in demand will put upward pressure on prices and consumption in the 1990s. Economic expansion will add to that pressure.

After continued stagnation through mid-1989 to late 1990, forecasts constructed with our model of U.S. oil demand suggest that world oil consumption will begin to accelerate under a variety of assumptions about oil prices and economic growth. By late 1992 to early 1995, strong growth in oil consumption will push OPEC close to full capacity. As OPEC nears full capacity, prices are likely to rise sharply.

Under conservative assumptions about world economic expansion, the price of oil will rise to more than $30 per barrel by the year 2000. With less conservative assumptions about economic growth, we forecast that prices of $35 to $40 per barrel will prevail by the year 2000. Adjusted for inflation, these prices are about 60 to 80 percent of the peak price established in early 1981.

Of course, these price forecasts are dependent upon a number of assumptions. If world capacity to produce oil is decreased, if OPEC restricts its production, if oil supplies are disrupted, or if economic growth is stronger, oil prices will be higher than we have forecast. On the other hand, if world capacity to produce oil is increased, if economic growth is weaker, or if energy taxation is increased, oil prices will be lower than we have forecast. Nevertheless, rising oil prices can be expected during the 1990s.

And as in the past, rising oil prices can be expected to reshape world economic activity. Rising oil prices will strengthen economic growth in energy-exporting countries while hindering economic growth in energy-importing countries like the United States. Within the United States, the price rise will cut unevenly, with energy-producing regions benefitting and energy-consuming regions suffering.[6]

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[5] *Of course, world oil capacity is unlikely to remain fixed. It grew by about 7 percent over the last decade. If capacity grows by another 7 percent, OPEC will be pushed to full capacity when U.S. oil consumption is 21.9 million barrels per day. In that case, the price of oil could be as much as $5 per barrel lower in the year 2000. If capacity falls 7 percent, OPEC will be pushed to full capacity when U.S. oil consumption is 19.0 million barrels per day. In that case the price of oil could be as much as $5 per barrel higher in the year 2000.*

[6] *See Brown and Hill (1988), Considine (1988), Hamilton (1983), Moroney (1988a, 1988b), and Tatom (1988).*

## Estimating U.S. Oil Demand*

We modelled U.S. oil consumption as a function of the general level of economic activity, the share of output in the industrial sector, and past and present real prices of crude oil. To allow for lags in price, but be parsimonious in estimating the model, we restricted the effects of price on consumption to a polynomial distributed lag. We used statistical tests to optimize the number of lags on price at 38 quarters and the degree of polynomial at 9.

We estimated the model in natural logs, so that the coefficients can be interpreted as elasticities. With quarterly data from the first quarter of 1972 through the first quarter of 1988, we estimated the coefficients shown in Table B1.

As indicated by the adjusted $R^2$ and the overall *F*-value for the regression, the model fits the data well. With the exception of the industrial production variable, the coefficients are significant and of the right sign. A low *F*-value found for the polynomial restriction indicates that the restriction is not objectionable.

The estimated coefficients for price and its lags indicate a short-run (same quarter) price elasticity of oil demand of -0.08 and a long-run price elasticity of demand of -0.56. At 1.13, the estimated coefficient for GNP indicates an income elasticity of demand that is not significantly different from one. The coefficient for industrial production's share of GNP is not different from zero at the 5-percent level of significance.

Though similar, our approach improves upon that used by Gately and Rappoport (1988). They used ad hoc methods to select lag length and the degree of polynomial, while we used statistical procedures. In addition, their model was estimated with annual data and suffers from a very high degree of autocorrelation in the residuals. Our model was estimated with quarterly data and shows no significant autocorrelation.

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*For a more detailed discussion of the model, see Brown and Phillips (1989). For a copy of this technical paper, write Research Department, Federal Reserve Bank of Dallas, Station K, Dallas, TX 75222.

**Table B1**

Estimated Coefficients for U.S. Oil Consumption

| | Intercept | Oil price in period t | Oil price in periods t-1 to t-38 | Real GNP | Industrial production share of GNP |
|---|---|---|---|---|---|
| Coefficient | 2.01 | –0.08 | –0.48 | 1.13 | –0.23 |
| t-statistic | 2.62 | –5.64 | 70.22** | 11.80 | –1.73 |

| Summary Statistics: | | |
|---|---|---|
| | Overall *F*-Value | 77.86 |
| | Adj $R^2$ | 0.93 |
| | Durbin-Watson | 1.69 |
| | *F*-value for polynomial | 0.54 |

**The statistic reported for the lagged values of the oil price is an *F*-statistic.

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# Texas in Transition: Dependence on Oil and the National Economy

"As the oil patch goes, so goes the Texas economy," according to the conventional economic wisdom of the day. Another popular wisdom would have it that "where the national economy goes, the Texas economy need not follow." Although casual inspection of the Texas economic data tends to support these wisdoms, a closer examination of the data—while allowing for structural change in the Texas economy from one Texas business cycle to the next—indicates that the conventional wisdoms probably no longer hold.[1]

This article evaluates these wisdoms critically. The article finds that the Texas economy is probably losing its independence vis-à-vis the national economy and, at the same time, appears to be growing less dependent on fluctuations in the price of oil. In fact, in comparing the Texas economy over the period 1974:Q1–1983:Q1 with the Texas economy over the period 1983:Q2–1988:Q1, our analysis indicates that, as of the latter period, the Texas economy is approximately 62 percent *less* sensitive to unexpected changes in real oil prices while being 338 percent *more* sensitive to unexpected changes in nonagricultural employment in the rest of the United States.

The reduced sensitivity of the Texas economy to oil price shocks and its increased openness vis-à-vis the economy of the rest of the nation are probably largely due to the fact that during the first period, Texas mining and manufacturing became 35 percent more specialized because of substantial growth in the oil and gas extraction industry. In the latter period, largely because of retrenchment in the oil and gas extraction industry, Texas mining and manufacturing became progressively more similar to the same sectors in the rest of the United States, to the point of being as similar to the rest of the United States as in 1975.[2]

In the second section, an economic history of Texas in the 1970s and 1980s is presented and casually inspected for the oil dependence and "maverick" traits in the Texas economy. Some data presented in the third section suggest that the Texas economy has been and continues to be in transition from an economy dependent on oil to one that more closely resembles the economy of the rest of the nation. In the fourth section, a small vector autoregressive model of the Texas economy is constructed that emphasizes the interplay between employment in the state, oil prices, and the national economy as measured by employment in the United States excluding Texas. Finally, some conclusions suggested by this research are presented in the last section of this article.

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[1] *The discussion here probably overstates the case that the above wisdoms are conventional and represent the majority view of watchers of the Texas economy. On the contrary, after watching the recent performance of the Texas economy, many may hold the perspectives uncovered by this article. However, setting up a straw man view that could easily be derived by inspecting the data casually offers a good counterpoint for a beginning discussion.*

[2] *No attempt is made here to provide a theoretical framework for analyzing either the role of regional sectoral shocks in restructuring a regional economy or the nature of that restructuring. For discussions along this line, see Neumann and Topel (1984) and Schmidt and Gruben (1988).*

## The conventional wisdoms

The supposition that oil prices affect the Texas economy seems beyond question. In fact, the price of oil is a leading indicator of the Texas economy. In Chart 1 the price of oil as measured in 1982 dollars is plotted, along with the number of workers employed in the state (excluding the agricultural sector), for the period 1974–88.[3] In general, during this time, increases in employment have followed increases in oil prices but with some delay. Likewise, declining oil prices have led to lower employment. The lead relationship that the real price of oil exhibits vis-à-vis Texas employment is clearly demonstrated following the major decline in oil prices beginning in the first quarter of 1981. One year later, Texas employment peaked and declined along with declining oil prices. Subsequent leads, though shorter and less definitive, are apparent. After the price of oil plateaued in 1982, Texas employment began to recover in 1983 and continued to do so until shortly after the next major decline in oil prices in late 1985 through 1986. Texas employment has since recovered slightly, reflecting the previous slow correction of oil prices upward beginning in the third quarter of 1986. Thus, surely the Texas economy has been dependent on oil prices.[4]

Chart 1
Real Price of Oil and Texas Nonfarm Employment

Sources of Primary Data: U.S. Department of Commerce, Bureau of Economic Analysis.
U.S. Department of Energy.
U.S. Department of Labor, Bureau of Labor Statistics.

The second conventional wisdom about the tendency for the Texas economy to move independently of the national economy is casually supported when comparing the business cycles of the Texas economy with those of the nation as a whole. The Texas coincident index recently developed by Phillips (1988) can be used to delineate Texas' economic past into well-defined upturn (recovery) periods and downturn (recession) periods. With the peaks and troughs in the Texas coincident index as indicators of Texas business cycle turning points, since 1971 the Texas economy has traveled through four upturns, spanning the periods August 1971–July 1974, June 1975–August 1981, May 1983–October 1984, and the present period beginning March 1987. Three downturns in the Texas economy occurred over the periods July 1974–June 1975, August 1981–May 1983, and October 1984–April 1987. These downturns are represented by the shaded areas in Chart 2.

In contrast, the nation's economy has sustained over the same period, as classified by the National Bureau of Economic Research, four upturns dated November 1970–November 1973,

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[3] *The real price of oil used in this study was calculated by dividing the domestic refiner acquisition cost of crude oil (from the U.S. Department of Energy) by the implicit GNP price deflator (Bureau of Economic Analysis, U.S. Commerce Department). Texas employment data came from the U.S. Bureau of Labor Statistics. All data are seasonally adjusted at their source except the Texas employment data, which were seasonally adjusted by means of the X-11 procedure.*

*The refiner acquisition cost of crude oil was used here because the data are the most readily available consistent series on oil prices. Although some oil price data exist prior to 1974, most are for specific grades of crude oil, rather than for a composite of crude types. Because economic decisions are likely to have been made for Texas on the basis of more than one crude grade, we decided that a composite measure was a better choice for the present study.*

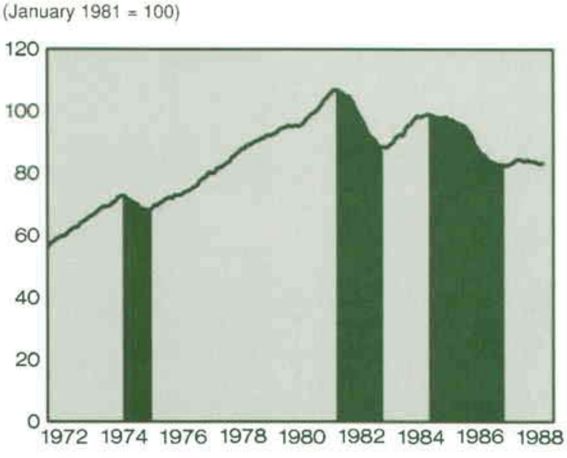
[4] *We are not trying to imply by Chart 1 and our interpretation of it that the price of oil is the only determinant of Texas employment. For example, Cox and Hill (1988) show that Texas manufacturing is moderately dependent on the value of the dollar and international trade.*

March 1975–January 1980, July 1980–July 1981, and November 1982 to present; and three downturns dated November 1973–March 1975, January–July 1980, and July 1981–November 1982. The Texas downturns (on the left) and the U.S. downturns (on the right) are represented by the juxtaposed shaded areas of Chart 3.

The supposition of a maverick Texas economy comes largely from the divergent performances of the Texas and U.S. economies over the 1970s and 1980s.[5] The national downturn of November 1973–March 1975 was matched by a Texas downturn but with a delay of roughly eight months. In addition, the Texas economy proved to be more resilient, in that the duration of the Texas downturn was approximately five months shorter. Unlike the national economy, the Texas economy did not sustain a recession during 1980, though the growth of the Texas coincident index did come to a virtual standstill. Evidently, the Texas economy was buoyed by significant increases in oil prices at the time (*See Chart 1*). What was a leg-iron for the national economy turned out to be a counterweight for the Texas economy.

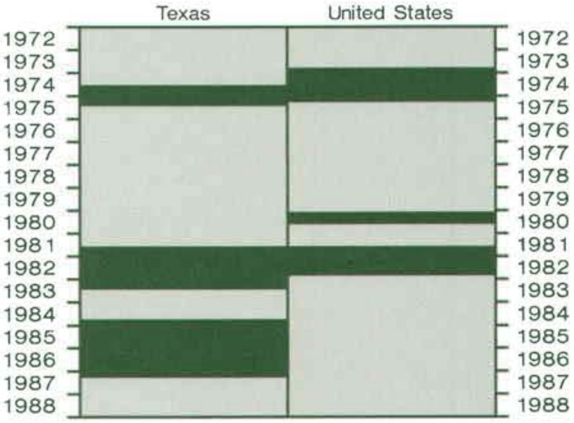
Further distinct performances occurred but with the Texas economy carrying the leg-iron. The July 1981–November 1982 national downturn was roughly matched by a Texas downturn, but the Texas economy was not as resilient this time and recovered six months later than the U.S. economy. Quite probably the extended duration of the Texas downturn during August 1981–May 1983 resulted because of the substantial fall in oil prices at the time (*See Chart 1*). Since November 1982, the U.S. economy has been enjoying the second longest upturn since the end of World War II. In contrast, the Texas economy faltered during the period October 1984–April 1987, again evidently because oil prices fell further beginning in 1984. These divergences in performance seem to support the contention that the Texas economy, because of its dependence on oil, is likely to exhibit business cycle behavior that is often distinct from that of the rest of the nation.

Chart 2
Texas Coincident Economic Indicator Index



Note: Recessions are denoted by shaded areas.
Source: Federal Reserve Bank of Dallas.

Chart 3
Comparison of Texas and U.S. Business Cycles Since 1972



Note: Recessions are denoted by shaded areas.
Sources: U.S. Department of Commerce, Bureau of Economic Analysis. Federal Reserve Bank of Dallas.

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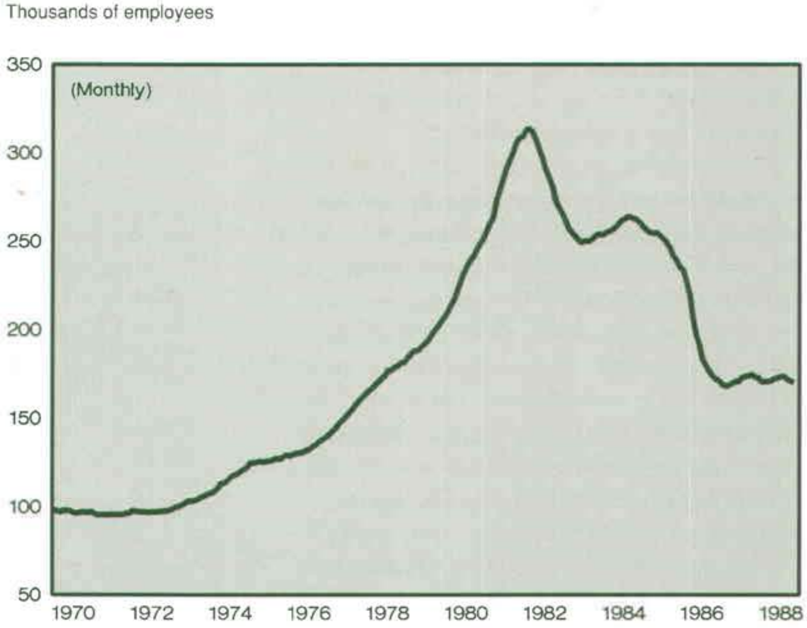
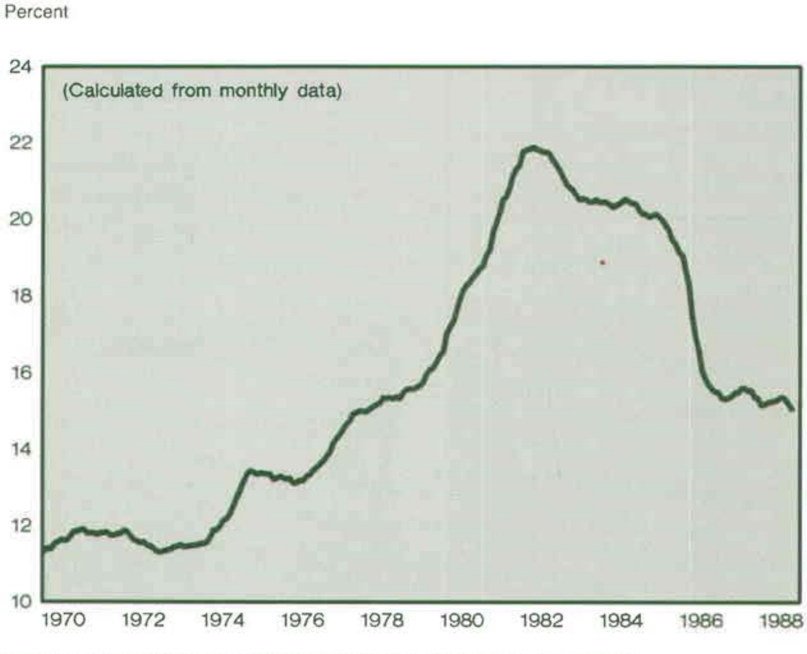
[5] The present comparisons of Texas business cycles with those of the U.S. economy are made somewhat imprecise by the fact that the simple methodology used here to determine turning points in the Texas economy is not the same methodology used by the National Bureau of Economic Research (NBER) to determine the turning points in the national economy. In fact, the NBER uses a more eclectic approach whereby a consensus is sought among many economic variables, there being no simple definition of consensus.

## Chart 4
## Texas Employment in Oil and Gas Extraction



Source: U.S. Department of Labor, Bureau of Labor Statistics.

## Chart 5
## Texas Employment in Oil and Gas Extraction as a Percentage of Texas Mining and Manufacturing Employment



Source of Primary Data: U.S. Department of Labor, Bureau of Labor Statistics.

## Indications of transition in the Texas economy

Since the major break in oil prices in 1981, the state's oil and gas extraction industry (Standard Industrial Classification Code 13) has been retrenching. Employment in this industry, expressed both as the number of workers employed and as a percentage of the Texas mining and manufacturing work force, is plotted in Charts 4 and 5.[6] Although employment in the industry from 1983 to mid-1984 responded positively to what at the time appeared to be a leveling of oil prices, employment has otherwise been in steady decline since 1982 until a recent leveling began in 1987. Likewise, the industry's share of Texas mining and manufacturing employment has fallen from a high of 22 percent in 1982 to approximately 15 percent, which was typical in 1978.

Given the smaller absolute size of the oil and gas extraction industry and its supposedly leaner work force, a given percentage change in oil prices is likely to result in a smaller percentage change in the industry's work force than was the case in the early 1980s, when the industry was highly leveraged to meet what appeared to be an ever-increasing demand for Texas petroleum products. The sensitivity of overall Texas employment to oil price changes is likely to be less than before because the oil and gas extraction industry's employment now represents a smaller fraction of mining and manufacturing.

Quite separate from the above retrenchment argument, once oil prices moved to more realistic levels after 1981, reduced expectations about future price increases were likely to prevail in subsequent Texas business cycles. Related industries (for example, construction, real estate, and banking) could react more slowly to movements in oil prices, if nothing else out of self-defense and the desire to confirm new plateaus in oil prices. Thus, the argument can plausibly be made that, with respect to employment, the Texas economy is probably less sensitive to oil price fluctuations now than it was in the early 1980s. These arguments, of course, bring into question the conventional wisdom that "as the oil patch goes, so goes the Texas economy."

But what about the maverick status of the Texas economy? A closer examination of mining and manufacturing employment in Texas by two-digit SIC Code industries indicates that, since the oil price break of 1981, the Texas economy has been slowly evolving toward an employment composition that more closely mirrors the employment composition of the mining and manufacturing sectors of the rest of the nation. Table 1 contains three time-specific snapshots of the composition of mining and manufacturing employment in Texas and the rest of the United States. The first snapshot is that of the employment composition in the first quarter of 1975, when oil prices were beginning to rise. The second snapshot is dated the second quarter of 1982, when oil was king in Texas and 21.85 percent of Texas mining and manufacturing employment resided in the oil and gas extraction industry. This employment percentage represents an all-time high. Obviously, the Texas economy was highly specialized then and quite susceptible to declines in the price of oil. The third snapshot presents the composition of mining and manufacturing employment as of the third quarter of 1988. To offer perspective, the average composition of mining and manufacturing employment for Texas and the rest of the United States over the period 1975:Q1–1988:Q3 is contained in the last display in Table 1.

The snapshots of Table 1 convey a picture of the Texas economy becoming more specialized as oil prices rose. Then, with the oil price shock of 1981, the oil and gas extraction industry began a retrenchment. Thereafter, the Texas economy has progressively become less specialized and, as a result, has come to resemble more closely the economy of the rest of the nation.

To formalize the measurement of the degree to which the Texas economy has differed from the economy of the rest of the United States, we present two "dissimilarity" measures that provide summary characterizations of the disparity between the proportions of employment in the

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[6] *There was a major labor strike in the oil and gas extraction industry during the first quarter of 1980. Because the strike had an effect that was not typical of the basic trend in the industry at the time, we chose to smooth Charts 4 and 5 by replacing the actual data with interpolated values.*

Table 1

## Composition of Mining and Manufacturing Employment in Texas and Rest of United States at Given Times

1975:Q1

| Industry (SIC Code) | Texas employment (Percent) | Rest of U.S. employment (Percent) |
|---|---|---|
| Mining except oil and gas (10, I2, 14) | 0.726 | 2.239 |
| Oil and gas extraction (13) | 13.326 | 1.083 |
| Food and kindred products (20) | 9.291 | 8.538 |
| Tobacco products (21) | 0.000 | 0.411 |
| Textile mill products (22) | 0.722 | 4.503 |
| Apparel and other textile products (23) | 7.270 | 6.224 |
| Lumber and wood products (24) | 2.866 | 3.117 |
| Furniture and fixtures (25) | 1.662 | 2.171 |
| Paper and allied products (26) | 1.897 | 3.460 |
| Printing and publishing (27) | 4.891 | 5.738 |
| Chemicals and allied products (28) | 7.251 | 5.237 |
| Petroleum and coal products (29) | 4.100 | 0.828 |
| Rubber, miscellaneous plastics products (30) | 2.150 | 3.221 |
| Leather and leather products (31) | 0.699 | 1.286 |
| Stone, clay, and glass products (32) | 3.622 | 3.322 |
| Primary metal industries (33) | 4.103 | 6.399 |
| Fabricated metal products (34) | 8.197 | 7.702 |
| Industrial machinery and equipment (35) | 10.800 | 11.146 |
| Electronic and other electric equipment (36) | 6.354 | 9.199 |
| Transportation equipment (37) | 7.021 | 9.020 |
| Instruments and related products (38) | 1.916 | 2.988 |
| Miscellaneous manufacturing industries (39) | 1.135 | 2.167 |

1982:Q2

| Industry (SIC Code) | Texas employment (Percent) | Rest of U.S. employment (Percent) |
|---|---|---|
| Mining except oil and gas (10, 12, 14) | 0.763 | 2.260 |
| Oil and gas extraction (13) | 21.848 | 2.313 |
| Food and kindred products (20) | 7.059 | 8.159 |
| Tobacco products (21) | 0.000 | 0.367 |
| Textile mill products (22) | 0.387 | 4.005 |
| Apparel and other textile products (23) | 4.783 | 5.863 |
| Lumber and wood products (24) | 2.643 | 2.991 |
| Furniture and fixtures (25) | 1.157 | 2.217 |
| Paper and allied products (26) | 1.611 | 3.416 |
| Printing and publishing (27) | 4.909 | 6.405 |
| Chemicals and allied products (28) | 5.983 | 5.315 |
| Petroleum and coal products (29) | 3.021 | 0.840 |
| Rubber, miscellaneous plastics products (30) | 2.336 | 3.576 |
| Leather and leather products (31) | 0.757 | 1.129 |
| Stone, clay, and glass products (32) | 3.214 | 2.866 |
| Primary metal industries (33) | 3.346 | 4.809 |
| Fabricated metal products (34) | 7.032 | 7.219 |
| Industrial machinery and equipment (35) | 13.271 | 11.364 |
| Electronic and other electric equipment (36) | 7.337 | 10.256 |
| Transportation equipment (37) | 5.751 | 8.943 |
| Instruments and related products (38) | 1.842 | 3.708 |
| Miscellaneous manufacturing industries (39) | 0.951 | 1.979 |

Table 1—*Continued*

## Composition of Mining and Manufacturing Employment in Texas and Rest of United States at Given Times

### 1988:Q3

| Industry (SIC Code) | Texas employment (Percent) | Rest of U.S. employment (Percent) |
|---|---|---|
| Mining except oil and gas (10, 12, 14) | 0.837 | 1.600 |
| Oil and gas extraction (13) | 15.378 | 1.291 |
| Food and kindred products (20) | 8.446 | 7.990 |
| Tobacco products (21) | 0.000 | 0.268 |
| Textile mill products (22) | 0.353 | 3.756 |
| Apparel and other textile products (23) | 4.786 | 5.405 |
| Lumber and wood products (24) | 2.971 | 3.764 |
| Furniture and fixtures (25) | 1.428 | 2.724 |
| Paper and allied products (26) | 2.299 | 3.470 |
| Printing and publishing (27) | 6.531 | 7.792 |
| Chemicals and allied products (28) | 6.599 | 5.191 |
| Petroleum and coal products (29) | 2.808 | 0.707 |
| Rubber, miscellaneous plastics products (30) | 2.921 | 14.405 |
| Leather and leather products (31) | 0.740 | 0.722 |
| Stone, clay, and glass products (32) | 3.758 | 2.832 |
| Primary metal industries (33) | 2.550 | 3.950 |
| Fabricated metal products (34) | 6.697 | 7.220 |
| Industrial machinery and equipment (35) | 9.018 | 10.696 |
| Electronic and other electric equipment (36) | 10.464 | 10.455 |
| Transportation equipment (37) | 8.316 | 10.204 |
| Instruments and related products (38) | 1.931 | 3.619 |
| Miscellaneous manufacturing industries (39) | 1.168 | 1.940 |

### Average for 1975:Q1–1988:Q3

| Industry (SIC Code) | Texas employment (Percent) | Rest of U.S. employment (Percent) |
|---|---|---|
| Mining except oil and gas (10, 12, 14) | 0.768 | 2.021 |
| Oil and gas extraction (13) | 17.194 | 1.530 |
| Food and kindred products (20) | 8.137 | 8.169 |
| Tobacco products (21) | 0.000 | 0.350 |
| Textile mill products (22) | 0.475 | 4.169 |
| Apparel and other textile products (23) | 5.633 | 5.985 |
| Lumber and wood products (24) | 3.072 | 3.440 |
| Furniture and fixtures (25) | 1.459 | 2.389 |
| Paper and allied products (26) | 1.883 | 3.434 |
| Printing and publishing (27) | 5.369 | 6.429 |
| Chemicals and allied products (28) | 6.531 | 5.144 |
| Petroleum and coal products (29) | 3.452 | 0.798 |
| Rubber, miscellaneous plastics products (30) | 2.550 | 3.714 |
| Leather and leather products (31) | 0.688 | 1.064 |
| Stone, clay, and glass products (32) | 3.683 | 3.027 |
| Primary metal industries (33) | 3.250 | 4.987 |
| Fabricated metal products (34) | 7.157 | 7.440 |
| Industrial machinery and equipment (35) | 11.110 | 10.836 |
| Electronic and other electric equipment (36) | 8.230 | 10.074 |
| Transportation equipment (37) | 6.528 | 9.551 |
| Instruments and related products (38) | 1.771 | 3.423 |
| Miscellaneous manufacturing industries (39) | 1.060 | 2.027 |

SOURCE OF PRIMARY DATA: U.S. Bureau of Labor Statistics.

various two-digit Texas mining and manufacturing industries and the proportions of employment in the same industries for the rest of the nation. The first dissimilarity measure used here is based on the so-called expected information measure proposed by Theil (1972).

$$DS1_t = \sum_{i=1}^{n} E_{US,t,i} \ln\left(\frac{E_{US,t,i}}{E_{TX,t,i}}\right),$$

where $E_{US,t,i}$ denotes, at time $t$, the proportion of total mining and manufacturing employment for the rest of the United States represented by the $i$th industry in the mining and manufacturing sector. The term $E_{TX,t,i}$ is similarly defined for Texas. The natural logarithmic function is denoted by ln, and $n$ denotes the number of industry classifications in the mining and manufacturing sector used in this study, namely 22. As in the classifications of Table 1, these industries consist of the 20 two-digit industries in manufacturing (SIC Codes 20–39) and, in mining, the oil and gas extraction industry (Code 13) and the rest of mining (the collection of Codes 10, 12, and 14).

The second dissimilarity measure used here is of the form of a goodness-of-fit measure analogous to the goodness-of-fit statistic used in examining the closeness of an empirical distribution to a postulated theoretical distribution.[7] The goodness-of-fit dissimilarity measure is

$$DS2_t = \sum_{i=1}^{n} \frac{\left(E_{TX,t,i} - E_{US,t,i}\right)^2}{E_{US,t,i}},$$

where the notation is the same as before.[8]

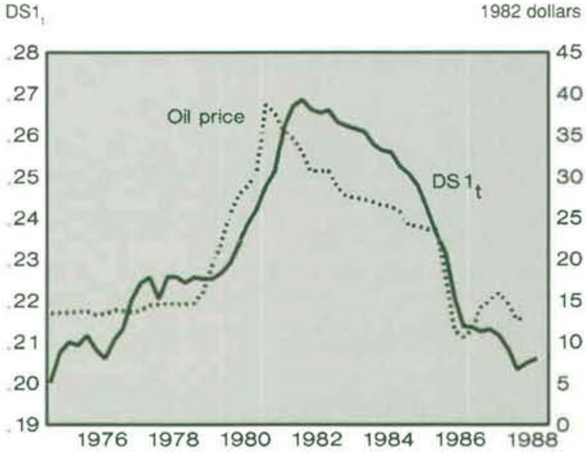
These dissimilarity measures have the common characteristics that, as the proportions $E_{TX,t,i}$ and $E_{US,t,i}$ become more unequal, the dissimilarity measures become larger. In contrast, as the Texas economy becomes more like the economy of the rest of the United States and as $E_{TX,t,i}$ and $E_{US,t,i}$ become more equal, the dissimilarity measures become smaller and approach zero, the lower limit for both measures that would denote perfect coincidence between the employment proportions for Texas and the rest of the United States. Greater dissimilarity between Texas and the rest of the nation thus reflects greater specialization within the Texas economy and a greater reliance on a few key industries for continued growth.

These dissimilarity measures, along with the real price of oil, are plotted in Charts 6 and 7, beginning with 1975. The story told by these measures is roughly the same. Texas mining and manufacturing became increasingly more specialized (dissimilar) as oil prices rose through the early 1980s, to the extent of being 35 percent more specialized than in 1975. The Theil information-based dissimilarity measure, $DS1_t$, indicates an almost immediate impact of the 1981 drop in oil prices on the specialization in the Texas economy; the goodness-of-fit dissimilarity measure, $DS2_t$, indicates a delayed movement away from specialization beginning in late 1983. Both measures, nevertheless, indicate that the Texas economy is currently much less specialized

Chart 6

Information-Theoretic Dissimilarity Measure of the Texas Economy and the Real Price of Oil

(Calculated from quarterly data)



Sources of Primary Data: U.S. Department of Commerce, Bureau of Economic Analysis.
U.S. Department of Energy.
U.S. Department of Labor, Bureau of Labor Statistics.

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[7] For a discussion of goodness-of-fit tests, see, for example, Hogg and Craig (1970).

[8] Sherwood-Call (1988) uses the same measure (except for sign) to determine the relative diversities of the state economies in the United States and the effect such diversity has on the strength of the linkage of a state's economy to the national economy.

as a result of the 1981 fall in oil prices and is approximately as similar to the economy of the rest of the United States as it was in 1975, before the substantial increase in the price of oil in the late 1970s. In this sense, the Texas economy is much less reliant on its oil and gas extraction sector than it was in 1981.

## A VAR model of the Texas economy

The previous examination of the Texas economy's dependence on oil prices and independence of the national economy proceeded by heuristic means—that is, visual examinations of time series plots, trends, and lead and lag relationships. A more sophisticated econometric examination of the interplay between Texas nonagricultural employment, oil prices, and nonagricultural employment in the rest of the nation would be desirable.

One approach that has proven useful in uncovering systematic relationships between regional and U.S. economic time series is the estimation of vector autoregressions (VARs).[9] To establish some notation, let $x_t$, $y_t$, and $z_t$ denote observations on three economic variables of interest that occur at time $t$. A trivariate vector autoregression of $(x, y, z)$ with each variable entering with equal lag length, $l$, is represented by

$$(1)\quad \begin{aligned} x_t = \alpha_0 &+ \alpha_1 x_{t-1} + \ldots + \alpha_l x_{t-l} \\ &+ \beta_1 y_{t-1} + \ldots + \beta_l y_{t-l} \\ &+ \psi_1 z_{t-1} + \ldots + \psi_l z_{t-l} + u_t , \end{aligned}$$

$$(2)\quad \begin{aligned} y_t = \delta_0 &+ \delta_1 x_{t-1} + \ldots + \delta_l x_{t-l} \\ &+ \varepsilon_1 y_{t-1} + \ldots + \varepsilon_l y_{t-l} \\ &+ \gamma_1 z_{t-1} + \ldots + \gamma_l z_{t-l} + v_t , \end{aligned}$$

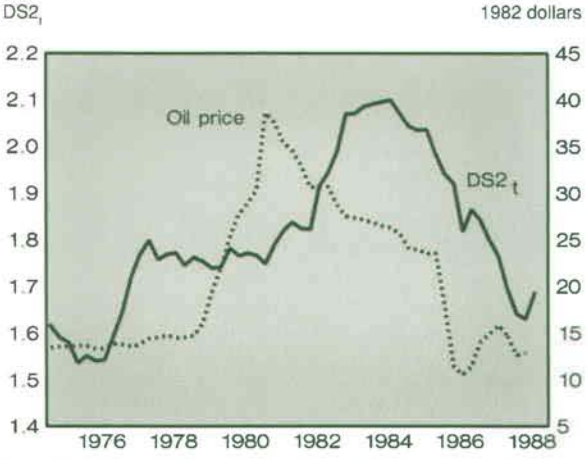
and

$$(3)\quad \begin{aligned} z_t = \theta_0 &+ \theta_1 x_{t-1} + \ldots + \theta_l x_{t-l} \\ &+ \eta_1 y_{t-1} + \ldots + \eta_l y_{t-l} \\ &+ \mu_1 z_{t-1} + \ldots + \mu_l z_{t-l} + w_t . \end{aligned}$$

The regression coefficients to be estimated are represented by the α's, β's, and so on, while $u_t$, $v_t$, and $w_t$ represent the unobserved errors of the respective equations. The system consisting of equations 1, 2, and 3 is estimated by applying the method of least squares, equation by equation. Because the regressors of the three equations are identical, the least squares and seemingly unrelated regression estimates coincide. Thus, even if the errors $u_t$, $v_t$, and $w_t$ exhibit contemporaneous correlation, the method of least squares is fully efficient relative to estimation of seemingly unrelated regressions.

The adoption of equal lag length for each variable in each equation is more of a convenience than a necessity. Allowing each variable in each equation to enter with different lag lengths ($l_1$, $l_2$, and so on) would increase substantially the number of possible model specifications that would have to be examined.[10] Choosing $l$ to be as large as any lag length in the "true" model ensures that the least squares estimates of the equal-length VAR parameters will nevertheless be unbiased and consistent. A cost of the equal lag

Chart 7
Goodness-of-fit Dissimilarity Measure of the Texas Economy and the Real Price of Oil
(Calculated from quarterly data)



Sources of Primary Data: U.S. Department of Commerce, Bureau of Economic Analysis.
U.S. Department of Energy.
U.S. Department of Labor, Bureau of Labor Statistics.

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[9] *For applications of VARs in regional and macroeconomic forecasting and simulation, see Anderson (1979) and Litterman (1986).*

[10] *In a trivariate system assuming a maximum lag length M, the equal lag length specification requires a search over*

length specification, however, is the potential loss of efficiency in estimation due to the need to estimate an unnecessarily large number of parameters. Because the present study is exploratory in nature, the equal lag length specification is adopted here.

The variables chosen for examination were quarterly time series observations on the real price of oil, Texas nonagricultural employment, and nonagricultural employment in the rest of the United States for the period 1974:Q1 through 1988:Q1. The length of the data is limited by the unavailability of the real price of oil before 1974:Q1.

A preliminary investigation of the data indicated that each series was nonstationary in its mean, with the variability of each series increasing somewhat in levels. In addition, inspection of the series for co-integrability indicated no need to model equations 1 through 3 using error correction terms, as in Engle and Granger (1987).[11] Given these findings, it was decided to model each series in percentage growth form by taking differences in the natural logarithms of each series. Using the above notation, the variables $x_t$, $y_t$, and $z_t$ chosen for the VAR of the Texas economy were, respectively, the quarterly percentage change in the real price of oil, Texas nonagricultural employment, and nonagricultural employment in the rest of the nation.[12]

With respect to choosing a lag length, $l$, for the VAR system, a pragmatic approach was taken. The maximum lag length considered was $l = 4$. The averages of the adjusted $R^2$'s of the three equations in the VAR system, computed using the entire span of the data (1974:Q1–1988:Q1), were 0.469, 0.527, 0.532, and 0.370, respectively, for equal lag lengths $l = 1, 2, 3$, and 4. Though the second- and third-order systems fit the data equally well while providing better fits than the first- and fourth-order systems, it was decided to focus on the results of the second-order system—this system being smaller and thus much easier to present in the subsequent discussion. Despite this choice of simpler model, the qualitative results produced by the third-order system are the same as those reported for the second-order system.

Now we turn to the empirical analysis of the second-order system, using the entire data set 1974:Q1–1988:Q1. The estimated model is reported in Table 2, along with *F*-tests of the joint significance of the various variables in each equation. For example, the first *F*-test reported for the first equation, where $x_t$ is the dependent variable, examines the joint significance of $x_{t-1}$ and $x_{t-2}$ in explaining the variation in $x_t$. The second *F*-test examines the joint significance of $y_{t-1}$ and $y_{t-2}$ in explaining the variation in $x_t$. The rest of the *F*-tests are similarly defined. A Box-Pierce *Q* test of the residuals of each model indicates that they are white noise, implying that no systematic variation in the equations remains to be explained by additional parameters. Thus, overall, the reported second-order system seems to fit the data quite well.

The *F*-tests reported in Table 2 indicate (1) the real price of oil is exogenous, in that it is independent of fluctuations in nonagricultural

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*only $M + 1$ specifications, $l = 0, 1, 2, \ldots, M$. In allowing for unequal lag length but with a maximum of $M$, the number of specifications that must be examined increases to $3(M + 1)^3$. In the case of a reasonable specification of $M = 4$ in the presence of quarterly data, five specifications must be examined for the equal lag length, and 375 for the unequal lag length.*

[11] *To determine if the logarithms of the three series contain a unit root, augmented Dickey-Fuller equations including a time trend (to model the apparent drift in all series) were estimated. Varying the number of augmented terms between zero and four, the $\hat{\tau}_\tau$ statistics for each variable and over all equations were always greater than $-3.50$, the one-tailed 5-percent critical value for 50 observations. Thus, each logged variable appears to have a unit root. For discussion of the $\hat{\tau}_\tau$ statistic and its critical values, see Table 8.5.2, p. 373, in Fuller (1976) and see Dickey and Fuller (1979).*

*To test for co-integration, the residuals of level equations in the logarithms of the variables were examined and tested for unit roots using augmented Dickey-Fuller equations of the form found in Engle and Yoo (1987). See equations 19 and 20, p. 152. The $\hat{\tau}$ statistics over all possible normalizations of the co-integrating equation and for all Dickey-Fuller equations having between zero and four augmented terms were greater than $-3.75$, the one-tailed 5-percent critical value for 50 observations. See Table 3, p. 158. Thus, the three logged variables of interest appear to constitute a multivariate system with three unit roots and no co-integrating vectors.*

[12] *The RATS computer program was used to calculate all the empirical results presented in this study. See Doan and Litterman (1981).*

Table 2

## Estimation Results for Second-Order Texas VAR System, 1974:Q1–1988:Q1

Dependent variable: $x$ (percentage change in real price of oil)

| Variable | Lag | Coefficient | Standard error | Significance level |
|---|---|---|---|---|
| $x$ | 1 | 0.7054 | 0.1409 | .8305E-5 |
| $x$ | 2 | −0.3351 | 0.1500 | .3027E-1 |
| $y$ | 1 | −1.3525 | 2.7013 | .6189 |
| $y$ | 2 | 3.4371 | 2.4344 | .1645 |
| $z$ | 1 | 3.4566 | 2.8048 | .2239 |
| $z$ | 2 | −4.8703 | 2.7500 | .8304E-1 |
| Constant | 0 | −0.9983E-2 | 0.1696E-1 | .5589 |

$\bar{R}^2 = .2982$; $Q(21) = 8.2618$ ($P = .9939$).

Tests for joint significance, dependent variable = $x$

| Variable | $F$-statistic | Significance level |
|---|---|---|
| $x$ | 12.5536 | .4283E-4 |
| $y$ | 1.3646 | .2654 |
| $z$ | 1.5693 | .2188 |

Dependent variable: $y$ (percentage change in Texas nonagricultural employment)

| Variable | Lag | Coefficient | Standard error | Significance level |
|---|---|---|---|---|
| $x$ | 1 | 0.2228E-1 | 0.8759E-2 | .1430E-1 |
| $x$ | 2 | −0.1883E-2 | 0.9322E-2 | .8407 |
| $y$ | 1 | 0.6462 | 0.1678 | .3554E-3 |
| $y$ | 2 | 0.4234E-1 | 0.1512 | .7807 |
| $z$ | 1 | 0.2655 | 0.1742 | .1342 |
| $z$ | 2 | −0.1715 | 0.1708 | .3205 |
| Constant | 0 | 0.1602E-2 | 0.1053E-2 | .1351 |

$\bar{R}^2 = .6316$; $Q(21) = 21.5900$ ($P = .4234$).

Tests for joint significance, dependent variable = $y$

| Variable | $F$-statistic | Significance level |
|---|---|---|
| $x$ | 3.6283 | .3424E-1 |
| $y$ | 19.1440 | .8287E-6 |
| $z$ | 1.1684 | .3197 |

Dependent variable: $z$ (percentage change in nonagricultural employment in rest of United States)

| Variable | Lag | Coefficient | Standard error | Significance level |
|---|---|---|---|---|
| $x$ | 1 | −0.8330E-2 | 0.6849E-2 | .2299 |
| $x$ | 2 | 0.3635E-2 | 0.7289E-2 | .6202 |
| $y$ | 1 | 0.3849 | 0.1312 | .5170E-2 |
| $y$ | 2 | −0.4805 | 0.1182 | .1828E-3 |
| $z$ | 1 | 0.7226 | 0.1362 | .3004E-5 |
| $z$ | 2 | −0.1366E-1 | 0.1336 | .9190 |
| Constant | 0 | 0.2387E-2 | 0.8241E-3 | .5701E-2 |

$\bar{R}^2 = .6503$; $Q(21) = 15.6182$ ($P = .7907$).

Tests for joint significance, dependent variable = $z$

| Variable | $F$-statistic | Significance level |
|---|---|---|
| $x$ | 0.7396 | .4827 |
| $y$ | 8.2714 | .8360E-3 |
| $z$ | 27.9609 | .1000E-7 |

employment in Texas and in the rest of the United States; (2) Texas nonagricultural employment is heavily dependent on its own past history, as well as past movements in real oil prices, though seemingly independent of U.S. nonagricultural employment; and (3) nonagricultural employment in the rest of the nation is heavily dependent on its own past and to a lesser extent on nonagricultural employment in Texas. Stated another way, the real price of oil is determined outside the system (equations 1 through 3) and, in turn, feeds into the Texas economy by way of employment. Though employment in the rest of the United States is largely self-determined, it evidently can be affected by the fluctuations in Texas employment that have causes affecting employment in other states as well. On the other hand, Texas employment seems to be impervious to fluctuations in U.S. employment.

Treating the structure of the Texas economy as unchanged from 1974 to the present, one comes to the impression that the real price of oil has been and remains a very crucial determinant of the Texas economy and that the Texas economy operates independently of the national economy. As suggested earlier, however, the Texas economy has undergone structural changes in response to the oil price shocks of 1981 and 1986. In particular, there has been substantial retrenchment in the oil and gas extraction industry, making it a less significant portion of Texas economic activity. The Texas economy now more closely resembles the rest of the U.S. economy with respect to the employment composition of its mining and manufacturing sectors.

Obviously, the transition in the Texas economy has been a gradual one. An observer would be hard-pressed to designate an exact date that might serve as a dramatic break between the "old" Texas and "new" Texas economies. Despite this difficulty, it was decided to analyze the Texas VAR by major business cycle periods. With the Texas coincident economic indicator and the real price of oil as guides, the first business cycle period was defined to span the period 1974:Q1 through 1983:Q1; the second business cycle period was defined to span 1983:Q2 through 1988:Q1.[13] The logic here is that once the Texas economy has lived through a major correction in oil prices—as represented by the first period—it would take on a more defensive posture in the second period and, by so doing, become more insulated from subsequent oil price fluctuations.

To test for a significant structural change in the Texas VAR over the two defined periods, each equation of the VAR was subjected to a Chow (1960) test. The resulting *F*-statistics for the oil price, Texas employment, and rest of U.S. employment equations were 1.509, 3.413, and 1.089, respectively, indicating that the Texas employment equation underwent a significant structural change between the two periods.[14]

The nature of the structural change in the Texas employment equation is revealed in the estimation results reported in Table 3. The estimation results for the first period, 1974:Q1–1983:Q1, are presented in the upper portion of the table while those for the second period, 1983:Q2–1988:Q1, are reported in the lower portion. In contrast to the impression conveyed by the comprehensive estimation results for the Texas employment equation reported in Table 2, Texas employment is now more dependent on the national economy, as represented by the substantial joint significance of nonagricultural employment in the rest of the United States in the latter period. The real price of oil and Texas employment's own past history, though still significant at the 10-percent level, have lost significance relative to employment in the rest of the nation.

Thus, though still dependent on the price of oil, the Texas economy is probably less so than

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[13] *Rather than throw away some of the data at the fringes of the exact turning points of the two Texas business cycles, and thereby lose valuable degrees of freedom, it was decided to include the observations for the dates January 1974–May 1975 in the first business cycle period, instead of starting at the June 1975 trough in the Texas coincident indicator. Similarly, the observations for the dates April 1987–March 1988 were included, though they actually follow the ending trough of the second Texas business cycle. Thus, the term business cycle period is adopted here.*

[14] *The appropriate critical values for the Chow test are 2.25 for a 5-percent level of significance and 3.12 for a 1-percent level of significance. The degrees of freedom for the F-statistic are 7 for the numerator and 40 for the denominator.*

Table 3

## Estimation Results for Texas Nonagricultural Employment

(Dependent variable = *y*)

1974:Q1–1983:Q1

| Variable | Lag | Coefficient | Standard error | Significance level |
|---|---|---|---|---|
| *x* | 1 | 0.2763E-1 | .1411E-1 | .6062E-1 |
| *x* | 2 | 0.4616E-2 | .1562E-1 | .7698 |
| *y* | 1 | 0.9509 | .2149 | .1428E-3 |
| *y* | 2 | –0.5063 | .2373 | .4215E-1 |
| *z* | 1 | 0.1681 | .1767 | .3499 |
| *z* | 2 | 0.1012 | .1755 | .5688 |
| Constant | 0 | 0.4028E-2 | .1809E-2 | .3456E-1 |

$\bar{R}^2 = .6752$; $Q(15) = 7.5542$ ($P = .9404$).

Tests for joint significance, dependent variable = *y*

| Variable | *F*-statistic | Significance level |
|---|---|---|
| *x* | 2.9342 | .7028E-1 |
| *y* | 10.3211 | .4682E-3 |
| *z* | 1.2042 | .3155 |

1983:Q2–1988:Q1

| Variable | Lag | Coefficient | Standard error | Significance level |
|---|---|---|---|---|
| *x* | 1 | 0.2684E-1 | .1071E-1 | .2627E-1 |
| *x* | 2 | –0.1065E-1 | .9763E-2 | .2950 |
| *y* | 1 | 0.4783E-1 | .2246 | .8346 |
| *y* | 2 | 0.5173 | .2318 | .4389E-1 |
| *z* | 1 | 2.3187 | .6077 | .2143E-2 |
| *z* | 2 | –1.3852 | .4535 | .9220E-2 |
| Constant | 0 | –0.6083E-2 | .4186E-2 | .1699 |

$\bar{R}^2 = .7284$; $Q(10) = 7.2394$ ($P = .7026$).

Tests for joint significance, dependent variable = *y*

| Variable | *F*-statistic | Significance level |
|---|---|---|
| *x* | 3.1516 | .7656E-1 |
| *y* | 3.3882 | .6541E-1 |
| *z* | 8.2107 | .4946E-2 |

NOTE: *x* = percentage change in real price of oil.
*y* = percentage change in Texas nonagricultural employment.
*z* = percentage change in nonagricultural employment in rest of United States.

Table 4

## Impulse and Cumulative Responses of Texas Nonagricultural Employment to One-Standard-Deviation Shock in Real Price of Oil and in Nonagricultural Employment in Rest of United States, 1974:Q1–1988:Q1

| | Responses to oil price shock | | Responses to U.S. employment shock | |
|---|---|---|---|---|
| Period | Impulse | Cumulative | Impulse | Cumulative |
| 1 | .0000E+0 | .0000 | .0000E+0 | .0000 |
| 2 | .1906E-2 | | .1103E-2 | |
| 3 | .2226E-2 | | .1118E-2 | |
| 4 | .1732E-2 | | .8423E-3 | |
| 5 | .1070E-2 | .6935E-2 | .4072E-3 | .3471E-2 |
| 6 | .6471E-3 | | .8947E-4 | |
| 7 | .4355E-3 | | -.7491E-4 | |
| 8 | .3284E-3 | | -.1286E-3 | |
| 9 | .2614E-3 | | -.1287E-3 | |
| 10 | .2159E-3 | .8824E-2 | -.1089E-3 | .3119E-2 |
| 11 | .1854E-3 | | -.8484E-4 | |
| 12 | .1631E-3 | | -.6310E-4 | |
| 13 | .1437E-3 | | -.4629E-4 | |
| 14 | .1250E-3 | | -.3462E-4 | |
| 15 | .1071E-3 | .9548E-2 | -.2699E-4 | .2863E-2 |
| 16 | .9086E-4 | | -.2201E-4 | |
| 17 | .7655E-4 | | -.1853E-4 | |
| 18 | .6429E-4 | | -.1586E-4 | |
| 19 | .5394E-4 | | -.1364E-4 | |
| 20 | .4527E-4 | .9879E-2 | -.1170E-4 | .2782E-2 |
| 21 | .3802E-4 | | -.9992E-5 | |
| 22 | .3197E-4 | | -.8482E-5 | |
| 23 | .2692E-4 | | -.7168E-5 | |
| 24 | .2267E-4 | | -.6039E-5 | |
| 25 | .1911E-4 | .1001E-1 | -.5079E-5 | .2745E-2 |
| 26 | .1610E-4 | | -.4270E-5 | |
| 27 | .1357E-4 | | -.3591E-5 | |
| 28 | .1140E-4 | | -.3021E-5 | |
| 29 | .9639E-5 | | -.2543E-5 | |
| 30 | .8121E-5 | .1007E-1 | -.2142E-5 | .2729E-2 |

NOTE: All responses are in terms of quarterly growth rates.

before, owing to retrenchment in the oil and gas extraction industry. Possibly because of its greater resemblance to that of the rest of the nation, the Texas economy is now a more open economy, in that the economies of the other states are now playing a greater role in affecting the Texas economy.

To emphasize further what appears to have been a significant shift in the nature of the Texas economy over the past two Texas business cycles, an impulse response function analysis of the Texas VAR was conducted, first over the entire period and then with respect to the two business cycle periods defined. Impulse response functions give the dynamic responses of the VAR system's three variables ($x$, $y$, $z$) to a shock to the system. The mathematical details of impulse response functions are discussed in the Appendix.

With the estimation period taken to be the entire data set 1974:Q1–1988:Q1, the impulse and cumulative responses of Texas employment to a one-standard-deviation shock (0.0855) in the growth rate of real oil prices and to a one-standard-deviation shock (0.00415) in the growth rate of nonagricultural employment in the rest of the United States are given in Table 4. To illustrate, consider a "surprise" 8.55-percent quarterly increase in the real price of oil at time $t = 1$. Then, given the second-order VAR estimated for the entire period and reported in Table 2, Texas nonagricultural employment will, on average, grow at a 0.19 percent faster quarterly rate at time $t = 2$ than would otherwise be expected. The additional unexpected quarterly increases for subsequent periods arising because of the given oil price shock are 0.22 percent, 0.17 percent, 0.10 percent, and so on. The cumulative effect of such a shock after 30 periods is 1.007 percent in unexpected growth.

Obviously, given the perspective of the entire sample, an unexpected increase in oil prices results in substantial unexpected increases in Texas nonagricultural employment. In a similar manner, given the perspective of the entire sample, a "surprise" 0.415-percent quarterly increase in nonagricultural employment in the rest of the United States implies that additional unexpected quarterly increases in Texas employment for periods 1 onward would be 0.11 percent, 0.11 percent, 0.084 percent, and so on, with the cumulative effect of such a shock being 0.273 percent.

As indicated by the previous Chow tests, the Texas economy appears to have undergone a structural change between business cycles. To follow up on this theme, the impulse response functions for the two separate periods were computed and compared with the response functions for the entire sample period. By way of an abbreviated presentation, the 30-period cumulative responses of Texas nonagricultural employment to a 0.0855 shock in oil prices (the same used in Table 4) and to a 0.00415 shock in nonagricultural employment in the rest of the United States (again the same used in Table 4) for the two separate business cycle periods, 1974:Q1–1983:Q1 and 1983:Q2–1988:Q1, are reported in Table 5. For the purpose of comparison, the cumulative responses for the entire sample period are reported in Table 5 as well.

The cumulative responses reported in Table 5 (as well as the *F*-tests in Table 3) clearly indicate that, compared with behavior in the first Texas business cycle, the Texas economy appears now to be somewhat less responsive to oil price shocks while being much more responsive to shocks in U.S. employment. In fact, comparing the 30-period cumulative responses of Texas nonagricultural employment to shocks over the two periods shows that, as of the second period, the Texas economy is approximately 62 percent *less* sensitive to real oil price shocks while being a surprising 338 percent *more* sensitive to shocks in nonagricultural employment in the rest of the United States.

## Conclusion

The recent instability of the Organization of Petroleum Exporting Countries does not necessarily bode well for Texas, but it should be of less concern now than back in the early 1980s. Results obtained here indicate that, even though negative oil price shocks still imply reduced growth in Texas employment, their present cumulative effect is substantially less than the cumulative effects of the early 1980s.

Analysis of the Texas economy during the period 1974:Q1–1983:Q1 conveys a picture of a fragile economy, probably somewhat leveraged, that was highly sensitive to oil price shocks. As of 1981, however, the Texas economy began to make accommodations for the continuing weakness in the price of oil.

The oil and gas extraction industry began to retrench by cutting employment and production, with inefficient workers and production probably the first to be eliminated. The industry is now much leaner. At the same time, the Texas economy, partially because of the smaller extraction sector, became less specialized and took on a mining and manufacturing employment composition much more similar to that of the rest of the nation. Through this process it appears that Texas has become a more open economy. Fluctuations in nonagricultural employment in the rest of the United States play a much more important role than in the past in determining nonagricultural employment in Texas. As goes the nation, so will Texas likely follow. Thus, the health of the national economy should now be more of a concern to Texans than in the past. Fortunately, the Texas economy is no longer a one-horse chaise. For this, Texans can currently be thankful.

In the future, oil is likely to play an ever-declining role in the Texas economy. As the Texas economy becomes larger over time, a future expansion in the oil industry, even of the magnitude exhibited in the heyday period of 1974–81, will play a smaller role, proportionately, in providing employment in the state. Moreover, given the experiences of the 1981 and 1986 oil price shocks, oil-related investment is likely to be more circumspect. Thus, the rapid growth in Texas nonagricultural employment that previously has been fueled largely through abundant natural resource endowments is much less likely to be forthcoming in the future. This is not to say that the state is not fortunate to have such endowments, nor that it will not later benefit from their presence; rather, Texas growth in the future will be dependent on other sources more so than before. Texas growth can no longer be taken for granted.

Table 5

**The 30-Period Cumulative Responses of Texas Nonagricultural Employment to One-Standard-Deviation Shock in Real Price of Oil and in Nonagricultural Employment in Rest of United States**

| 30 periods | 1974:Q1–1983:Q1 | 1983:Q2–1988:Q1 (Percent) | 1974:Q1–1988:Q1 |
|---|---|---|---|
| Cumulative response to oil price shock | 0.755 | 0.287 | 1.007 |
| Cumulative response to U.S. employment shock | 0.602 | 2.637 | 0.273 |

NOTE: The shocks equal the respective standard deviations of oil price and U.S. nonagricultural employment that were calculated for the entire sample period 1974:Q1–1988:Q1. All responses are in terms of quarterly growth rates.

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## Appendix

## The Mathematics of Impulse Response Functions

The vector autoregression represented by equations 1 through 3 is rewritten in moving-average form as

$$\mathbf{Y}_t = \sum_{d=0}^{\infty} A_d \mathbf{U}_{t-d} ,$$

where $\mathbf{Y}_t = (x_t, y_t, z_t)'$; $A_d$, $d = 0, 1, 2, \ldots$, is the delay-$d$ response coefficient matrix of dimension 3x3; and $\mathbf{U}_{t-d} = (u_{t-d}, v_{t-d}, w_{t-d})'$. Assume the usual normalization $A_0 = I_3$, where $I_3$ denotes a third-order identity matrix. Thus, the response $\mathbf{Y}_t$ at time $t = k$ to an initial shock $\mathbf{s}$ at time $t = 0$ in the $\mathbf{U}$ error process is $A_k \cdot \mathbf{s}$. Furthermore, the response at step $k$ to a unit shock in equation $i$ ($i = 1, 2, 3$) is just the $i$th column of the $A_k$ matrix. In a similar manner, the cumulative effect, after $d'$ periods, of an initial and sustained shock $\mathbf{s}$ in the error process is just $\Sigma_{d=0}^{d'} A_d \cdot \mathbf{s}$.

Of interest here are the impulse responses of Texas employment to an oil price shock and to a shock to the national economy. The shock, say $s_1$, to the real price of oil multiplied by the first column of the estimated response coefficient matrices $A_d$, $d = 0, 1, 2, \ldots$, would provide the vector of intertemporal responses of oil prices, Texas employment, and rest of U.S. employment to an $s_1$ innovation (surprise) in real oil prices. Similarly, the first column of $s_1 \cdot \Sigma_{d=0}^{d'} A_d$ would provide the vector of cumulative responses to an innovation in the real price of oil after $d'$ time periods. The impulse and cumulative response coefficients for a shock, say $s_2$, to national employment are analogously defined using the third columns of $A_d$ and $\Sigma_{d=0}^{d'} A_d$.