# New Drilling Technology

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MACROECONOMIC POLICYMAKERS FACE TWO FUNDAMENTAL WORRIES. THE FIRST IS WHETHER THE ECONOMY IS ON A GOOD OR DESIRABLE GROWTH PATH. ECONOMIC FORECASTS USUALLY ANSWER THIS QUESTION, SHOWING THE PROBABLE COURSE OF THE ECONOMY OVER THE NEXT FEW QUARTERS IF SOME BASIC SET OF CONDITIONS REMAINS STABLE OR AT LEAST BEHAVES AS PREDICTED. THE SECOND FUNDAMENTAL WORRY IS WHETHER THESE BASIC ASSUMED CONDITIONS MIGHT CHANGE RADICALLY AND QUICKLY, PUSHING THE ECONOMY AWAY FROM ITS FORECAST PATH. THESE UNFORECASTABLE DISTURBANCES ARE KNOWN AS ECONOMIC SHOCKS.

Shocks are mostly of concern when the potential outcome is bad. The most infamous example of a negative economic shock occurred in the 1970s, when the Organization of Petroleum Exporting Countries (OPEC) imposed oil embargoes. Serious negative economic consequences resulted and proved especially problematic for policymakers because of their sudden, essentially unforeseen onset.

Shocks do not, however, have to be negative. Indeed, this article suggests that at the moment the energy extraction industry is in the midst of a very positive shock caused by a combination of two new technologies. These technologies emerged very quickly, and while either technology by itself would have improved the drilling process, as discussed below, it is the combination of the innovations that has served to substantially reduce energy extraction costs in certain types of geological formations.

The oil and gas industry has seen a series of dramatic technical developments in two distinct areas: three-dimensional imaging and directional (or horizontal) drilling. Combined, these two revolutionary techniques have significantly lowered the net extraction costs of oil and made feasible the reopening of wells and fields that had ended their economic usefulness under the old technology. The result has been a surge in the energy sector that is all the more significant because it is being pushed not by a spike in prices but rather by a drop in production costs and may therefore be lasting.

So far this positive technology shock has most affected the oil and gas industry in the Gulf of Mexico. The new technologies are particularly advantageous for the kinds of fields characteristic of the gulf, and their early application there can yield information about what to expect as use of the technologies spreads. The impacts on extraction and exploration costs in other fields in the United States and abroad are likely to be significant.

The purpose of this article is to examine these changes in the energy extraction industry, focusing on Louisiana for examples of the particular benefits in the Gulf of Mexico. This regional focus is appropriate for two reasons. First, the geology of energy deposits in the gulf is relatively complex, so the benefits of the new technology are even greater in its fields than in other parts of the world where the formations are simpler. Second, the drilling technologies have their greatest payoff in offshore fields like Louisiana's, where the costs of exploratory drilling are greatest.

The article is of direct interest at the regional level in terms of what the new technologies promise for Louisiana's economy. In a larger sense, this inquiry offers the rare opportunity to observe a major technological revolution taking place in a mature industry. The oil and gas extraction business, an important and already well capitalized industry, is experiencing a major, identifiable, positive technology shock.

The discussion begins with a short history of drilling in the Gulf of Mexico, a microcosm of the industry's development that helps set the stage for discussing the significance of the new technologies. A close look at the two innovations in drilling technology and what they mean for the energy industry follows. The discussion concludes with a return to Louisiana, why these developments matter so directly to the state, and what Louisiana's experience might, in turn, imply for other oil-producing regions.

## A History of Offshore Drilling in Louisiana

Offshore oil and gas exploration in the Gulf of Mexico began off the Louisiana coast. By the early 1930s the major oil companies dominated onshore production and prospects in Louisiana, and offshore drilling remained too risky an experiment for them to undertake. Instead, small independent oil companies took up the challenge and built the first wooden oil platform in waters near Creole, Louisiana, in 1933 ("1947" 1997). Eventually, wooden platforms gave way to cheaper and sturdier steel platforms, allowing safer work farther from shore. In 1947 one of the small independents, Kerr McGee, hit oil nine miles off Louisiana's outer islands ("Milestones" 1997). Constrained by limited finances, Kerr McGee built a small platform in the deep water and tendered a U.S. Navy yard freighter to it for support. The ship had space onboard for crews to sleep, and drilling operations could continue for longer periods each day. The success of Kerr McGee's operation encouraged drilling activity in the gulf, but costs remained high.

It was not until the end of World War II that naval architects were able to turn their attention to the oil industry. The first technical push was for simple well-to-well mobility and the ability to work in greater water depths. Eventually, the industry moved from fixed drilling platforms such as jackups and submersibles, which rest on the ocean floor, to semisubmersibles and drillships, which are held in place by a set of anchors and thus capable of working in much deeper water. These innovations allowed operations to move easily when necessary, further reducing costs. During the 1950s the settlement of a long-running tideland ownership dispute between the federal government and states, which facilitated offshore leasing by establishing jurisdiction, also boosted drilling activity, as did the successful introduction of new marine seismic techniques ("1947" 1997).

**Revolutionary techniques have significantly lowered the net extraction costs of oil and made feasible the reopening of wells and fields that had ended their economic usefulness under the old technology.**

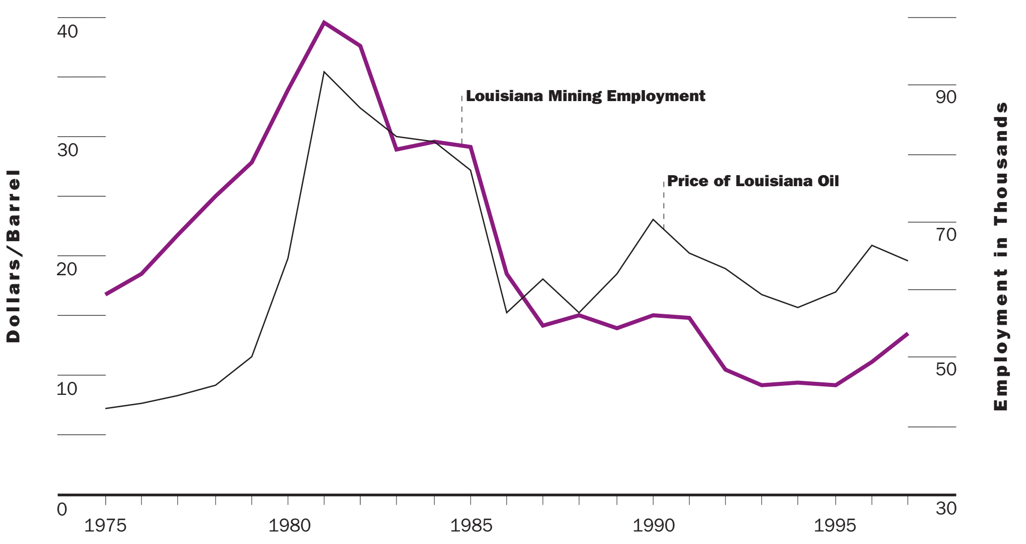
During the mid-1950s the offshore industry in the gulf began to slow down. Nuclear energy was emerging, and oil was plentiful worldwide. Crude oil prices, in relative terms, dropped dramatically, and domestic price controls provided additional distortions to the domestic production market (Bennett, Cole, and Dym 1980–81). At the same time, more and more operators in the gulf were hitting dry holes. The resulting slowdown lasted until 1970, when the excess oil supply had been extinguished and a market had been established for natural gas, which is relatively abundant in the gulf.

The first wide-scale oil embargo among OPEC nations took place in 1973, and supply problems increased as lines formed at gas stations and pump prices rose dramatically. Domestic price controls began to be lifted, and drilling activity in the gulf picked up, spurred further by rising prices in the late 1970s. (Chart 1 shows the path of oil prices and related employment in Louisiana beginning in 1975.) At the same time, introduction of a seismic technology that allowed a look essentially straight down into the earth made it much easier to find likely concentrations of potential hydrocarbon deposits and for the first time enabled searches for oil beyond the continental shelf.[1]

The second OPEC oil embargo resulted from a revolution and political turmoil in Iran during 1978 and 1979 that significantly cut the country's oil production. The embargo continued as Iraq invaded Iran in 1980. Oil prices rose sharply, and drilling activity in the Gulf of Mexico followed suit; however, during this time offshore

1. *This seismic technology allowed a detailed analysis of a change in the characteristics of the reflected waves, focusing on subsurface areas where the geology was most consistent with hydrocarbon deposits.*

**CHART 1 Louisiana Oil Prices and Related Employment, 1975–96**




Source: Price of Louisiana oil from Louisiana Department of Natural Resources (1996, 21); mining employment statistics from the U.S. Bureau of Labor Statistics

costs were also rising, in part because of increased environmental concerns regarding offshore oil development and because new discoveries were getting smaller. The industry expected that high oil prices would remain in place for some time, but in 1985 Saudi Arabia decided it would no longer restrict its supply of oil. Instead, Saudi Arabia decided to adopt a high production rate, which meant immediate increases in crude oil supply and a sharp decline in prices ("1947" 1997). When oil prices plunged in the fall of 1985, operators in the Gulf of Mexico could not continue to produce oil at those prices because of the high cost of extraction and its associated maintenance offshore. Hundreds of leases in the Gulf of Mexico were returned to the government, drilling was cut back significantly, and employment in the sector declined.

By 1988 oil prices began to recover somewhat, but major oil companies were no longer interested in the deep water of the gulf. However, independent (and largely local) operators remained interested and went heavily in debt purchasing large tracts of offshore extraction rights from the major companies. In an effort to make their purchases pay off quickly, exploration drilling (in search of new deposits) gave way to development drilling to more rapidly exploit known deposits, and independent operators ultimately drilled more wells in the gulf than the major oil companies did. Somehow, the independents had to cut drilling costs significantly, and they did so by erecting low-cost minimal platforms, as described earlier, and by refurbishing cheap old platforms. Despite efforts at cost-cutting and switching from drilling for oil to drilling for natural gas, 1992 and 1993 were painful years for gulf operators as gas prices fell dramatically and oil prices dropped to below $18 per barrel. Finally, however, in 1994 the merging of several new technologies, in tandem with rising oil and gas prices, culminated in both lower drilling costs and higher profits for gulf operators.[2] It is to these new technologies that the discussion now turns.

## The Symbiosis in Two New Technologies

Around 1994 two relatively new groups of technologies were combined to drastically reduce oil and gas extraction costs. The first of these is three-dimensional seismic imaging, and the second is controlled directional (steerable, as opposed to the conventional vertical) drilling.[3]

Three-dimensional seismic imaging is a combination of recent innovations that provides geophysicists with very large quantities of seismic data for greater precision in defining and creating images of possible deposits of oil and gas in deep geologic formations. Scientists can model and identify those formations likely to contain extractable hydrocarbon deposits, hence reducing uncertainty—and thus costs—in the exploration process.

Directional drilling proceeds with fair precision along a long and complex path. This innovation offers two related but distinct advantages over a traditional vertical well. First, it allows access and more precise exploitation of complex deposits identified through three-dimensional imaging. Being able to accurately identify deep formations would be of little use if drilling technology did not permit access to them. On the other hand, of course, the ability to precisely locate a drilling path would be of limited use if deposits cannot be precisely identified.

The second advantage to steerable drilling techniques is directly related to drilling offshore. Because the drill can now be steered horizontally (or in any direction), the ultimate location of the oil deposits no longer has to be particularly close to the drilling platform. The oil- or gas-bearing formations in the Gulf of Mexico are typically quite complex and not economically accessible by conventional wells. Now that drilling is no longer limited by the position of the rig, one offshore drilling platform can effectively exploit many different deposits in a wide subsea area. As a result, offshore drilling costs less.

**Three-Dimensional Imaging.** Three-dimensional seismic imaging combines two important innovations: relatively inexpensive computing power and some geophysical algorithms that can interpret seismic data to form 3-D images. The two technologies have depended on each other to make 3-D imaging practically—or economically—feasible (Neff and Thrasher 1993).

The geophysical problem in seismic imaging is that different geologic formations allow seismic pulses to travel at different rates of speed. These differences in rates of wave propagation and reflection are what allow the images to be made in the first place, much like radar depends on the reflective properties of different materials to produce an image. However, as the geologic formations become more complex, either because the imaging process is probing more deeply or because it is looking at a particularly complex formation, it becomes exponentially more difficult to extract a true image. In addition, some geologic formations distort sonic waves so much that traditional two-dimensional imaging techniques are overwhelmed by the distortion. Salt deposits, a common feature in the Gulf of Mexico, are such a formation (Neff and Thrasher 1993). Addressing these issues is one of the more powerful applications of 3-D imaging in the gulf.

The 3-D imaging process itself is dependent upon several key recent technical innovations. Instead of surveying a specific surface block and creating a two-dimensional image of what is beneath (as occurs in surveying for conventional well-shaped deposits), the three-dimensional process requires information from all the blocks around the block of interest. Moreover, the finer the ultimate precision of the image is, the more raw data is needed for interpretation. Only in the last decade has adequate computing and data power made it feasible to economically gather, store, and manipulate such massive quantities of data.

Just as important in offshore work is that the process of gathering the survey data depends on knowing the precise location of data sensors. Low-cost and highly accurate geopositioning satellite technology, available only within the last decade, provides an enormous improvement in accuracy and efficiency over the days when one ship carried one sensor by allowing a single ship to tow a lengthy array of sensors, the location of which can be known with some certainty.

Transforming the raw data into an image requires an implementable mathematical formula—an algorithm. Researchers have recently developed improved algorithms for interpreting seismic data that can yield detailed three-dimensional images. In addition, the availability of supercomputers small and robust enough to be taken into the field has made the 3-D seismic mapping process economically viable. The new technology allows a resolution fine enough for 3-D mapping of deep geologic formations and therefore suitable for the guidance of exploratory and developmental wells. This process is continuously being refined and with enough success that the current leading-edge imaging technology is referred to as 4-D.

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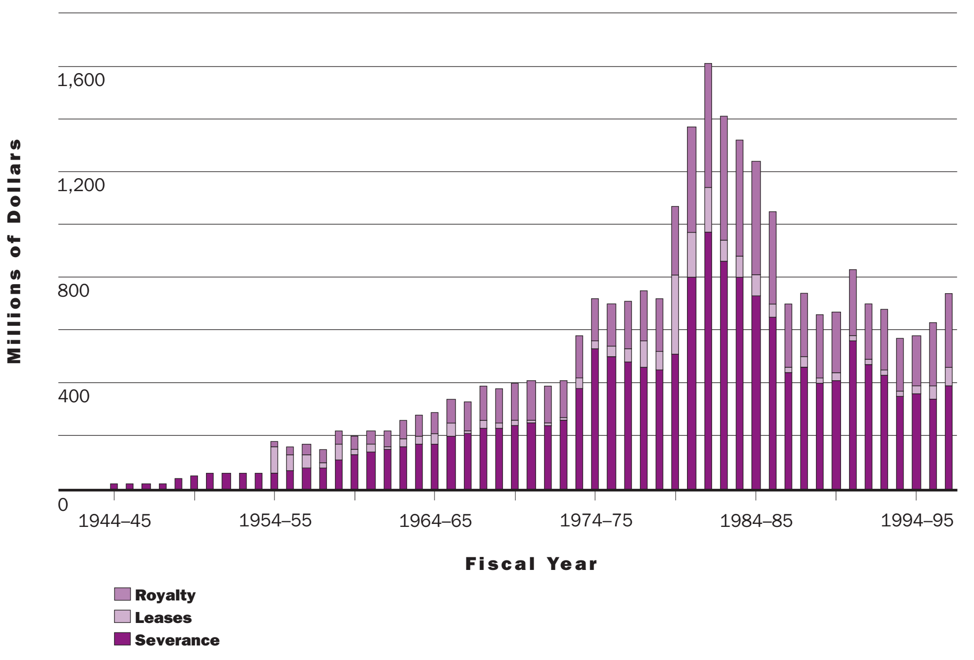
On an operational level, the new technologies are not wholly without drawbacks. Because both technologies are relatively sophisticated, there is a high premium on specialized human capital. During the last drilling slowdown, many experienced workers left the industry, and their defection has placed an even greater premium on specific skills in the industry. Also, the technology offers its greatest comparative advantage in deep-water exploration, and drilling off the continental shelf requires large investments and relatively long planning lags.

**Directional Drilling and the Problem of Irregularly Shaped Deposits.** Drilling used to be, literally, a fairly straightforward matter. Although not necessarily strictly vertical, wells were largely straight-line constructions. This approach works well if the oil or gas deposit happens to be held in a conveniently shaped straight formation or is so vast that the precise placement of the well does not really matter, as in the Persian Gulf and some of the early Texas oil fields, for example. In the Gulf of Mexico, however, the irregular shapes of formations necessitated a great deal of drilling to get at the deposits, hence making it economically infeasible to extract most of the deposit.

The limitation of previous technology was that it provided no way to effectively steer the bit once it was

2. *See the Web site of the Center for Energy Studies, Louisiana State University (www.enrg.lsu.edu), for more energy statistics and additional oil industry links.*
3. *For a more detailed description of these technologies, see* Oil & Gas Journal *on-line at www.ogjonline.com.*

**CHART 2 Louisiana Revenue from Oil and Gas Production, 1944–97**




Source: Louisiana Department of Natural Resources unpublished data

far below ground. One issue was how to determine exactly where the bit was and where it was going and communicate this data back to the driller. Unrefined versions of the two basic systems for navigating a drill—magnetic and gyroscopic—were conceptually available earlier than the recent boom, but both methods had fairly complex telemetry requirements. This problem was overcome for only the shallowest of wells until, not entirely coincidentally, about the time the laptop computer appeared. Previously, drillers monitored geologic conditions by examining the drilling mud, a method both imprecise and not timely.

The results provided by magnetic drill navigation, which functions much like a complex compass, can be distorted by local geologic formations, and these change as drilling proceeds. Solving this problem called for a model of different formations' magnetic distortion and an accurate picture of the formations the drill is passing through so that corrections for distortions could be made. Until the advent of 3-D imaging provided a usefully complete picture of formations that would alter the magnetic locational data, this requirement was not feasibly met.

The second method of navigating a drill is to use a gyroscopic guidance system analogous to the inertial guidance systems in airplanes, in which analysis of momentum on a gyroscope can provide relative location information without any external signals or information. Because gyroscopic guidance is self-contained, it can avoid the magnetic distortion problem, but the technology is inherently more complex and difficult to make reliable. A continuous, real-time gyroscopic guidance system that was rugged, reliable, and accurate enough to greatly enhance the precision of the steerable drill became commercially available in 1995.

These developments overcame the engineering problem of having drills make fairly precise and sharp turns at arbitrary depths. With their availability, the entire process of steering the drilling of a well to fit whatever line was required became feasible.

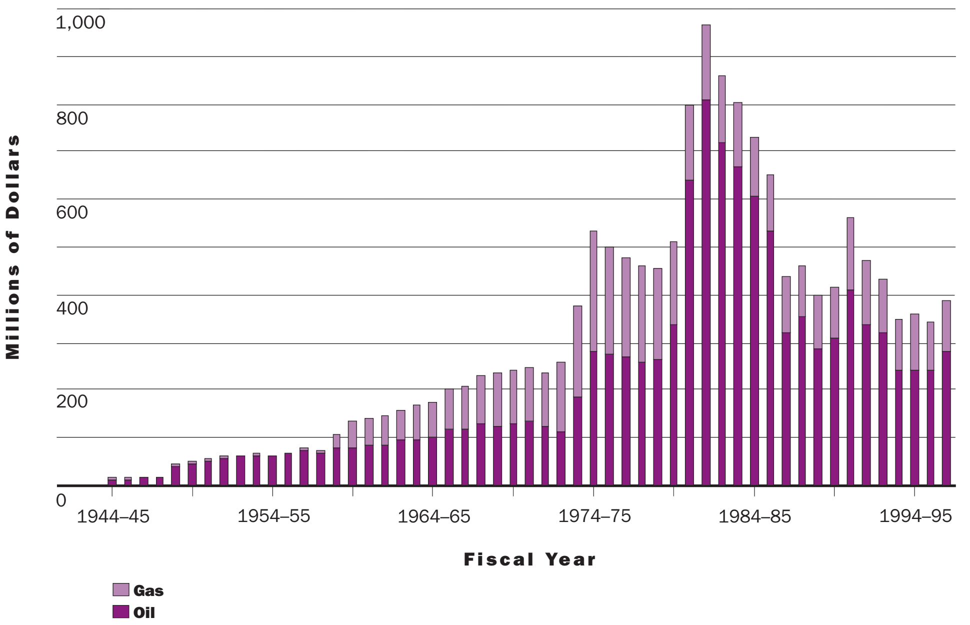
## Implications for Louisiana

The application of these technical innovations in the Gulf of Mexico has resulted in something of a mini-boom. A broader application may cause positive, though probably lesser, shocks in other oil-producing regions and could eventually alter the world's energy economy. To get some idea about how economies and governments' fiscal condition in other oil-producing regions might react, an analysis of effects on the Louisiana economy is in order.

The energy extraction industry in Louisiana has expanded rapidly over the last few years. This growth has occurred despite considerable volatility in the price of a barrel of crude—a mild run-up in 1995 and 1996 and, more recently, a run back down, with little net price movement from the beginning of the gains in drilling in 1995 (see Chart 1).

Louisiana was a prime beneficiary of the last surge in energy extraction activity, during the high oil prices of

CHART 3 Louisiana Severance Tax Revenue from Oil and Gas, 1944–97




Source: Louisiana Department of Revenue and Taxation unpublished data

the 1970s and early 1980s. The energy industry directly provided a large portion of the state's overall tax revenue as well as considerable personal and business income to the workers and firms employed in, and in support of, the energy extraction process. Given the sudden increase in the real cost of energy in 1974, this result is not especially surprising. In turn, when the real (and nominal) price of oil began to fall in the mid-1980s, Louisiana fell on comparatively hard times as energy income diminished.

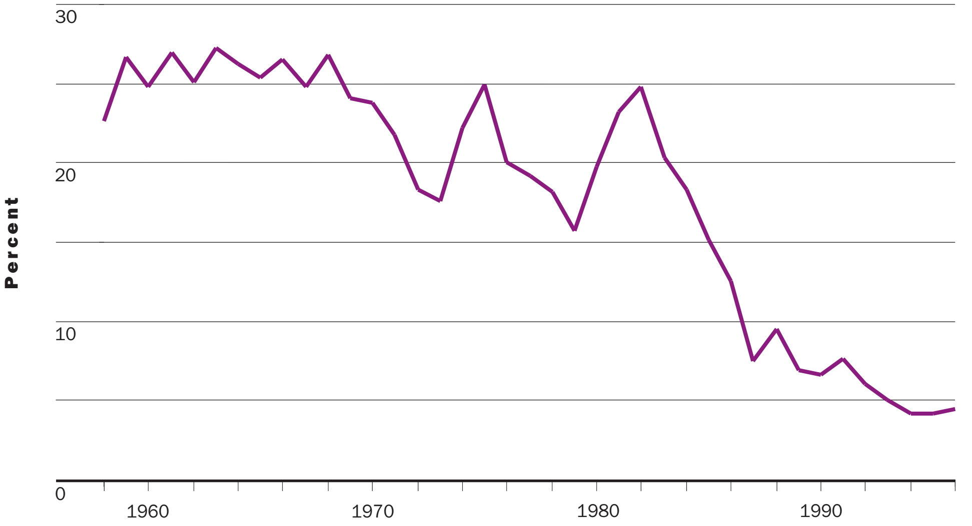
Over the past year, although oil prices have fallen, Louisiana's energy industry has continued its prosperity begun in the mid-1990s. This time around, however, the energy industry's continued strength has not been powered by some externally imposed increase in the price of oil or gas, as discussed earlier. Growth in Louisiana's mining sector—essentially all oil and gas extraction—picked up dramatically in late 1995, and that rate of growth has only incrementally slowed since then. At the same time, the price of oil rose mildly through mid-1997 but then fell off rapidly, and it did so with no concomitant spillover into mining employment growth.

Good times in the oil and gas industry have historically meant good times for Louisiana. Will the current positive energy shock based on technological innovation have implications for the state similar to those of an increase in the price of energy? To date at least, the energy sector of the state's economy and state tax revenues has clearly benefited.

Louisiana had traditionally relied heavily upon the oil and gas industry for revenue; however, that reliance waned over the last decade in response to the industry's slump. The state collects tax revenue directly from the industry in the form of severance taxes, royalty payments, and lease fees. Indirectly, the state collects moneys from corporate and personal income taxes, corporate franchise taxes, sales taxes, and property taxes, all of which may be influenced by the condition of the local oil and gas industry. The postwar history of oil and gas total dollar revenue collections for Louisiana is shown in Chart 2, broken down by tax classification. Chart 3 shows the composition of severance tax collections in Louisiana, divided between oil and gas.

During the 1960s, Louisiana received nearly 25 percent of its tax revenue funds from oil and gas severance taxes, royalty payments, and lease fees (see Chart 4). During the 1970s the proportion of revenues from the oil and gas industry was slightly more volatile (as were product prices) but remained strong (as, again, did the product price). When oil prices began to tumble in the 1980s due to the increase in world oil supply, Louisiana's state oil and gas revenues began to drop largely due to the falloff in crude oil prices. The state lost additional income as drilling firms and their suppliers closed up shop and laid off employees. By 1990 oil and gas revenue accounted for slightly less than 7 percent of Louisiana's total state revenues. Despite a minor resurgence in oil and gas exploration and production in the Gulf of Mexico during the first half of the 1990s, the petroleum industry's share of total state revenue has continued to dwindle. However, the total amount of revenue con-

**CHART 4**
**Louisiana Oil and Natural Gas Severance Taxes, Royalty Payments, and Lease Fees as a Percentage of Total State Revenue, 1958–96**




Source: Louisiana Department of Natural Resources unpublished data and U.S. Bureau of the Census, *Government Finances,* various issues

tributed to state coffers by oil and gas extraction has remained relatively stable. The decline in share may be due to substantial growth in the total overall amount of revenue that Louisiana brings in.

Even though the petroleum industry has once again become interested in drilling prospects in the waters off Louisiana's coast, oil and gas production remain far below that of the late 1970s, and relatively low oil prices have prevented the state from realizing a windfall in tax receipts. Additionally, since the late 1970s a greater proportion of oil and gas has been extracted from deeper waters that are the jurisdiction of the federal government and are thus not directly subject to state taxes.[4] According to the state department of natural resources, Louisiana has largely been unsuccessful at directly recovering what it believes are costs of creating infrastructure to support the now more intense offshore operations. Several attempts have been made at taxing oil and gas retrieved from federal waters and imported into the state for refinement. These efforts have been limited, however, largely because of the fear that over the long run taxation would divert refining investment to other Gulf Coast states (Pulsipher 1990).

In addressing the relative position of Louisiana in terms of energy industry taxation, researchers at Louisiana State University in 1993 found that the tax burden on firms that find and produce oil and natural gas in Louisiana did not differ significantly overall from that in competing states (Pulsipher, Baumann, and Iledare 1993). Louisiana does, however, limit its revenues. The state taxes oil at a higher rate than natural gas, although for mostly geophysical reasons Louisiana produces roughly twice as much gas as oil.

Severance tax collections make up the largest portion of direct revenue collected from the oil and gas industry. A severance tax is generally levied on all natural resources extracted from the soil or water and in Louisiana is paid by the natural resource owner. More than 95 percent of the state's severance tax collections are attributed to oil and gas extraction. In 1910 the state administered its first severance tax on oil and gas production through a minimal occupational license tax, and then in 1922 constitutional authority was given for a severance tax (Louisiana Department of Revenue and Taxation 1997, 151). Since that time there have been many changes to the tax rate, the most significant being that collections have moved from a volume basis to a percentage-of-value basis.

Oil production accounts for the majority of severance tax collections, and the amount of revenue the state collects from oil is more dependent upon the price of oil than on the amount of oil produced. Since 1974 most oil wells have been taxed at the rate of 12.5 percent of value produced (Louisiana Department of Revenue and Taxation 1997, 151). According to the Louisiana Department of Natural Resources, "At constant production, the State Treasury gains or loses about $20 million of direct revenue from oil severance taxes and royalty payments for every $1 per barrel change in oil prices. This figure rises to $30 to $40 million per dollar change when indirect revenue impacts are included" (Louisiana Department of Natural Resources 1997). Severance tax collections from oil peaked during the 1981–82 fiscal year at more than $809 million. Similarly, the average wellhead price of Louisiana crude oil rose to its highest level at $33.84 per barrel during the same fiscal year, which runs from July to June. Oil production at that time was rather modest when compared with its highs of the mid-1970s. At that time the oil severance tax was collected at the rate of $0.18 to $0.26 per barrel based upon its weight. In 1986, when the bottom dropped out of oil prices, the average Louisiana wellhead price for crude oil during the fiscal year fell to $15.43 per barrel. Likewise, collections from the oil severance tax fell to slightly more than $318 million during the 1986–87 fiscal year. Since that time collections for oil have ranged between $239 million and $354 million, with the exception of fiscal year 1990–91, when collections rose to just over $412 million because of the run-up in oil prices associated with the Persian Gulf conflict.

Natural gas severance tax collections are smaller than oil collections despite the fact that Louisiana produces much more gas than it does oil. Unlike oil severance taxes, which have been tied to oil's price, natural gas severance tax collections have been closely associated with production. In 1972 natural gas was taxed at the rate of $0.033 per thousand cubic feet (mcf). That rate grew to $0.07 per mcf in 1974 and then to $0.10 per mcf in 1990. Since that time natural gas prices have, on net, moderated somewhat, but in July 1997 the rate was set at $0.101 per mcf (Louisiana Department of Revenue and Taxation 1997, 151). The share of total severance tax collections from gas severance tax collections became significant during the early 1960s and grew through the 1970s as marketable uses for natural gas were established and grew. During the late 1970s collections for natural gas approached those of oil, but in the early 1980s surging world oil prices and moderate levels of gas production combined to push natural gas severance taxes' share of total collections down.

## Conclusion

Because new technologies are making it easier to identify potential energy deposits and more feasible to extract oil from existing formations and are also enhancing overall efficiency, the average production cost of oil and gas extraction is being driven down. Importantly for the Gulf of Mexico, this beneficial effect of the new technologies becomes relatively more valuable as the geology becomes more complex. That is, extraction costs will fall more dramatically in the gulf, where plentiful oil and gas deposits are found in complex formations, and relatively less in geologically less complex regions like the Middle East, where optimally positioning a well will save some money but the extraction process more resembles draining a large underground pool. In the most extreme cases in the Gulf of Mexico, the net effect of the new technologies is to move oil recovery rates from around 30 percent of potential to over 80 percent.

This analysis suggests some good things for the state of Louisiana, which is the first in line to benefit from these positive industry developments. The current boom is not being fueled by an external rise in product price but rather by a technologically induced reduction in costs. Since the shock to technology will not disappear, the employment and associated income gains seen recently appear likely to last. As a result, the Gulf of Mexico has some immediate gains relative to other, simpler, geologies. Given the state's current taxation policies, however, its tax revenue gains will be limited, coming mostly from rising personal and corporate income because severance revenue is dependent upon the price of oil rather than its profitability (although that may be captured in part by income taxes). This tax structure is similar to other states' and is not necessarily a bad thing, in particular since it looks like gains may be very long term.

**The state taxes oil at a higher rate than natural gas, although for mostly geophysical reasons Louisiana produces roughly twice as much gas as oil.**

This news comes at a particularly fortuitous time for Louisiana. In the early 1990s, prior to the resurgence in drilling, the state's economy had seen particular strength in tourism and gambling-related construction, and state government had received an increasing share of its revenue from social medical insurance funds. Gambling did not work as well for Louisiana as it did for Mississippi, and most of the growth in, and income from, gambling-related service and construction jobs in Louisiana was short-lived. At the same time tourism, especially in the New Orleans area, grew to its capacity in the mid-1990s, hence limiting further revenue growth. While state tax revenue collection growth was slowing, at the federal level Louisiana was being pressured to reduce the size of its Medicaid expenditures (State Policy Research). These trends, combined with slowing in some previously hot areas of the private sector, made the effects of the technological revolution in the oil industry—particularly its apparent ability to last at current oil prices—a welcome development.

*4. The boundary between federal and state waters is typically about three and a half miles from shore.*

For the world, the effects of this technology shock have yet to be felt, particularly its implications for offshore energy development. The Gulf of Mexico and Brazil account for almost three-fourths of all deep-water drilling, and the North Sea is rapidly emerging as a significant source. The remainder of the world's deep-water oceans remain unexplored, and the most dramatic reductions in exploration costs are likely to be seen in these untapped regions. Momentum is gathering for deep-water exploration off west Africa, northwestern Europe, and in the Pacific off the coast of several Asian countries ("Deepwater" 1996).

Judging from the case of Louisiana, the other oil- and gas-producing regions will be better off too. The new technology permits greater production at prevailing energy prices. In turn, Louisiana has experienced a very solid base of employment in the relatively high wage energy extraction and related industries. And this surge in employment may not be as fragile as during the OPEC embargoes, when considerable international collusion was required to keep prices up. At the same time, however, this surge in income may have less fiscal impact depending on regions' systems for taxing energy.

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