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THE KANSAS OIL AND GAS INDUSTRY: AN ENDURING MODEL OF HIGH-TECH ENTREPRENEURSHIP

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About The Center for Applied Economics

The KU School of Business established the Center for Applied Economics in February of 2004. The mission of the Center for Applied Economics is to help advance the economic development of the state and region by offering economic analysis and economic education relevant for policy makers, community leaders, and other interested citizens. The stakeholders in the Center want to increase the amount of credible economic analysis available to decision makers in both the state and region. When policy makers, community leaders, and citizens discuss issues that may have an impact on the economic development potential of the state or region, they can benefit from a wide array of perspectives. The Center focuses on the contributions that markets and economic institutions can make to economic development. Because credibility is, in part, a function of economic literacy, the Center also promotes economics education.

About the Author

Arthur P. Hall is the founding Executive Director of the Center for Applied Economics at the University of Kansas School of Business. Before joining the KU School of Business, Hall was Chief Economist in the Public Affairs group of Wichita, KS-based Koch Industries, Inc. In that capacity, he worked with business leaders to define how public policy initiatives would influence the structure of the markets in which the company participates. Koch sponsored Hall's directorship of Kansas Governor Sebelius' Budget Efficiency Savings Teams from April 2003 until his departure from the firm in February 2004.

Before joining Koch Industries in May 1997, Hall was Senior Economist at the Washington, D.C.-based Tax Foundation, where he produced quantitative and qualitative research pertaining to the economics of taxation and acted as an economic advisor to The National Commission on Economic Growth and Tax Reform. Before that, he worked as a financial economist at the U.S. General Accounting Office. Hall has taught university-level economics at both the undergraduate and MBA level. He received his doctorate in economics from the University of Georgia and his bachelor of arts in economics from Emory University.

The opinions expressed are those of the author; they should in no way be interpreted as the viewpoints of the University of Kansas (or any subunits thereof) or the Kansas Board of Regents.

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THE KANSAS OIL AND GAS INDUSTRY: AN ENDURING MODEL OF HIGH-TECH ENTREPRENEURSHIP

> *The oil game is one pioneering activity that has never had a frontier, and until the last porous stratum of rock is explored it never can have one. There would be mirth-provoking irony in a map of the United States showing the boundaries, lateral and horizontal, beyond which dogmatists have at one time or another said oil could not be found—which mental barbed-wire fences have snapped under the irrepressible urge of the . . . wildcatter's boundless energy, curiosity, ambition, and skill with a string of tools.*
>
> — Samuel W. Tait, Jr. [1]

The renaissance in United States oil and gas production reaffirms the timeless tribute Mr. Tait made to the nation's petroleum entrepreneurs almost 70 years ago. The tools have changed—a lot—but the pioneer spirit has not. Boundless entrepreneurial energy and an increasingly sophisticated, high-tech string of tools has created a genuine opportunity for the United States to become a net energy exporter instead of a net energy importer. Kansas helped deliver the original birth of the U.S. oil and gas industry and now the state may help deliver the industry's rebirth.

Early in Kansas history, after the first oil and gas booms, people fretted about depleting the state's oil and gas reserves.[2] Similar fretting has taken place globally; the notion of "peak oil" has attracted widespread attention since at least the 1950s. These ideas can seem intuitive. The earth is finite.

Yet, such mindsets inevitably underestimate the power of economics and the relentless drive of entrepreneurs. Geologist Walter Youngquist captured a more apt perspective in a communication to Dan Merriam, Senior Scientist Emeritus at the Kansas Geological Society: "Kansas experience shows that aging oil regions can still be given a drink from the Fountain of Youth if the imagination and ingenuity of the human mind is diligently and persistently applied."[3]

The independent oil and gas producers of Kansas have demonstrated clear diligence and persistence. They have drilled an average of 2,750 wells per year over the past 20 years, implying an average investment in the Kansas economy of at least $700 million annually (in 2010 dollars). A group of entrepreneurial companies in the Mid-Continent have poured decades of imagination and ingenuity into the quest for developing unconventional oil and gas supplies—the shale-related oil and gas supplies that have recently captured the public's attention.

High-tech entrepreneurship and economics help frame the core definitional element of "proved" oil and gas reserves, underscoring Dr. Youngquist's suggestion that oil and gas supplies are a moving target, a result of entrepreneurial initiative. The U.S. Energy Information Administration defines "proved reserves" as "the estimated quantities which analysis of geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under existing economic and operating conditions." Since 1990, the U.S. has increased its proved reserves of natural gas by 60 percent, back up to levels recorded

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[1] Samuel W. Tait, Jr., *The Wildcatters: An Informal History of Oil-Hunting in America* (Princeton: Princeton University Press, 1946), p. xiii.

[2] Phyllis Jacobs Griekspoor, "The First 150 Years: From the Efforts of the Early Kansas Explorers to the Modern Petroleum Industry," The Wichita Eagle Beacon Publishing Company, August 2010.

[3] Daniel F. Merriam, "Advances in the Science and Technology of Finding and Producing Oil in Kansas: A Critique," *Oil-Industry History*, Vol. 7, No. 1, 2006, p. 44.

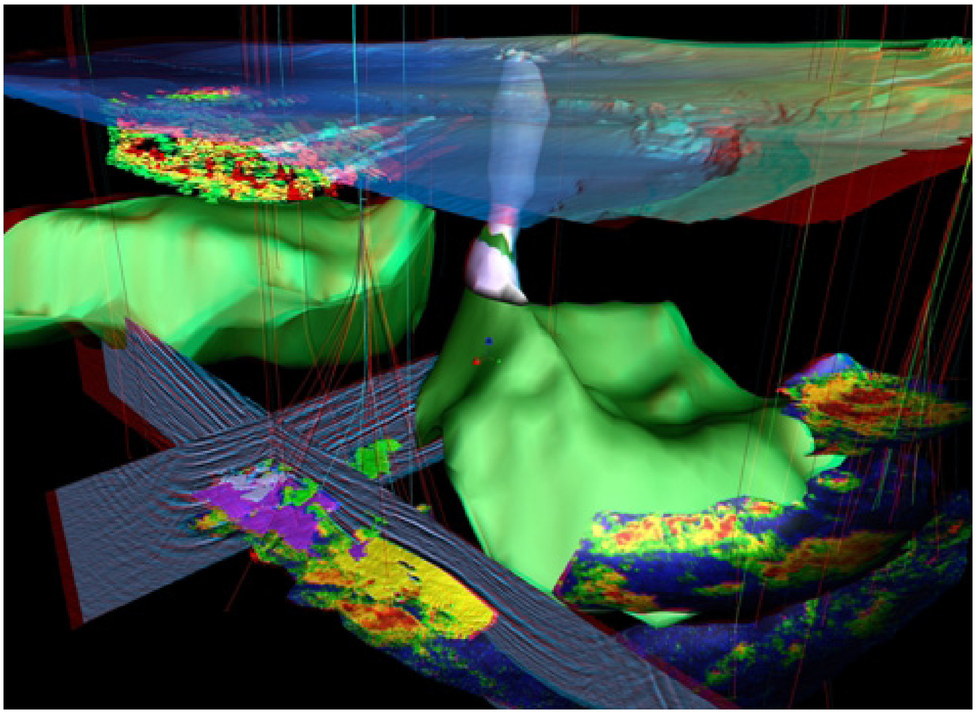
in the early 1970s. Proved reserves of crude oil have also begun to increase. The changes have resulted from entrepreneurs going after supplies that geologists have long suspected to exist but could not be reached in accord with the prevailing technology and economics—until now.

Like many dramatic changes in industry, what seems sudden and new actually took decades to develop. The word "fracking" has entered the public's lexicon. But the popular use of the term actually embodies three different, mutually-reinforcing (and increasingly integrated) technologies:

1. **Hydraulic fracturing**. The term "fracking" refers to a process of fracturing underground rock and sediment layers to help trapped oil and gas flow more freely. The idea dates back to the pre-1900 days of drilling in Kansas—only in those days a few Wild-West-type gentlemen practiced the entrepreneurial art of "shooting" a well with a nitroglycerin-fueled "torpedo." Kansas entrepreneurs used this technique on the first commercial oil well in Kansas—the so-called Norman #1 well located in Neodesha (drilled in 1892 and shot in 1893).[4] The first hydraulic fracturing experiment was conducted in 1947 at the Hugoton gas field in Grant County, Kansas.[5] The process involves pumping a mixture of fluid and sand into the well. The hydraulic pressure fractures the rock and sediments. The sand keeps the fractures open and porous.

Exhibit 1

A 3-D Seismic-Generated Image Underneath the Gulf of Mexico



A complete 3D picture of the subsurface near two producing oil fields in the Gulf of Mexico not only shows the sea bed at some 1,000m water depth, but features such as salt structures in green and a salt diapir that penetrates the sea bed (white). Thin lines show the paths of wells drilled to over 2000m below the sea bed to develop the fields, fanning out to penetrate various reservoirs. Shallow bodies in front of the well paths on the left hand side may provide hazards to drilling. Oil field reservoirs can be seen in color (yellows and reds) at deeper levels. Most features are extracted from the actual data, though parts of two seismic profiles are shown in black and white near the base of the display.
Source: http://www.geolsoc.org.uk/gsl/geoscientist/features/page2722.html

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[4] Craig Miner, *Discovery!: Cycles of Change in the Kansas Oil and gas Industry, 1860-1987* (Wichita, Kansas: KIOGA, 1987), p. 41.

[5] http://en.wikipedia.org/wiki/Hydraulic_fracturing

2. **Horizontal drilling**. A patent for the forerunner of horizontal drilling tools was issued in 1891. The first true horizontal well was drilled in 1929 in Texas.[6] Techniques associated with horizontal drilling gradually improved following World War II, but the economics remained unfavorable until the late 1980s. Horizontal wells cost significantly more to drill than traditional vertical wells. By about 1990, horizontal wells comprised an estimated 10 percent of all U.S. wells drilled. The improving technology and economics (which often also implies a reduced environmental footprint), motivated further expansion of horizontal drilling, much of it in association with the Austin chalk geologic formation in Texas and the Bakken shale formation underneath Montana and North Dakota.[7]

3. **3-D seismic imaging**. Seismic imaging for purpose of oil and gas exploration dates back to the mid-1920s. The technology, in one way or another, blasts sound waves into the earth and records the echoes that return. Different substances produce different echoes, creating identifiable patterns. Early techniques created 2-D images or cross sections of the subsurface. 3-D techniques, significantly aided by the advent of digital computer technology in the 1980s, allow for the creation of a three-dimensional picture of the targeted subsurface. These 3-D pictures can reveal much more detailed patterns and, therefore, allow for much better precision in the exploration and drilling processes. (Independent producers in Kansas have put—continually-improving—3-D seismic imaging technology to work since about 1990.[8] In many cases, it has brought new life to old producing properties.) 3-D seismic imaging projects cost about $40,000 per square mile in Kansas. Exhibit 1 vividly demonstrates the types of images that experts can create from raw 3-D seismic data.

A complete list of causes contributing to the U.S. oil and gas rebirth should also add: (1) well-defined private property rights and (2) well-functioning futures markets. As a *Wall Street Journal* editorial argued: "'Whoever owns the soil, it's theirs up to Heaven and down to Hell.' So goes the ancient common-law principle. Today, however, almost no major country recognizes full subsurface private property rights, except for the United States. . . . What has given the U.S. its edge is that the early development risks were largely borne by small-time entrepreneurs, drilling a lot of dry holes on private land. These 'wildcat' developers were gradually able to buy up oil, gas and mineral leases from private owners while gathering enough geological data to bring in commercial producers."[9] Veteran petroleum economist Philip Verleger has argued that: "Financial engineering underpinned the renewal of U.S. oil and gas production. While most writers and analysts credit petroleum, chemical, and computer engineers for developing technologies that led to the rebirth of American oil and gas output, the initial catalyst was the developers of futures markets. The financial engineers who brought the risk management techniques devised originally for agriculture to energy provided a system that allowed smaller firms to operate successfully despite very large swings in oil and gas prices."[10]

Kansas producers have effectively employed all of these innovations. Looking at Kansas opportunities prospectively, horizontal-drilling technologies have made it possible to freshly explore the potential of rock formations that have yielded oil and gas for years, as detailed below in the Mississippian Lime discussion. Many of these innovations may also help advance gas extraction from the coalbeds of eastern Kansas, an enormous resource that has received the attention of Kansas producers for only a few decades.

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[6] Bill D. Berger and Kenneth E. Anderson, *Modern Petroleum: A Basic Primer of the Industry*, 3rd Edition (Tulsa: PennWell Publishing Company, 1992), p. 127

[7] American Petroleum Institute, et al., "Joint Association Survey on Drilling Costs, 1995", p. 3.

[8] Susan Nissen, et al. "3-D Seismic Applications by Independent Operators in Kansas," Petroleum Technology Transfer Council, January 2003. http://www.nmcpttc.org/Case_Studies/PTTCseismic_case/3d-seismic_appl.html

[9] Editorial Board, *Wall Street Journal*, "The Shale Gas Secret," July 13, 2012. http://online.wsj.com/article/SB10001424052702303919504577520421300962752.html

[10] Philip K. Verleger, Jr., "The Amazing Tale of U.S. Energy Independence," *The International Economy*, Spring 2012, p. 54.

VISUALIZING THE MODEL OF HIGH-TECH ENTREPRENEURSHIP

The laws of economics work in a vivid fashion in the oil and gas industry. First, oil and gas have commodity-like properties. Hydrocarbons extracted from different geologies are not identical, but experts can measure and economically value their differences. Second, the entire oil and gas value chain—from hydrocarbons in the ground to the consumption of end-use fuels—operates within a constrained, chemistry-based, highly engineered, and highly capital-intensive delivery system. These two general industry attributes explain why the markets for oil and gas—but most especially oil—operate as highly integrated world markets—markets that react swiftly, and often dramatically, to seemingly small disturbances.

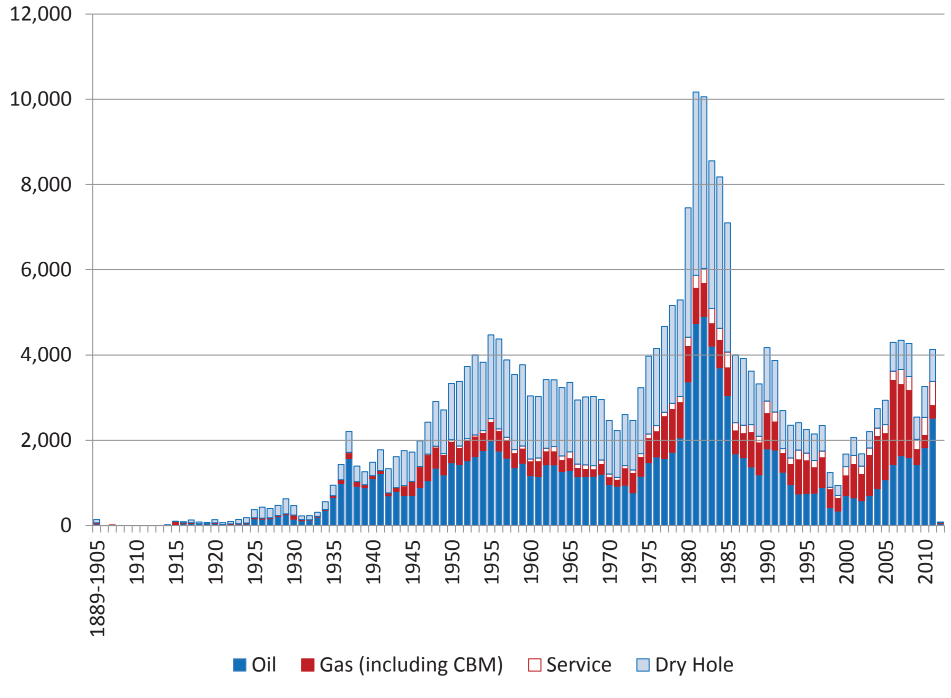
Kansas producers, and their colleagues around the world, succeed in these volatile world markets by being more entrepreneurially deft than their competitors. The essence of the high-tech entrepreneurship embodied in the oil and gas industry can be captured by three sets of metrics: the odds of drilling a producing well, the cost of drilling a well, and the price of oil or gas. Chart 1, Chart 2, and Chart 3 capture these metrics. The upstream oil and gas businesses face enormous discovery, production, and price risks coupled with high-cost, capital-intensive processes. The development of increasingly sophisticated tools for management of the risks defines the high-tech nature of the oil and gas business. The willingness to embrace and prudently manage the full array and complexity of the risks defines the entrepreneurship necessary to succeed in the oil and gas business.

Chart 1 illustrates the recorded history of drilling in Kansas. It counts four types of wells: wells that produce oil; wells that produce natural gas (including coalbed methane); wells used to service producing wells (perhaps for the disposal of water or executing enhanced recovery procedures); and wells that produce nothing—dry holes. (Many wells, of course, produce both oil and natural gas.)

Over the entire history of Kansas oil and gas well drilling, excluding service wells, 40 percent of the wells drilled have been dry holes—expensive risks taken for no economic gain. Notice on Chart 1, however, the

Chart 1

Number of Kansas Wells Drilled, by Type, 1889-2011



Source: Kansas Geological Survey

steady decline in the percentage of dry holes over the past three decades. During the 1970s, drilling in Kansas resulted in dry holes 48 percent of the time; during the 1980s, 42 percent of the time; during the 1990s, 31 percent of the time; and during the 2000s, dry holes resulted 21 percent of the time. This improved success rate tracks national trends and has primarily resulted from superior—but more costly—technologies related to oil and gas discovery. As mentioned above, Kansas producers began using 3-D seismic imaging technology about 1990, which helps explain the impressive gains in cost-control related to drilling investments.

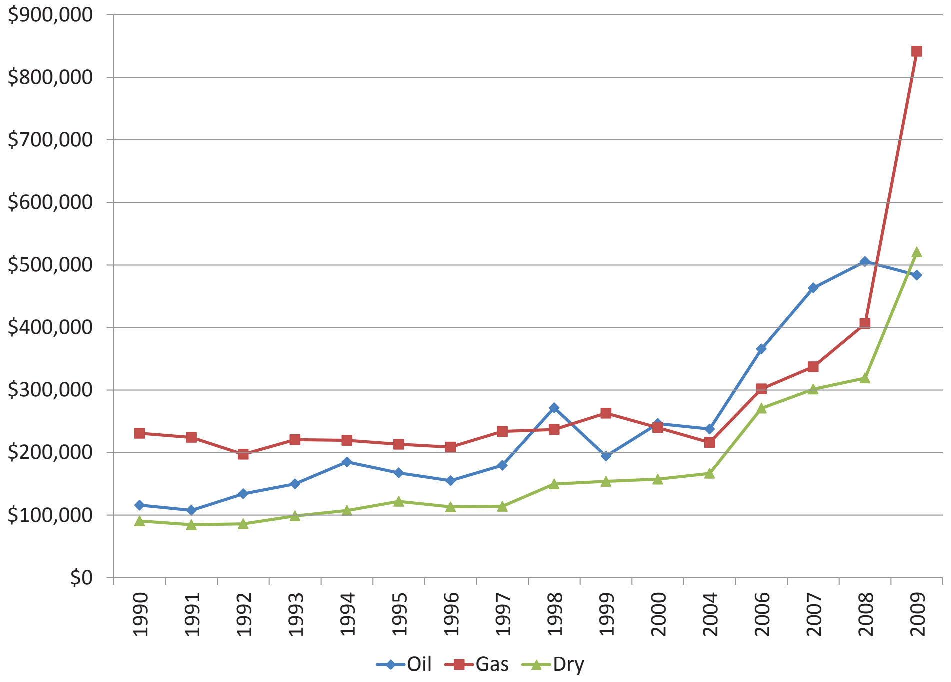
Chart 2 provides estimates on the average drilling costs incurred in Kansas. Readily available cost of drilling data begins in 1990. Based on the data in Chart 1 and Chart 2, Kansas oil and gas producers lost an average of about $110 million per year on drilling dry holes.

The escalating costs beginning in 2004 have two general explanations. First, as discussed below, escalating oil and gas prices created a surge in demand for drilling resources, thereby bidding up the cost. National data show a similar escalation in per-well costs during the late 1970s and early 1980s, the years corresponding to the Kansas drilling surge shown in Chart 1. Second, according to Kansas Geological Survey records, the average depth of Kansas wells increased in a stepwise fashion from 2,565 feet in 2006 to 2,932 in 2009. (Nationwide, the increase in horizontal drilling techniques have driven up the average cost per well. Horizontal wells can more than double the cost per foot to drill compared to traditional vertical wells.[11] However, horizontal wells in Kansas represent less than one percent of wells drilled.)

Map 1 shows why the average drilling cost estimates reported in Chart 2 require a broader perspective. Average well depths vary significantly from one part of the Kansas to the next. Table 1 provides estimates of the average per-foot costs implied by the per-well costs reported in Chart 2. (Table B1 in Appendix B reports by county the number of wells drilled in each county and the depth of the deepest well drilled in each county.)

Chart 2

Kansas Cost Per Well Drilled, by Type (2010$)



Source: Kansas Geological Survey

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[11] http://www.horizontaldrilling.org/

Table 1

Estimated Average Well Cost per Foot, Select Years

	2006	2007	2008	2009
Oil	$100	$131	$168	$179
Gas	140	176	216	361
Dry	66	72	82	132

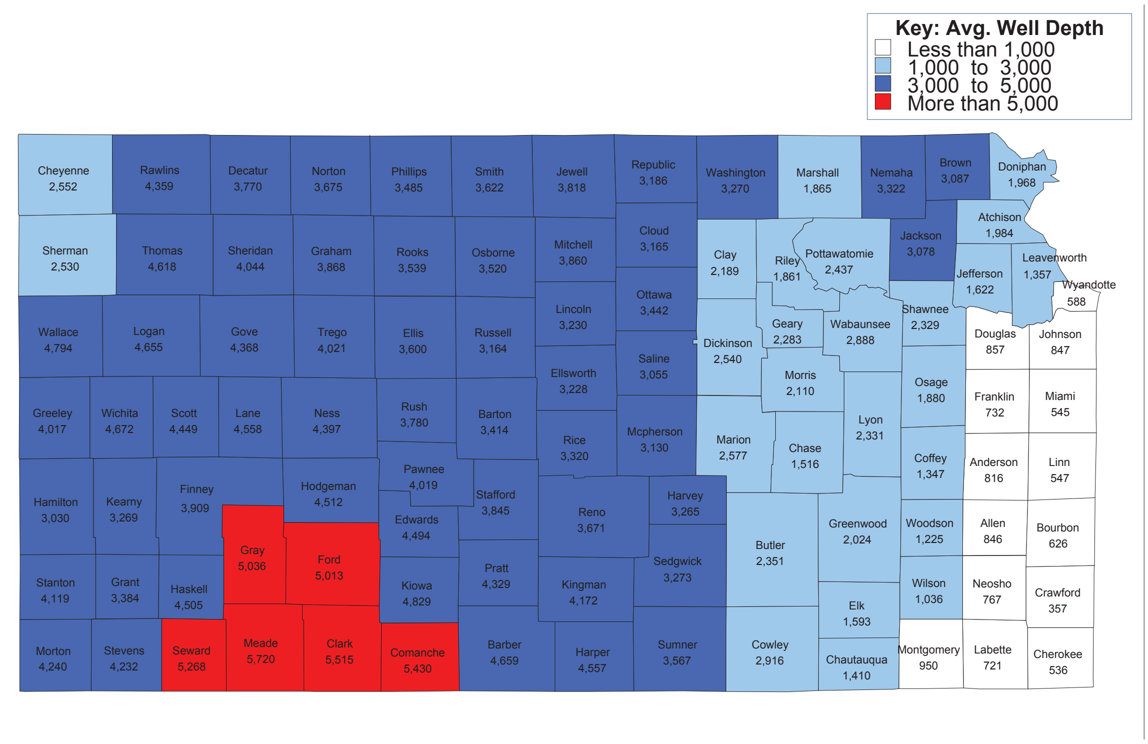
Successful discovery of oil or gas and the development of a producing well do not guarantee business success. The business must sell the production volumes at prices sufficient to cover the development and production costs—and the business owners' opportunity costs of investment capital. World markets set oil and gas prices; Kansas producers must accept these prices if they choose to sell.

Chart 3 shows inflation-adjusted monthly prices for Kansas oil and natural gas from 1978 through 2011. Statistical tests confirm what the eye can see: the prices of oil and gas have become more volatile in the past decade than they were in the previous two decades. Notice that the prices of oil and natural gas tend to move together (although natural gas prices tend to have greater volatility than oil prices). Before the clear deviation in the two price series beginning in January 2010, the two Kansas price series had a statistical correlation coefficient of 0.56, where a coefficient of 1.0 indicates perfect co-movement. (Nationally, the correlation coefficient was 0.75.) From January 2010 to December 2011, the coefficient became -0.55, indicating a stark divergence of price trends rather than the traditional co-movement. The volatility of prices underscores a key entrepreneurial risk faced by Kansas oil and gas producers.

Historically, natural gas prices have adjusted (imperfectly) to the movement in oil prices, because natural gas and refined petroleum products have competed as the fuel of choice for a variety of industrial uses. No doubt this price-linkage will eventually restore itself as producers adjust to the natural gas price decline related to the recent, technology-induced surge in production. (A more detailed discussion of oil and gas price-setting mechanisms follows.)

Map 1

Average Well Depths by County, in Feet



Source: Kansas Geological Survey

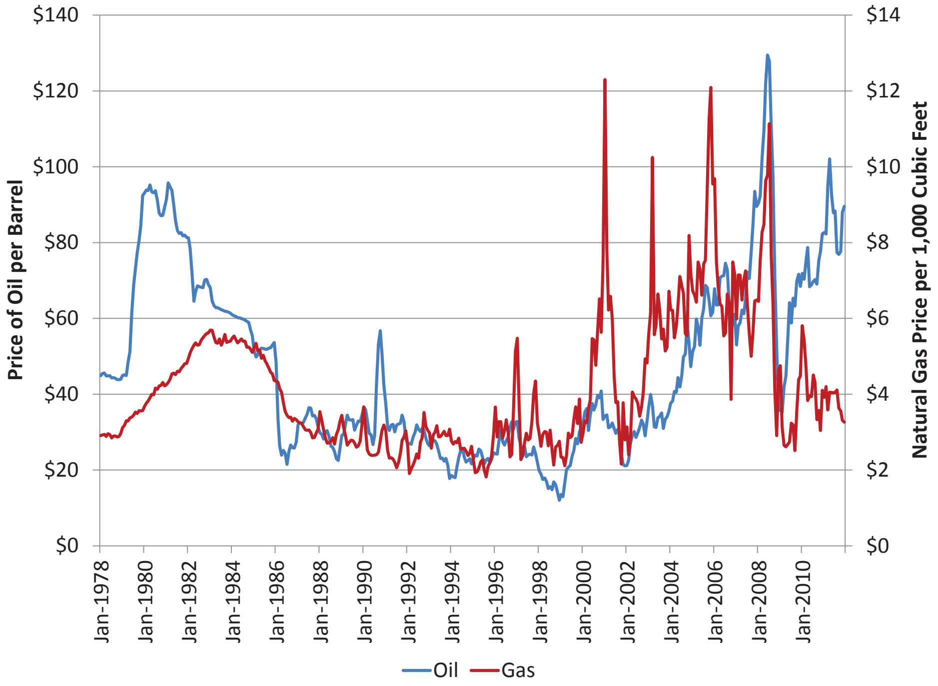
The maturity of the Kansas oil and gas industry intensifies rather than ameliorates the entrepreneurial challenge faced by Kansas producers. Pending further discoveries, Kansas producers have already found the large oil and gas pools. So-called marginal wells (or stripper wells) account for a large percentage of Kansas oil and gas production. Definitions can vary, but the industry typically defines a marginal oil well as one that produces 10 barrels of oil per day or less over a 12 month period and defines a marginal gas well as one that produces 60,000 cubic feet per day or less. Using these definitions, from 2005 through 2009, marginal oil wells accounted for 61.4 percent of Kansas production and marginal gas wells accounted for 30.0 percent of Kansas production. Expanding the definition to 15 barrels per day for oil wells and 80,000 cubic feet per day for gas wells, the averages, respectively become 68.5 percent and 66.6 percent.[12]

For Kansas producers, the predominance of stripper wells adds to entrepreneurial risk for two reasons. First, Kansas businesses specializing in production must have an active drilling program to keep a full portfolio of producing wells—wells that they expect will have relatively low reserves or relatively low production rates. This facet of the industry, in part, helps explain why Kansas ranks fifth among the states in the total number of wells drilled, as reported in Chart 8, but ranks ninth in total production, as illustrated in Chart 9. (See Table B2, B3, and B4 in Appendix B for more detailed state-by-state drilling data.) Second, the relatively low revenue generation created per stripper wells makes drilling and operating costs per well a more substantial part of the profit-or-loss equation.

To provide insight into the mechanics and economics of stripper wells, Chart 4 and Chart 5 provide a portrait of one such oil well and Chart 6 and Chart 7 provide a portrait of one such gas well. On average, the oil well has produced 11.3 barrels per day and the gas well has produced 51,407 cubic feet per day. Notice several important features of these portraits:

Chart 3

Price of Kansas Oil & Natural Gas (2010$)



Source: U.S. Energy Information Administration; Independent Oil & Gas Services (Red Top News)

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[12] U.S. Energy Information Administration: http://www.eia.gov/pub/oil_gas/petrosystem/ks_table.html

Chart 4

Example Oil Well: Production Curve and Oil Prices (2010$)

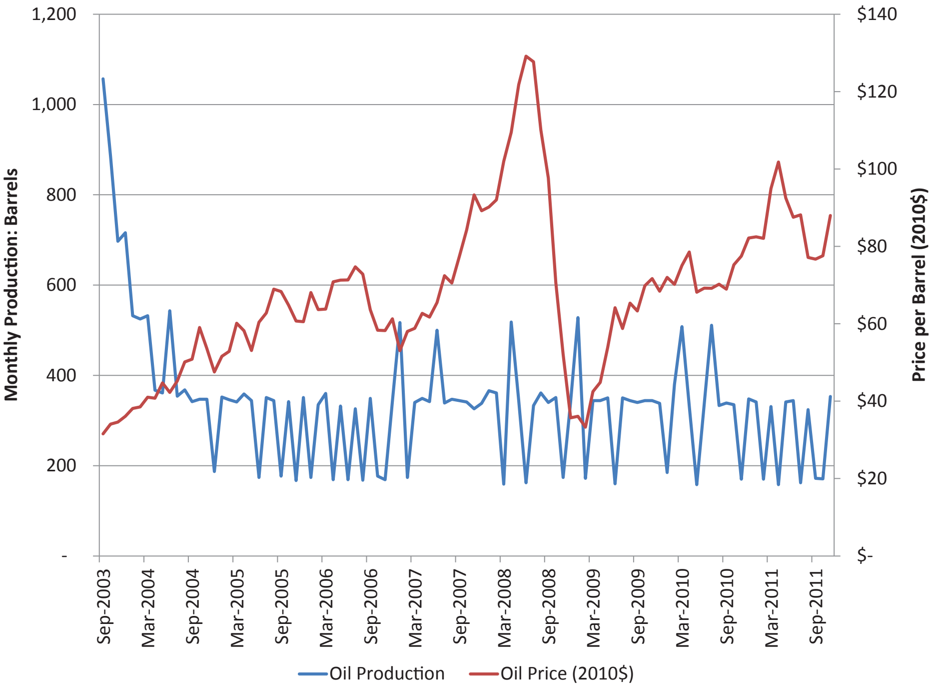
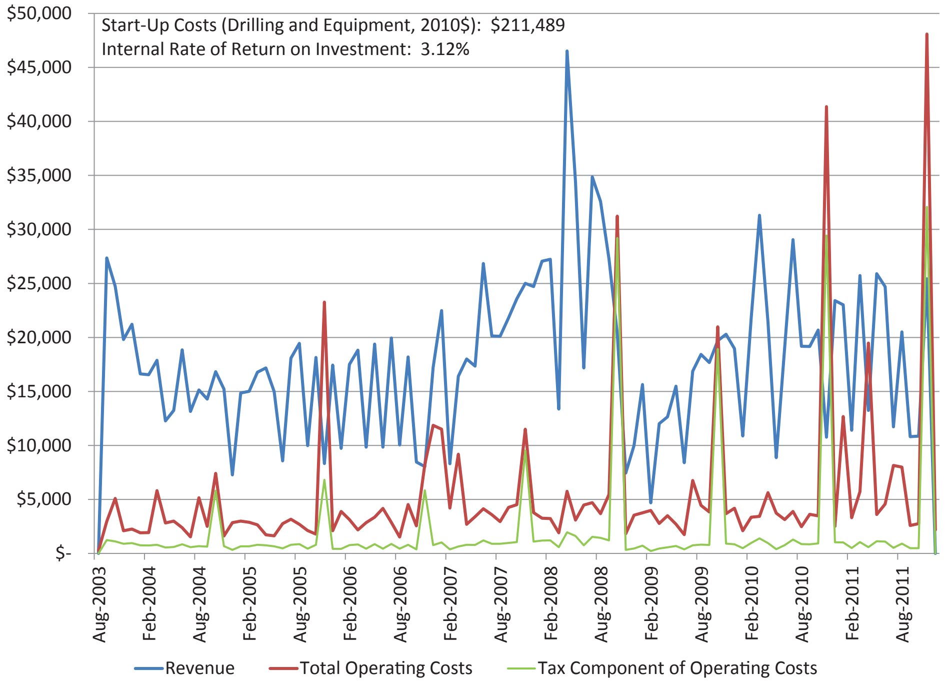


Chart 5

Example Oil Well: Revenues and Operating Costs (2010$)



Source: KIOGA member company.

Chart 6

Example Gas Well: Production Curve and Gas Prices (2010$)

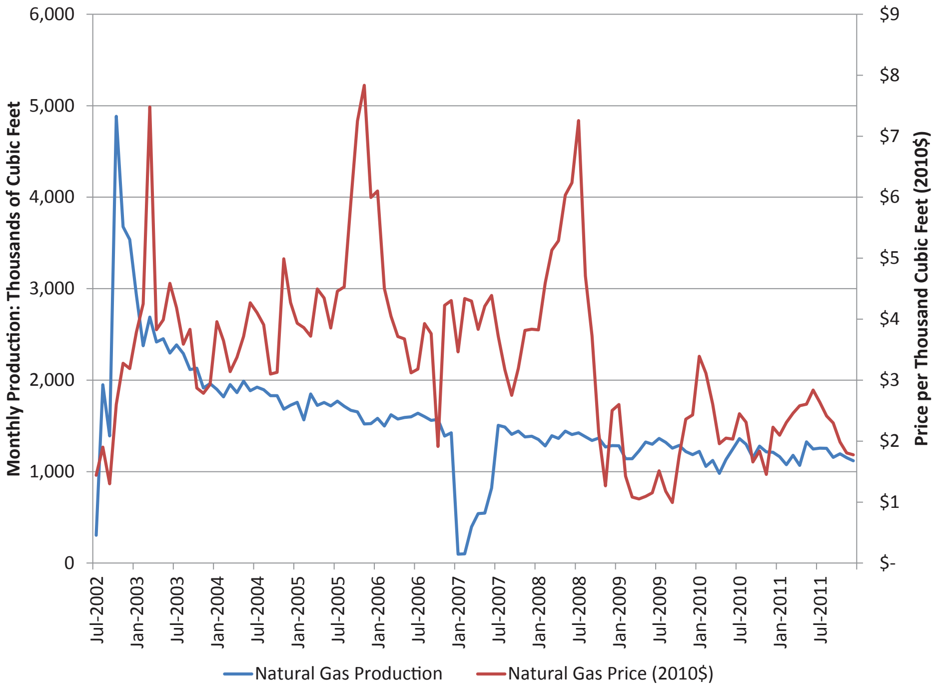
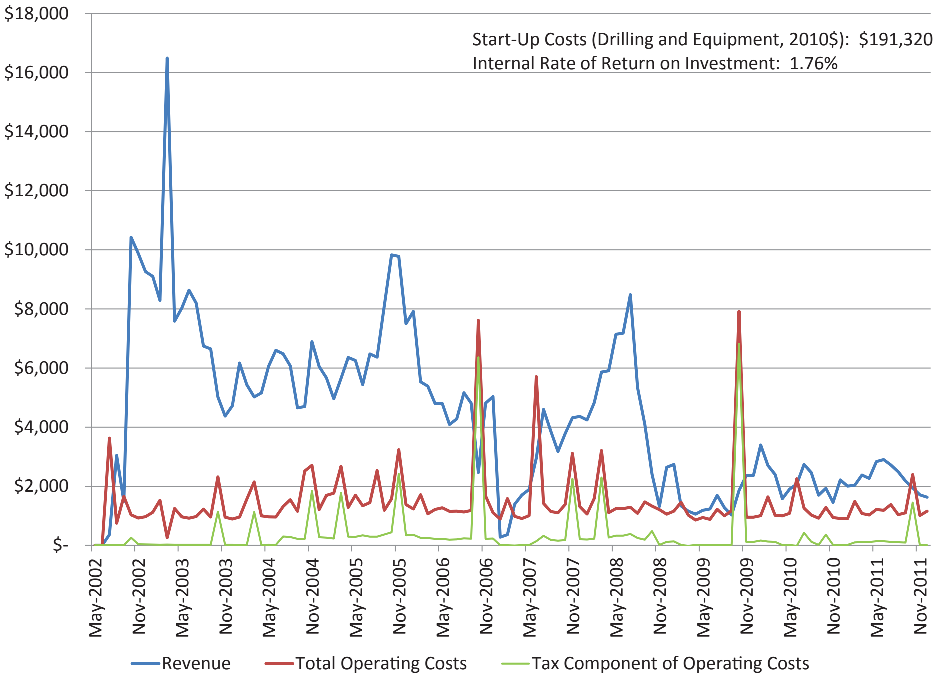


Chart 7

Example Gas Well: Revenues and Operating Costs (2010$)

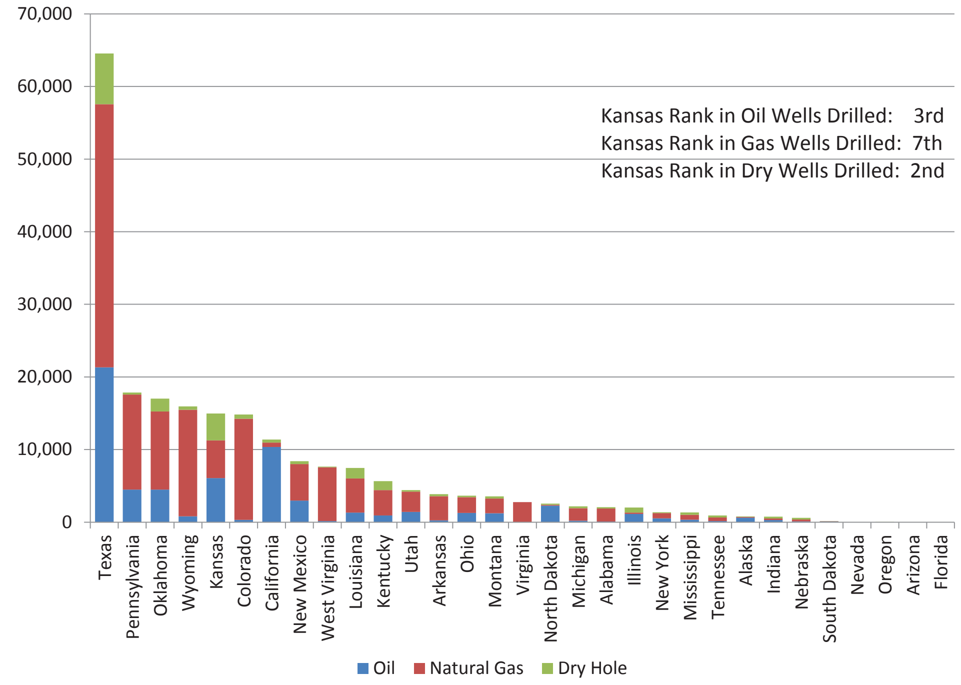


Source: KIOGA member company.

- Oil and gas wells have limited reserves. The industry often describes the characteristics of a given well by its "decline curve." Each well faces different decline characteristics, depending on the associated geology producing the oil or gas. Chart 4 and Chart 6 both show decline curves, although the decline element is more pronounced for the gas well. These decline curves factor into the effort by production companies to maintain their portfolio of producing wells through an on-going drilling program.
- Chart 4 and Chart 6 include the price of oil and gas received by the producer. As mentioned above and discussed in detail below, Kansas producers must accept market prices as a risk factor beyond their control. With regard to the time period covered by the charts, oil prices have shown a favorable trend and gas prices have shown an unfavorable trend, primarily because of the price collapse in 2008 that took the price back to 2002 levels.
- The production volatility and price volatility combine to generate the revenue volatility illustrated in Chart 5 and Chart 7. The overall pattern of revenue volatility (when combined with the pattern of costs) plays a significant role in determining the producer's and investors' rate of return on the well. The oil well has generated an inflation-adjusted rate of return of 3.12 percent; the gas well 1.76 percent.
- Drilling costs (and the other costs associated with bringing a well on-line) happen up-front, of course. Note on Chart 5 and Chart 7 that the drilling costs for the example oil and gas well at $211,489 and $191,320, respectively, are roughly consistent with the statewide averages illustrated in Chart 2. These costs have a significant impact on a well's investment rate of return.
- The on-going operating costs of a well may be less obvious to people unfamiliar with the oil and gas business. These costs—and the time pattern in which they materialize—act as

Chart 8

Total Number of Oil, Gas, and Dry Wells Drilled by State, 2005-2009

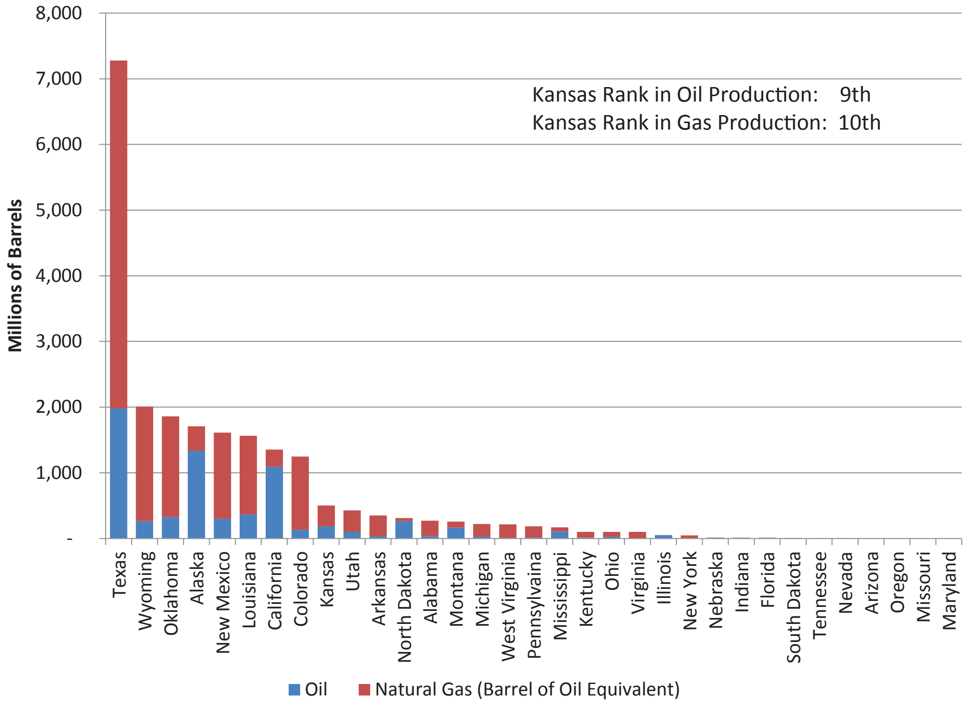


Source: IHS Energy; Independent Petroleum Association of America

a substantial risk factor in the economics of a well. Chart 5 and Chart 7 illustrate total operating costs and the tax-related subcomponent of operating costs. For the oil well, the primary non-tax operating costs involve well repairs, electricity consumption, and salt water disposal. For the gas well, the primary non-tax operating costs involve labor for pumpers, who measure and maintain the well, and overhead expenses associated with the business management of the well. The large spikes in the tax-related operating costs come from the (primarily local government) property tax. As explained toward the end of the report, Kansas law levies property tax on oil and gas reserves in the ground. A significant part of the tax calculation derives from an estimated price set for a prospective tax year by the Kansas Department of Revenue; this procedure represents another, less obvious, way in which price risk can influence the economics of a well for Kansas producers. The other taxes result from the severance tax and the production tax (a conservation fee charged by the Kansas Corporation Commission).

In summary, an oil and gas producer's ultimate success depends on replacing his reserves in a timely and economic manner. Once each well's production has declined to the point that the revenues will no longer cover its operating costs, the well has reached its economic limit—despite the fact it may still hold recoverable oil or gas. Once a well has reached its economic limit, the producer must evaluate different options. One likely option will involve plugging the well, removing the equipment, and forfeiting the leasehold interest in the land on which the well sits. In Kansas, the operator of a well has the ultimately responsible for plugging it.

Chart 9
Total Oil and Gas Production by State, 2005-2009



Source: U.S. Energy Information Administration

UNDERSTANDING GLOBAL PRICE-SETTING MECHANISMS IN THE CONTEXT OF INTEGRATED GLOBAL MARKETS

Kansas producers must accept daily oil and gas prices as an outcome beyond their control. Economists refer to them as "price takers," because they do not produce enough oil or gas to have any influence on global price-setting mechanisms. For perspective, consider that Saudi Arabia's giant Ghawar oil field produces about five million barrels per day.[13] That means the weekly production from this one field almost equals Kansas' annual production of about 40 million barrels.

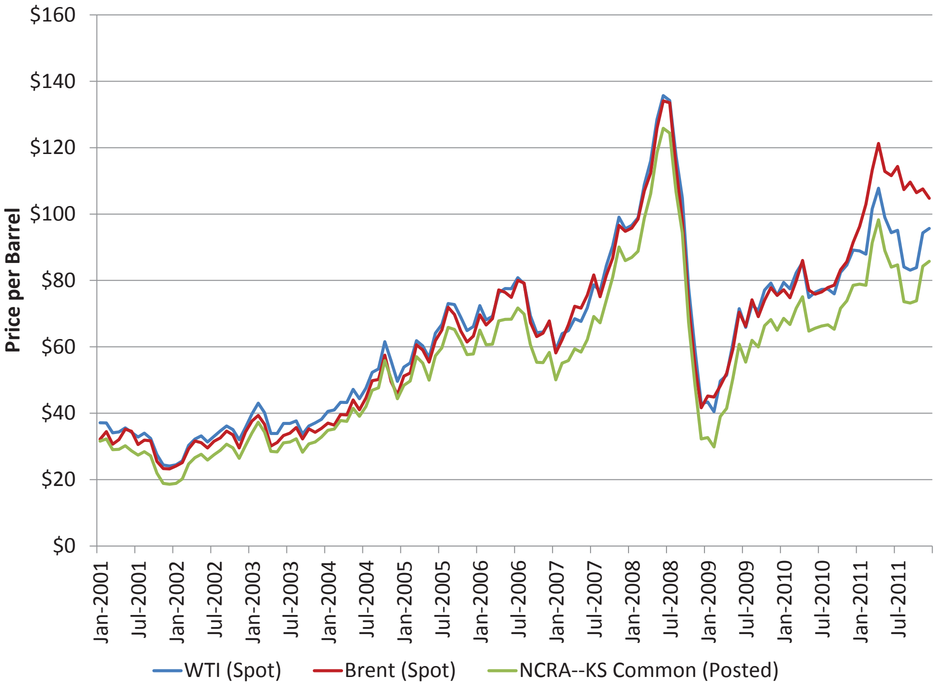
Chart 10 compares two widely traded crude oils with a crude oil known as Kansas Common, one of a few different types of Kansas crudes. The chart tells two important stories relevant for Kansas producers, as price takers. First, it shows that different crude oils tend to have relatively stable spot-market price-spreads relative to one another. Second, and more importantly, it shows how closely world crude oil prices tend to move together.

West Texas Intermediate (WTI) and Brent (a blend of crudes extracted from the North Sea) represent two of the three primary crude oil benchmarks in the world trading system. (The third is Dubai.) They trade more than any other types of crude oil in the world, because they form the basis for standardized futures contracts. WTI is the benchmark crude for futures contracts traded on the New York Mercantile Exchange. Such contracts specify Cushing, Oklahoma as the physical delivery point, although most futures contracts terminate without the requirement of physical delivery.

Crude oils extracted from different geographies and geologies have different physical and chemical properties. The establishment of benchmark crude oils helps the world trading system set crude oil prices because the benchmark crudes have well-defined physical and chemical properties that market participants can use for comparison against many other crude oils. The

Chart 10

A Comparison of Prices for Select Crude Oils (2010$)



Source: U.S. Energy Information Administration; National Cooperative Refinery Association

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[13] http://en.wikipedia.org/wiki/Ghawar_Field

differences help determine prices because they have practical importance for oil refiners—the key customer of oil producers.

Oil refining is a capital-intensive, chemistry-driven manufacturing process. Not all refineries have equal processing capability, and changes to capability requires long lead times for planning, capital investment, engineering, and construction. The configuration of a given refinery has significance for the processing required to profitably refine the petroleum products that end-use consumers demand. Consequently, refiners do not necessarily view different crude oils as perfect substitutes; they will value different crudes differently.

Generally, refiners will offer lower prices for crude oils that require more processing to extract the petroleum products most highly valued by end-use consumers. Table 2 offers an example from the average per-barrel prices posted in December 2011 by two Kansas-based refineries, the National Cooperative Refinery Association located in McPherson, Kansas and Coffeyville Resources located in Coffeyville, Kansas. The posted prices indicate the starting point for negotiations. Transportation costs and other market factors will contribute to the final price received by a given oil producer. Notice that, consistent with Chart 10, Kansas Common trades at a price lower than WTI. Also notice that the "sweet" crudes have a higher offer price than the "sour" crudes, because the sour crudes have more sulfur, which often requires additional processing, and also often requires different transportation and storage in order to keep it isolated from sweet crude.

Table 2

Average December 2011 Posted Prices per Barrel for Different Crude Oils

Crude Oil Type	NCRA	Coffeyville Resources
Kansas Common	$88.34	$88.34
Eastern Kansas	83.09	86.09
South Central Kansas	n/a	90.59
Nebraska Intermediate	86.59	86.09
Oklahoma Sweet	89.09	94.98
Western Oklahoma Sweet	88.59	n/a
Oklahoma Sour	n/a	82.59
West Texas Intermediate (WTI)	89.09	94.98
West Texas Sour	85.09	n/a
Wyoming Sweet	n/a	86.34

Source: Company websites

The price ultimately received by an oil producer obviously matters from a business perspective. However, the price spreads among different crudes tend to be relatively stable. The price is much less stable.

PRICE RISK AS A FORM ON ENTREPRENEURIAL RISK

The large trading volume of WTI (and Brent) suggests that it acts a price-setting mechanism for Kansas crude oils. Chart 10, like Chart 3, illustrates the volatile nature of oil prices, along with the tight co-movement among WTI, Brent, and Kansas Common. The monthly price movements of WTI and Kansas Common, for the dates shown in Chart 10, have a statistical correlation of 0.998, where 1.0 would mean perfect statistical co-movement. The statistical co-movement of Brent and Kansas Common would be just as tight if it were not for the divergence of Brent from WTI starting in 2011; a divergence that has an interesting meaning for world oil markets, as discussed later.

Kansas producers' price-taker status means that the volatility of oil prices vividly captures the entrepreneurial

Exhibit 2

Select Operating Information for Kansas-Based Oil Refineries

	National Cooperative Refinery Association	Coffeyville Resources LLC (CRV Energy)	HollyFrontier Corporation
Location	McPherson	Coffeyville	El Dorado
Capacity (Barrels per Day)	87,000	115,000	135,000
Throughput of Kansas Crude (%)	57-69%	20-22%	0-5%
Primary Product Marketing Area	Member-owned cooperatives in North Central U.S.	Arkansas, Iowa, Kansas, Missouri, Nebraska, Oklahoma and South Dakota	Eastern Colorado (including Denver), Eastern Wyoming, Plains states.

Source: Company websites and spokespersons challenge that Kansas oil (and gas) producers face in controlling their price-related business risks. Statistical research indicates that oil prices behave in a fashion known as a "random walk," meaning that the time path of price changes can be characterized as a sequence of random steps.[14] Producers can never confidently predict from one period to the next whether the price will go up or go down—or even if an upward or downward trend will prevail. At any given point in time, the current price of oil might be the most realistic forecast, regardless of how far into the future producers choose to project.

Table 3

99% Confidence Intervals for Oil Price Forecasts

Forecast Years into the Future	Forecast Price	Lower Bound	Upper Bound
1	$89.53	$42.06	$177.72
2	89.53	29.93	224.96
3	89.53	22.70	270.65
4	89.53	18.25	310.89
5	89.53	14.47	360.56
ROI from Example in Text	59%	-2.85%	149%

But any particular oil price forecast could be wildly wrong—and the imprecision becomes more amplified the further into the future the producer tries to forecast. To construct an example, refer back to Chart 3. Suppose a Kansas oil producer tried to forecast oil prices from December 2011 forward. In that month (the last data point in Chart 3), the average price of oil was $89.53. Adopting the proposition that oil prices move as a random walk, $89.53 is as good a forecast as any. However, note the significant breadth of possible price ranges captured by the statistical confidence intervals in Table 3. These confidence intervals derive from a computer simulation of a random walk process informed by the oil price data shown in Chart 3.[15] Statistically speaking, the intervals represent the lower- and upper-bound of the price ranges in which a producer could be 99 percent confident that the actual price would fall for a forecast of from one to five years into the future.

To put such unpredictability into an entrepreneurial profit-or-loss perspective, consider a simplistic example. Suppose that a Kansas producer intends to develop a new stripper well that will produce with certainty 10 barrels of oil per day for five years. Drilling the well will cost $500,000 (see Chart 2). A forecast price of $89.53 per year is a great price for Kansas producers (and Kansas property tax appraisers): given the assumptions, it offers the potential for a 59 percent rate of return on the investment after five years. However, if the example uses the Table 3 per-year lower- and upper-bound price instead of $89.53, the producer could face rates of return on investment (ROI) ranging from -2.85 percent to 149 percent. Producers, as entrepreneurs, face substantial financial risks—and the potential for handsome rewards. (From a theoretical perspective, if the low price series arrived, the producer could choose to keep the oil in the ground, but the drilling costs will have been incurred, so the rate of return on the investment will decline as time elapses. From a practical perspective, however, a variety of contractual arrangement related to land leases and engineering issues related to well stewardship generally make shutting in a well a cost-ineffective proposition.)

TRENDS IN THE GLOBAL CONSUMPTION AND PRODUCTION OF OIL

The general inability to predict oil prices results from the dynamic market processes taking place on a global scale. Crude oils trade in integrated world markets. The forces of global supply and demand set their prices. To make that statement is easy. To understand it in detail is hard.

Market prices play two fundamental roles. At a macro level, they act as a key mechanism for allocating scarce resources to their highest-valued use. At a micro level, they act as a vital tool for discovery; they act as the signal by which millions of individual actors in the marketplace make their decisions vis-à-vis all of the other actors. The more visible outcomes at the macro level result from the much less visible outcome of the millions of daily decisions that take place at the micro level, where time-and-place details and differences in perception matter.

Charts 11, Chart 12, and Chart 13, taken together, offer a way to summarize what has taken place at the macro

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[14] James D. Hamilton, "Understanding Crude Oil Prices," *The Energy Journal*, Vol. 30, No. 2, 2009, p. 181.

[15] The simulation generated 10,000 different price observations using a model of geometric Brownian motion for each of the forecast years. The monthly percent change in the price series has a standard deviation of 8.1%.

Chart 11

World Oil Production and Consumption

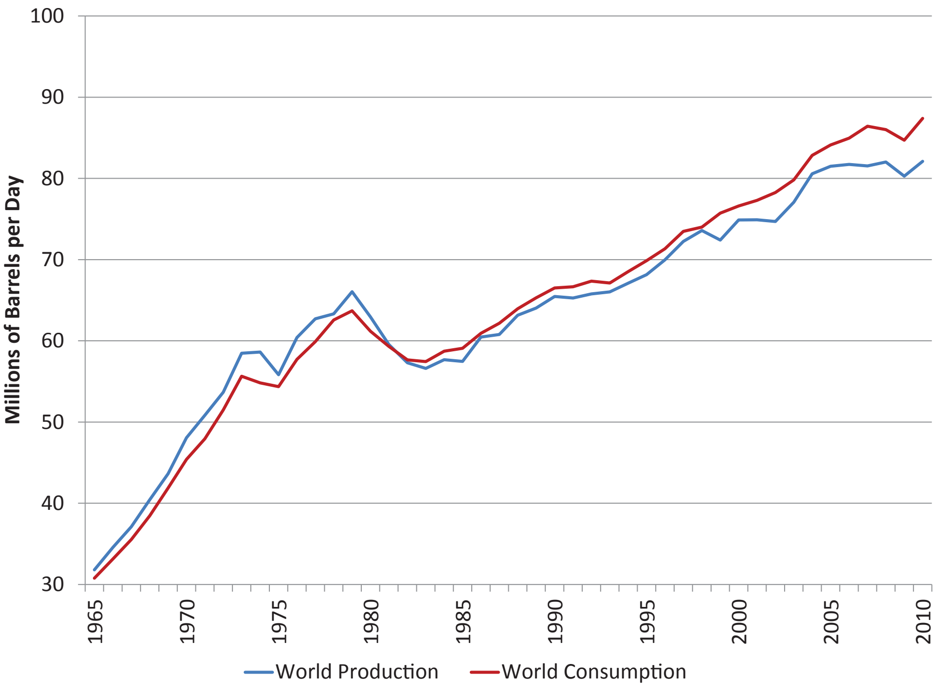
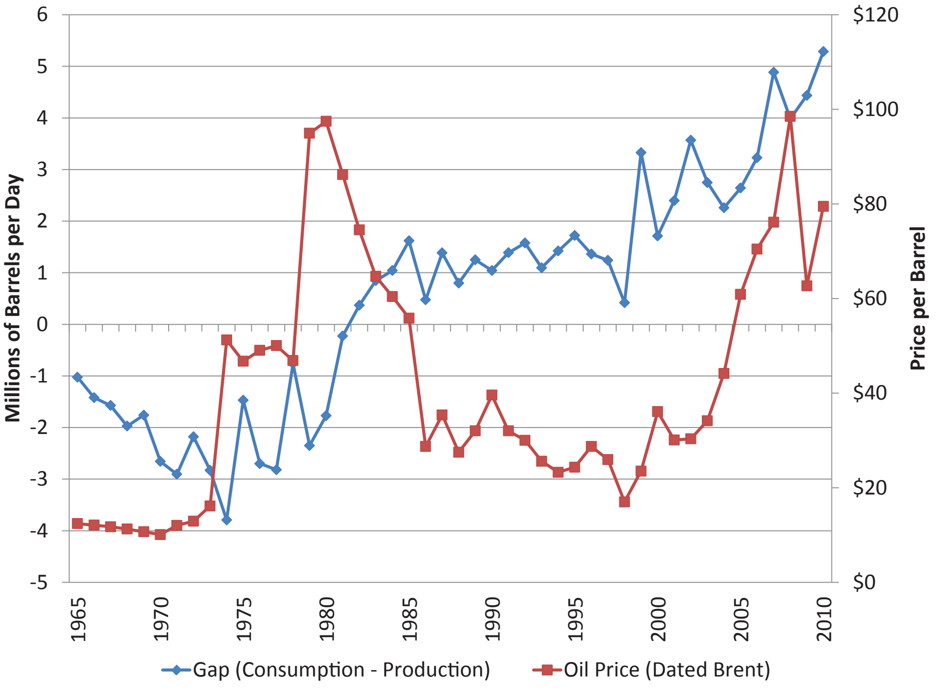


Chart 12

Oil Consumption-Production Gap and Oil Price (2010$)



Source: BP Statistical Review of World Energy, June 2011; Center for Applied Economics, KU School of Business level of the world crude oil market over the past few decades. The rapid escalation—and rapid collapse—of world oil prices between 2004 and 2009, shown in Chart 12, offers a useful case study for learning the global oil price-setting mechanisms. The discussion will build out the case study over the next several sections, as appropriate. The macro story suggests that the price escalation has explanations grounded in the fundamentals of supply and demand—not the activity of "speculators" often discussed in the popular media.

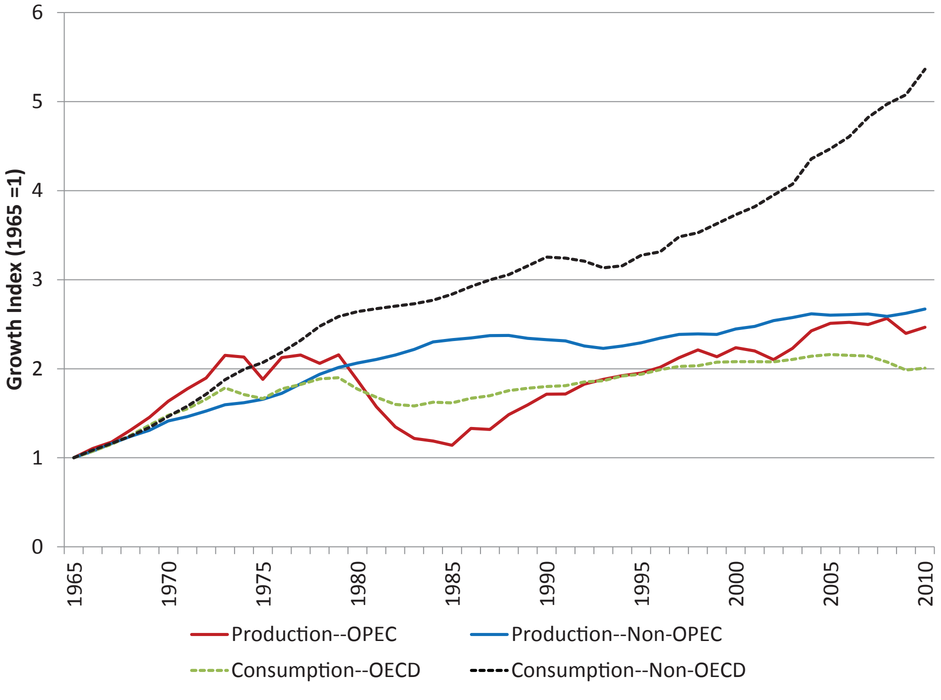
Chart 11 compares total world oil consumption with total world oil production. Notice the gap between the two curves. Before the early 1980s production exceeded consumption; then consumption began to exceed production. Stored inventories (stocks) of crude oil make possible the levels of consumption that exceed production. Inventory management is a fundamental aspect of petroleum markets—and the level of inventories plays a role in the global price-setting mechanism for crude oil.

Chart 12 compares two tends: (1) the trend in world oil prices (based, since 1984, on Brent at specific shipping dates) and (2) the gap between consumption and production, derived from Chart 11.

Volatility in the consumption-production gap has some relationship to the volatility of prices. A larger gap means that consumption grew relative to production, suggesting that demand grew relative to supply, resulting in higher prices (and vice versa). For example, from 1965 to 1972, production levels exceed consumption levels and oil prices remained low and stable. In October of 1973, several oil-producing Arab countries declared an oil embargo to protest U.S. support for Israel in the Yom Kippur War. The price spiked in anticipation of the reduced supply and then receded as more knowledge became available about market conditions. The same thing happened in 1979 and 1980 in the context of the Iranian Revolution and the Iran-Iraq war. The higher prices (and uncertainty of future supplies) motivated non-Arab countries to increase exploration and production (see Chart 13). That response ended up producing an oil glut in the 1980s that significantly reduced prices until the 2004-2009 events discussed below.

Chart 13

Trends in World Oil Production and Consumption



Source: BP Statistical Review of World Energy, June 2011; Center for Applied Economics, KU School of Business

Chart 13 provides a broad indication of who was doing the consuming (demanding) and producing (supplying). It provides relative growth trends for consumption and production. Two curves show consumption trends for countries belonging to the Organization for Economic Co-operation and Development (OECD), generally the more industrialized countries, and all those not belonging to the OECD. Two other curves show production trends for countries belonging to the Organization of the Petroleum Exporting Countries (OPEC) and all those not belonging to OPEC.

In 1990, non-OECD countries represented about 37 percent of world oil consumption; by 2010, they represented about 47 percent. On a 2010 consumption-weighted basis, the top-five non-OECD countries in terms of the 1990-to-2010 growth of oil consumption were: China, India, Saudi Arabia, Brazil, and Iran.

Saudi Arabia and Iran are also two key members of OPEC. The economic growth of many OPEC countries has resulted in them consuming an increasing share of their domestic oil production. OPEC countries supplied about 41 percent of world production in 2010. As the chart suggests, OPEC has steadily resumed a larger share of world production following the oil glut of the 1980s.

Details Related to Oil Supply

Recall, with reference to Chart 11, that crude oil inventories must account for the gap between oil consumption and oil production. From 1998 to 1999, inventories increase significantly and then begin to shrink, in fits and starts, until 2004. Chart 12 shows that the price of oil responded as expected, dropping and then rising, based on the fluctuation in the gap. Chart 13 shows that OPEC production leveled-off from its past growth at exactly the same time.

The post-1998 events began with a March 1998 meeting of OPEC and certain non-OPEC countries (Mexico, Norway, and Russia). Saudi Arabia and Venezuela convened the meeting. The Saudis, with full support from Venezuela, made it clear that they would act to further drive down prices if the group did not embrace the Saudis' desire to engage in a program of production control aimed at boosting the price of crude oil. The group complied.[16]

Interestingly, however, cuts in OPEC oil production per se did not cause the increase in oil price, as intuition might suggest. Instead, Saudi Arabia (and others) operationalized the OPEC effort by working to manage the world's crude oil inventories. This approach highlights an important institutional feature of world oil markets—and OPEC's market power.[17]

Unlike Kansas producers, who are price-takers, Saudi Arabia and other OPEC producers are price-makers. They announce the price at which they will sell (set as a fixed spread relative to well-defined market benchmarks, like WTI and Brent) and purchasers react to the administratively set price spread(s).

The 1998 price drop resulted from an increase in supply represented by a gradual build-up of oil inventories. The low prices motivated the Saudis to call their OPEC meeting. Price drifted higher, as shown in Chart 12, as OPEC's higher asking prices worked to manage (reduce) world inventories (as shown in Chart 11). The drop in OPEC production resulted from the drop in purchases triggered by OPEC's price-setting policies, as purchasers found it more economical to draw down inventories. The Saudi-led program worked as designed.[18] A sharp drop in inventories occurred in 1999. After that, inventory levels generally grew in absolute level, but at rates slower than the rate of the growth of oil consumption.[19]

An important economic issue related to oil supply is the responsiveness of producers to price changes, particularly price increases. Economists use the term "price elasticity" to characterize the idea of responsiveness. The so-called law of supply says that, all else equal, producers will increase the quantity supplied of oil as the price increases (and vice versa). Supply is "inelastic" if

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[16] Philip K. Verleger, Jr., "Anatomy of the 10-Year Cycle in Crude Oil Prices," March 2009, p. 6. https://www.theice.com/publicdocs/globalmarketfacts/docs/newsexperts/Anatomy_of_Price_Cycle_0309.pdf

[17] *Ibid*., p. 7.

[18] *Ibid*., p. 12-13.

[19] http://www.eia.gov/emeu/international/oilstocks.html

a one percent increase in price results in less than a one percent increase in quantity supplied. Supply is "elastic" if a one percent increase in price results in more than a one percent increase in quantity supplied.

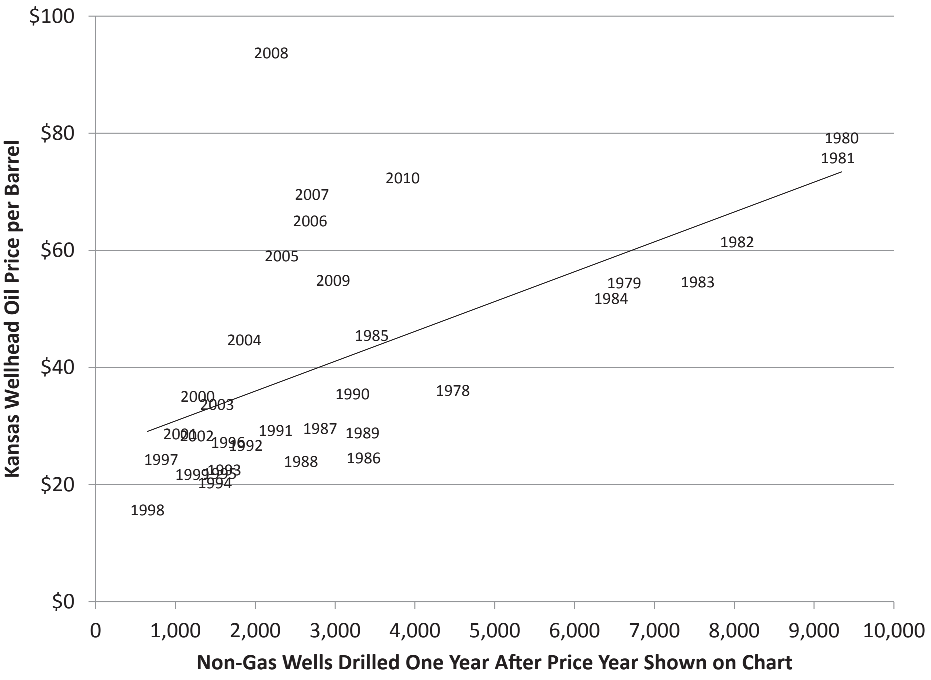
The notion of the elasticity of supply has a short run and a long run perspective. Producers cannot respond immediately to a demand-driven price increase if they already have their wells producing at their maximum flow rates. In such a situation, producers must drill new wells to respond to an increase in demand. That takes time and money, which highlights two important points. First, economists generally expect a much more inelastic price elasticity of supply in the short run compared to the long run (depending on the excess production capacity of existing wells or oil in storage). The more inelastic the supply response relative to demand-driven changes in price, the more price volatility market participants will experience. Second, demand-driven price increases make it possible to profitably explore for and produce more expensive sources of supply. (Recall that profitable production with known technology is a definitional component of the "proved reserves" of oil or gas.) This point is important for Kansas producers, because they face much higher incremental production costs than many of the world's produces.

Chart 14 shows that the law of supply operates as expected in the state of Kansas. (Charts 12 and Chart 13 helped show that it also operates as expected globally.) The chart compares inflation-adjusted annual average oil prices that Kansas producers received at the wellhead with the combined number of oil wells, service wells, and dry holes drilled one year after the year of the price reported on the chart. For example, the "2010" data point shown on the chart indicates that the price in 2010 ($72.43 per barrel) and the combined number of wells drilled in 2011 (3,843).

Examination of Chart 14 provides some insight into the time dimension associated with the Kansas price elasticity of supply. Oil prices escalated significantly in the 1970s—and peaked in 1980. Notice the escalating response in wells drilled (keeping in mind the year-after-price interpretation of the chart) resulting from prices

Chart 14

Kansas Wellhead Oil Price (2010$) and Non-Gas Wells Drilled One Year Later



Source: U.S. Energy Information Administration; Kansas Geological Survey reported for 1978 through 1981, and the rapid drop in drilling once it became clear prices had begun to fall. The same general pattern resulted for the 2004 through 2011 episode, but the price increases happened quickly and in a somewhat erratic fashion, so producers did not demonstrate as strong a response as in the 1970s episode. (Recall also from Chart 1 that Kansas producers drilled significantly fewer dry holes in percentage terms in the more recent time period.)

Physical Markets and Paper Markets: Prelude to Discussion of Oil Demand

"Speculators" often receive the blame for episodes of commodity price increases—like the oil price surge from 2007 to 2008 shown in Chart 12. Investigations into such charges usually reveal that market fundamentals related to supply and demand provide the more compelling explanations of price movements. A basic understanding of the institutional mechanisms that support "speculation" helps to explain why.

Crude oil, along with many other commodities, trades in physical markets and "paper" markets. The physical market represents the actual handling, processing, and movement of crude oil and refined petroleum products. The paper market primarily represents the buying and selling of oil-based futures contracts (and related financial derivatives). With regard to "speculators" causing sudden price changes, one point deserves emphasis: the paper market works in a way that has no automatic spillover influence on the activity in the physical market—the actual supply of and demand for oil.

Futures markets generate enormous benefits for the buyers and sellers of commodities. They serviced the market for agricultural products for more than a century before being applied to the markets related to oil and gas.

A futures contract is simply a business deal between two or more parties: for example, an obligation to deliver a specified volume of crude oil at a specified place and time for a specified price. Commodity futures exchanges—like the Chicago and New York Mercantile Exchanges—create the institutional foundation for the creation and trade of futures contracts (the futures market). The exchanges standardize contracts, oversee rules for orderly trading, and act as clearinghouses for contract settlements. Participants in the physical markets typically also act as participants in the paper market. Many participants in the paper market never participate in the physical market, because the institutional features of the exchanges make it possible for anyone to participate in futures markets without having to ever physically handle the commodities that form the basis of the futures contracts; they can settle their contracts for cash. This institutional feature helps explain why activity in the futures market determines the price of futures contracts, but not necessarily the price of the underlying commodities. Each market—the physical and the paper—has its own fundamentals.

Markets aggregate information and embed it into a single metric: price. The information built into the price embodies the unique perspectives of all participants in the market. The price, in turn, provides feedback that further influences the unique perspectives of the market participants. It is an on-going, iterative process. Markets are institutions that discover the prices that best allocate resources to their highest-valued use (and users).

The notion of markets as a price-discovery process makes the practical difference between the terms "speculator" and "entrepreneur" almost meaningless, from an economic perspective. A Kansas oil and gas producer that decides to drill a wildcat well can just as easily be called a "speculator" as an "entrepreneur." An oil trader in New York City who believes that "the market" is underpricing oil because it is underestimating the demand for heating oil—and buys oil futures based on an expectation that oil prices will eventually rise—can just as easily be called an "entrepreneur" as a "speculator." The risk-based calculation driving the action of each participant feeds information into the market that influences the price of oil, and thereby helps the other participants make better risk-based calculations for decision-making.

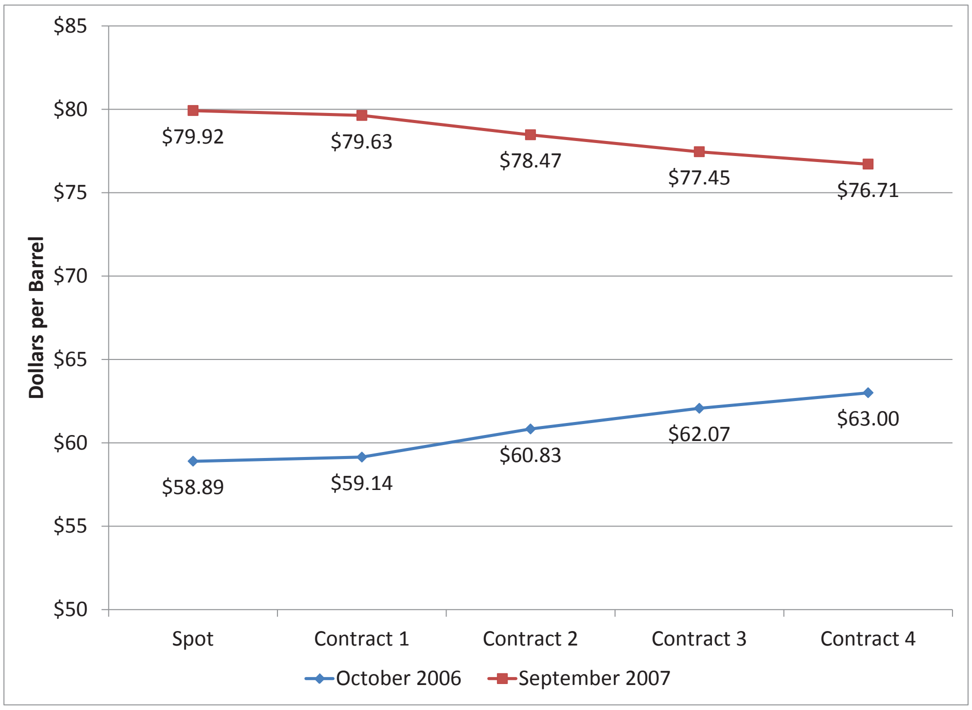
Research on the interaction between physical markets and paper markets helps confirm the symbiotic relationship between the physical and paper markets. One (imperfect) way of testing for causality is to determine what comes first: "speculative" trades in the paper market for oil or spot price increases in the physical market for oil. The tests tend to show that the two items often switch places. Price discovery often takes place in the paper market, but trades in the paper market often react to changes in the physical market.[20]

Futures contracts and well-functioning futures markets have several noteworthy attributes:

1. Participants in the physical market for crude oil (or any other commodity) use them as a tool to manage price risk. Through a process called hedging (buying futures contracts that specify future prices) oil producers or oil buyers can secure a known price to help business planning. The presence of "speculators" in the futures market reinforces this beneficial process rather than undermines it.
2. Hedging helps producers, as entrepreneurs, because the ability to manage price risk makes it easier to secure investment capital for new projects.
3. By mechanical necessity of the way futures contracts work (a guaranteed price at a guaranteed time), the market price of a particular futures contracts will always converge to the spot price of the underlying commodity at the time the contract expires. In the futures market, every gain is matched by a loss (and vice versa). The net financial result of every trade nets to zero from the perspective of the futures market—usually in the context of a cash settlement. Consequently, there is nothing about the supply and demand for futures contracts that inherently influences the supply and demand for physical crude oil (or any other commodity); meaning that there is nothing inherent in the activity of futures markets that influences the (spot) price of oil.
4. Trading activity in the futures market can only influence the spot price of crude oil if the price signals in the futures market convince participants in the physical markets to alter production rates or change

Chart 15

Examples of Contango and Backwardation in the Futures Market for West Texas Intermediate Crude Oil



Source: U.S. Energy Information Administration

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[20] Bahattin Büyüksahib and Jeffrey H. Harris, "Do Speculators Drive Crude Oil Futures Prices?" *The Energy Journal*, Vol. 32, No. 3, 2011, pp. 167-202.

net inventory levels to an extent sufficient to alter supply enough to change prices.

The last point is critical to understanding whether or not "speculators" caused, in whole or in part, the oil price surge from 2006 to 2008. Chart 15, Chart 16, and Chart 17 provide useful perspectives for evaluating the situation.

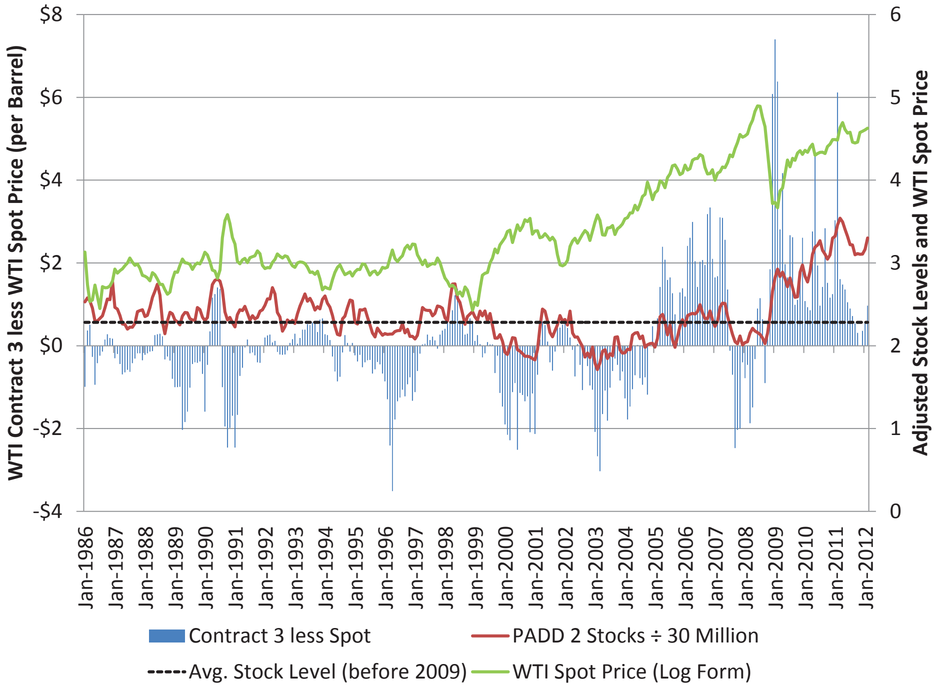
Chart 15 is educational in nature for those readers uninitiated with futures markets. It shows two different months in the 2006-to-2008 time frame—one month (October 2006) when the futures market for WTI was in "contango" and one month (September 2007) when it was in "backwardation." Contango refers to a situation in which the contact price for WTI is higher in the future than the present. Backwardation refers to the opposite situation—the contract price for WTI is lower in the future than the present. When markets move into contango, an economic incentive arises to hold crude oil inventories (which could include storing crude in the ground by deferring production). For example, in simplest terms, in October 2006, someone could buy a barrel of WTI for $58.89 and sell it four months later for $63.00. This plan would make sense if the price spread covered all of the costs associated with holding the crude oil. The level of the price does not matter—only the price spread matters.

Chart 16 demonstrates that the market generally behaves as theory predicts. It shows four data series:

1. The 3rd month WTI futures price less the WTI spot price.
2. The volume of crude oil inventories (stocks) held in the Petroleum Administration for Defense District (PADD) 2, which includes Cushing, Oklahoma, the delivery point for WTI futures contracts. The volumes exclude those held in the U.S. government's Strategic Petroleum Reserve, in order to better capture private business activity. (The stock levels have been arbitrarily, but proportionately, compressed to

Chart 16

Relationship among Futures Curves, Crude Stocks, and WTI Spot Prices



Source: U.S. Energy Information Administration

allow for a visually convenient comparison against other data series.)

3. The average (adjusted) PADD 2 stock levels before 2009, for purposes of establishing a visual benchmark.
4. The WTI spot price, charted in natural logarithm form for visual convenience.

When the WTI futures market has been in contango (blue bars above $0.0), oil inventories have tended to increase. When the market has been in backwardation, oil stocks have tended to decrease. Over the time period presented, PADD 2 oil stocks and the price spread registered a statistical correlation coefficient of 0.6.

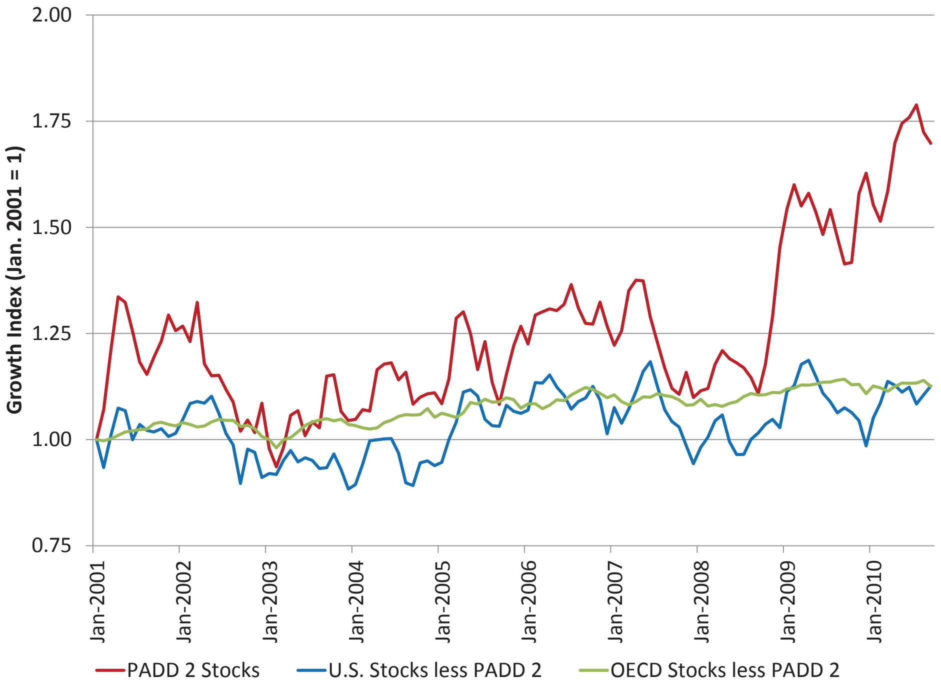
The relationship between the WTI spot price and inventory levels also behaves in the expected manner—up until about the end of 2004, the beginning of the case study under discussion. Generally speaking, all else equal, spot prices should increase when crude oil inventory declines, because supply becomes more constrained in the short run. Conversely, spot prices should decline when crude oil inventory increases. That pattern generally holds in Chart 16. From 1986 through 2004, the spot price and inventory levels register a statistical correlation of -0.67. From 2005 forward, the coefficient shifts to +0.2.

Most importantly for the case study, notice that the futures market moves into contango from the start of 2005 through the summer of 2007. This period corresponds to a large volume of new trading in the futures market based on the development of new financial products offered on Wall Street.[21] It also corresponds with a sustained increase in the spot price. This correspondence explains why so many commentators claimed that "speculators" drove the price increase.

Yet the price continued to escalate after the market shifted into backwardation. True, inventory levels decreased which suggests that the spot price should rise. However, the inventory levels remained well within

Chart 17

Relative Volatility of Select Regional Crude Oil Stock Levels



Source: U.S. Energy Information Administration

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[21] Philip K. Verleger, Jr., "The Role of Speculators in Setting the Price of Oil," Testimony before the U.S. Commodities Futures Trading Commission, August 5, 2009.

the range reflected in Chart 16, when prices were much lower.

Chart 17 provides an additional perspective on crude oil inventories. PADD 2 inventories show much more volatility than the rest of the United States, and much more volatility still with respect to the entire OECD. PADD 2 is somewhat unique in that it is the delivery point for WTI futures contracts. Although Chart 10 showed that different crude oils tend to move together—and that benchmark crudes can be expected to lead the price movements, total inventories should matter for global supply. Plus, Brent is traded (and delivered) in Europe.

Recall from the above discussion on supply that OPEC countries had had success in managing global inventories with its pricing policies. In that context, OECD inventory levels were quite stable during the price escalation, which is among the reasons that many commentators dismiss the speculator-did-it story. Professor James L. Smith captured this viewpoint (and summarizes the arguments made above): "The only avenue by which speculative trading might raise spot prices is if it incites participants in the physical market to hold oil off the market—either by amassing large inventories or by shutting in production. If participants in the physical market are convinced by speculative trading in the futures market that spot prices will soon rise, their reaction could cause inventories to rise and/or production to fall. However, neither phenomenon was observed during the recent price spike."[22]

Important Details Related to Oil Demand

Philip K. Verleger, Jr., a highly accomplished petroleum economist, has developed a compelling, well-documented narrative explaining the rapid 2006-2008 oil price increase.[23] He argues that the primary catalyst came from the implementation of ultra-low-sulfur diesel fuel regulations in the United States and Europe. Understanding his arguments—and understanding price volatility, in general—first requires understanding a few economic prerequisites related to petroleum demand.

The demand for oil is a derived demand. End-consumers demand refined petroleum products not crude oil per se. The demand for these products works backwards through the refining industry to the producers of crude. Consequently, an underappreciated fact of the petroleum market is that the prices of petroleum products (like gasoline, diesel fuel, or jet fuel) generally determine the price of crude oil(s), not vice versa.[24] The interaction of supply and demand determines market prices. But supply follows demand. Oil refiners continually assess consumer demand for refined product and then seek to procure oil at a price low enough to generate a sufficient profit.

This observation has general importance for understanding oil prices—and has a particular importance for the 2006 to 2008 oil price spike shown in Chart 12. The general importance relates to what economists refer to as the (1) income elasticity of demand and (2) the price elasticity of demand. The particular importance relates to how refiners had to respond to particular environmental regulations (and how the response interacted with the price elasticities of supply and demand).

Income elasticity of demand relates to the responsiveness of a change in demand resulting from a change in income; specifically, it calculates the percentage change in demand that results from a one percentage point change in income. In the context of this report, this metric helps explain the price-increase story told by Charts 11, Chart 12, and Chart 13. Research shows that the income elasticity of petroleum-related products hovers around a value of one, meaning that a one percent increase in income results in a one percent increase in the demand for petroleum products (and thus oil). However, in recent decades, the income elasticity appears much higher (more responsive) in developing countries compared to developed countries.[25] This finding helps explain the

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[22] James L. Smith, "World Oil: Market or Mayhem?" *Journal of Economic Perspectives*, Vol. 23, No. 3, 2009, p. 159.

[23] This section draws liberally from three works: Philip K. Verleger, Jr., "Anatomy of the 10-Year Cycle in Crude Oil Prices," March 2009; Philip K. Verleger, Jr., "The Margin, Currency, and the Price of Oil," *Business Economics*, Vol. 46, No. 2, April 2011, pp. 71-82; Philip K. Verleger, Jr., "Rising Crude Oil Prices: The Link to Environmental Regulations," *Business Economics*, Vol. 46, No. 4, September 2011, p. 240-248.

[24] Philip K. Verleger, Jr., "The Margin, Currency, and the Price of Oil," *Business Economics*, Vol. 46, No. 2, April 2011, p. 78.

relative growth differences in oil consumption by the OECD and non-OECD countries illustrated in Chart 13.

The price elasticity of demand shares all of the same definitional characteristics as the price elasticity of supply (discussed above)—except that there is an inverse relationship between price and quantity demanded. The so-called law of demand states that, all else equal, end-consumers will decrease the quantity demanded of petroleum products—and thus oil—as the price increases (and vice versa). Like the elasticity of supply, the quantity demanded for specific petroleum produces tends to be much more inelastic (unresponsive to price) in the short run than the long run. In the long run, consumers have much more opportunity to alter their overall consumption behavior.

Income elasticity tends to be much more important than price elasticity in determining the quantity demanded for petroleum products.[26] However, the relative inelasticity of both demand and supply for petroleum works together in important ways in the context of price volatility. For example, a short run price elasticity of demand for petroleum of -0.065 would be consistent with the findings of current research.[27] That means a one percent increase (decrease) in price would result in a 0.065 percent decrease (increase) in quantity demanded. Making an assumption that the elasticity of supply has the same measured value of 0.065, implies the following equation to calculate the price increase required to make demand and supply balance in the context of a shock to oil supply—say the loss of one percent of world supply (or, for example, the equivalent of about 20 percent of the supply that comes from Iran):

$$\Delta Price\ (\%) = \frac{\Delta Oil\ Supply\ (\%)}{(Elasticity\ of\ Supply - Elasticity\ of\ Demand)} = \frac{1.0}{(0.065 - (-0.065))} = 7.7\%$$

From the price forecasting example above, recall that the December 2011 Kansas wellhead price of oil was $89.53. A price increase of 7.7 percent would amount to $6.89 per barrel. If the oil shock amounted to five percent of supply—or roughly all of Iran's production—the price increase would be 5 x 7.7% = 38.5%, or $34.47 per barrel. The point: inelasticity makes small percentage changes in supply result in much larger percentage changes in price—explaining how price volatility can result from market fundamentals without the need to blame "speculators."

Environmental Regulations: An Explanation of the Price Spike of 2006-2008

The discussions above related to supply and demand prepare the reader for Philip Verleger's explanation for the price spike of 2006-2008. It provides a case study in the complex global dynamics that drive oil prices. He summarizes his analysis by arguing that "the determination of oil prices depends not only on the demand level but also on the mix of crudes, the industry's capacity to process the crudes, and the decisions by oil-exporting nations on the volume of sour crude produced."[28]

The following points summarize Verleger's logic in more detail:

- The marginal buyer in the marginal market sets the price for petroleum products and therefore the price of crude oil. Conceptually, the marginal demander in a market is that entity bidding for the last barrel available and the marginal supplier in a market is the entity fulfilling that demand (at a price sufficient to cover all of the economic costs involved). Identifying the marginal actors in the market at any given point in time presents a challenge, particularly on the demand side. Often, the high-cost suppliers act as the marginal supplier because the marketplace has exhausted the less costly alternative sources of supply. However, the marginal supplier could be the supplier with excess production capacity.

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[25] See the references in James D. Hamilton, "Understanding Crude Oil Prices," *The Energy Journal*, Vol. 30, No. 2, 2009, p. 190.

[26] Louis H. Ederington, Chitru S. Fernando, Thomas K. Lee, Scott C. Linn, and Anthony D. May, "Factors Influencing Oil Prices: A Survey of the Current State of Knowledge in the Context of the 2007-08 Oil Price Volatility," August 2011, p. 8. http://205.254.135.24/finance/markets/reports_presentations/factors_influencing_oil_prices.pdf

[27] Hamilton, "Understanding Crude Oil Prices," p. 190.

[28] Philip K. Verlerger, Jr., "Rising Crude Oil Prices: The Link to Environmental Regulations," p. 245.

Verleger argues that, with regard to transportation fuel, the United States is the marginal market for gasoline, Europe is the marginal market for diesel fuel, and Asia is probably the marginal market for jet fuel.[29] Each of these competing demands for different "cuts" of refined crude oil influences the market price—at the margin—for a given barrel of crude oil. As Verleger says: "Generally, the product in shortest supply in the market most dependent on imports [the high-cost source of supply] will effectively set prices globally."[30]

- Crude oils from around the world have different chemical properties. For purposes of Verleger's narrative, but oversimplified in reality, the world produces two types of crude oil: light-sweet and heavy-sour. The light-heavy continuum relates to the density of the oil, or how easily it flows. Light crude flows more easily because it has a higher concentration of fuel-grade hydrocarbons, which, in turn, makes it yield more end-consumer products with less processing. The sweet-sour continuum relates to sulfur (sour) content. As discussed above, two key benchmark crudes for the futures market are West Texas Intermediate and Brent, both of which have light-sweet characteristics. Oil from OPEC countries tends to have heavy-sour characteristics, which trades at a price discount to light-sweet crudes.

  Despite the different chemical properties, different crude oils compete in highly-competitive, integrated markets—which establish on-going, but fluctuating, price differentials among the different crudes. However, OPEC, as discussed above, has pricing power and can administratively restrain the price differential between light-sweet and heavy-sour crudes that might arise in the context of a more competitive market structure. OPEC, and especially Saudi Arabia, in effect, has the ability to position itself as the marginal source of supply, and set price discounts relative to the actively traded WTI and Brent crude oils.

- These differences in crude oil characteristics matter to oil refiners from a processing perspective. Different crudes produce different proportions of end-products depending on the amount and type of processing required. Refiners have a deep understanding of these differences and bid for crude oil from producers based on the expected product prices they can profitably charge end-consumers for the different petroleum products. That is why, ultimately, the direction of causality for crude oil prices runs from end-use demand to crude oil, not vice versa.

Table 4

Comparison of Refinery Distillation Yields and Other Characteristics

Type of Product	**Nigerian Bonny Light**	**Saudi Arabian Arab Heavy**
LPR (%)	0.9	2.8
Light Gasoline (%)	4.3	0
Light Naphtha (%)	13.4	6.7
Intermediate Naphtha (%)	0	8.7
Heavy Naphtha (%)	10.1	0
Kerosene (%)	**13.3**	**7.0**
Gasoil (%)	**22.7**	**12.5**
Intermediate Gasoil (%)	**0**	**9.7**
Residual Fuel Oil (%)	39.1	52.6
Sulfur Content Residual Fuel Oil (%)	0.3	4.1
Sulfur (Kilos per Barrel)	**0.2**	**4.1**
Total Gasoil Potential (%)	36.0	29.2

Source: EIG, International Crude Oil Handbook, 2010. Reproduced from: Philip K. Verleger, Jr., "Rising Crude Oil Prices: The Link to Environmental Regulations," *Business Economics*, Vol. 46, No. 4, September 2011, p. 244.

Table 4 provides a snapshot of the relevant refining chemistry. It compares the distillation (refinery) yields of two crudes: so-called Bonny Light crude oil from Nigeria, which is among the lightest, sweetest crudes, and so-called Arab Heavy from Saudi Arabia. Refineries not well equipped to process heavy-sour crudes can produce much more diesel-type fuels (those Table 4 items in bold text) from Bonny Light. Just as importantly, the amount of sulfur refiners must remove from Bonny Light is much lower

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[29] Philip K. Verleger, Jr., "The Margin, Currency, and the Price of Oil," *Business Economics*, Vol. 46, No. 2, April 2011, p. 72.

[30] *Ibid*.

than from Arab Heavy—making it much less expensive to meet the ultra-low-sulfur diesel fuel regulations implemented in the United States and Europe.

Not all refiners have equal capacity to refine all crude oils with equal efficiency of outcome. For example, refiners must build the expensive engineering processes required to efficiently process heavy crude oils and remove sulfur from refined products. Furthermore, the physical location of refineries with different processing capabilities matters in the price-setting process. Physical volumes depend on physical processing capacity and transportation, and the cost structures related to both.

- European consumers—helped along by public policy incentives—have gradually shifted from gasoline to diesel as a preferred transportation fuel. About 75 percent of vehicles sold in Europe have diesel engines. Europe is the marginal market for diesel fuel. (Verleger argues that this status—and the higher demand for light-sweet crudes that it implies—explains the divergence in the Brent-WTI spread discussed in the context of Chart 10.)
- In 2000 and 2003, the United States and Europe, respectively, implemented ultra-low-diesel fuel regulations that became binding in June 2006 and January 2009. According to Verleger: "European refiners did not respond to this situation by adding capacity to produce more diesel. Instead, they shut down facilities."[31] Europe had to import the diesel that it could not produce itself. Much of the imported supply came from the United States (because U.S. end-consumers had begun to substitute natural gas for distillate fuel oil). Furthermore, Europe's position as the marginal market meant that the marginal demand for diesel was denominated in Euros, which traded at a premium to dollars, thereby bidding up the dollar price of diesel (by about 16 percent, according to Verleger).
- The implementation of the ultra-low-sulfur-diesel rules increased the demand for the world's sweet crudes, which represent a fraction of world supply. At the same time, (1) the civil conflicts in Nigeria had reduced the production volumes of its Bonny Light (a key source of light-sweet supply) and (2) the United States chose to add to its Strategic Petroleum Reserves, removing even more sweet crude from the market. (At this point it is important to recall the discussion above about the magnifying influence on oil prices that results from inelastic demand and supply. The margins of the market during the 2006-2008 episode resulted from inelastic demand for diesel fuel produced from tight supplies of light-sweet crude, which accounts for a fraction—about 40 percent or less—of world crude production.)

  The pricing policies of OPEC countries (discussed above in the section on supply) amplified the oil-supply constraints. Recall that OPEC producers administratively set price differentials for their crude based on the price of benchmark crudes (which tend to be lighter and sweeter). "The resulting prices," argues Verleger, "bear no relationship to what would prevail in a free market."[32] Charts 11 and Chart 13 clearly show the slow-down in the rate of OECD crude oil consumption—and the concurrent slow-down in crude oil production—resulting from OPEC's artificially-high price for heavy-sour crude relative to light-sweet crude.
- Several factors contributed to the sharp drop in price from 2008 to 2009: the 2007 recession reduced consumption in OECD countries (see Chart 13); the U.S. Congress forced the Department of Energy to stop filling the Strategic Petroleum Reserve, thereby releasing supply; the Euro dropped against the dollar, thereby

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[31] Philip K. Verleger, Jr., "The Margin, Currency, and the Price of Oil," p. 75.

[32] Philip K. Verlerger, Jr., "Rising Crude Oil Prices: The Link to Environmental Regulations," p. 245.

dropping dollar-denominated prices for oil; new Gulf of Mexico sources for light-sweet crude came on line; and refiners responded to the high price of diesel by changing operation in a way that increased supply.

The Co-Movement of Oil and Natural Gas Prices

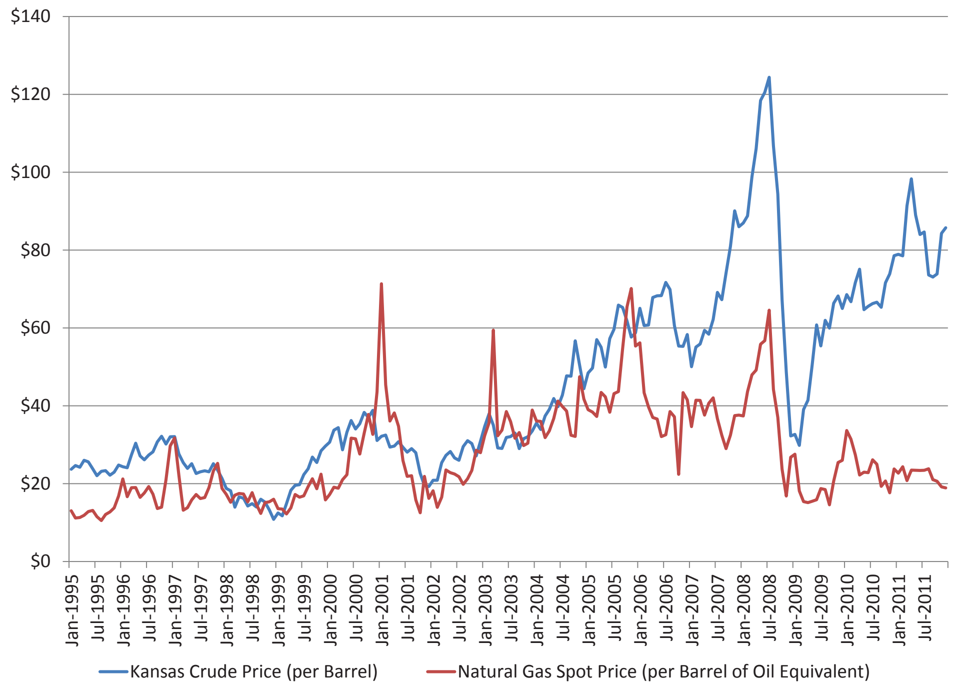
The physical attributes of natural gas—its gaseous nature—makes it a geologically and commercially distinct product from oil. Natural gas can be liquefied, but that process is expensive. So the piping and storage infrastructure required to bring natural gas from the wellhead to the end consumer tends to give it a regional-market character from a supply and demand perspective, as opposed to the globally-integrated market character of oil.

That said, however, the natural gas infrastructure in the United States is at a mature stage—with many regional inter-connections. One recent investigation identified eight regional markets for natural gas (from a price-setting perspective) and concluded that "the Canadian and U.S. natural gas market is a single highly integrated market."[33] This market integration, the investigating economists argued, means that the 1970s deregulation of the natural gas market worked. Price signals now do the job of efficiently allocating natural gas to its highest-valued uses.

Domestic U.S. natural gas production accounts for about 90 percent of U.S. consumption. The remainder is mostly imported from Canada. (A small amount of liquid natural gas is imported from a variety of countries around the world.[34]) As with oil, the fundamentals of supply and demand drive the price of natural gas.

Chart 18

Prices for Kansas Crude and Natural Gas (per Barrel, 2010$)



Source: Independent Oil and Gas Service, Inc. (Red Top News)

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[33] Haesun Park, James W. Mjelde, and David A. Bessler, "Price Interactions and Discovery among Natural Gas Spot Markets in North America," *Energy Policy*, Vol. 36, 2008, p. 290.

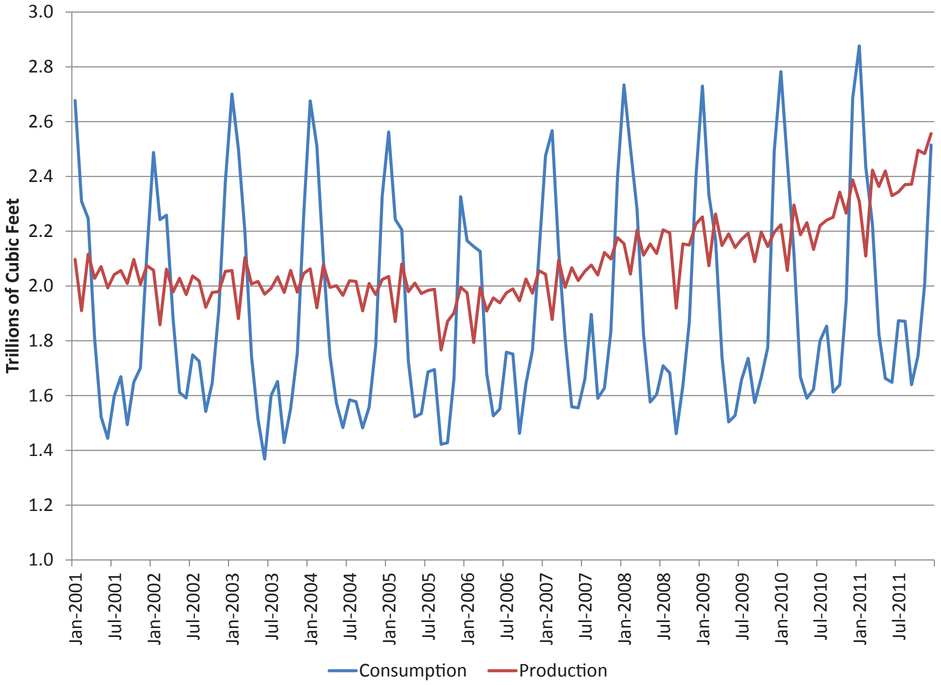
Chart 18 offers one way to display the relative price trends between oil and natural gas. It shows the price of Kansas crude and the (Panhandle Eastern Pipeline) spot price of natural gas on a barrel-of-oil-equivalent basis. Note the much greater volatility of the natural gas price series. Also note the obvious break in co-movement between the two price series in January 2010 (as noted above in connection with Chart 3). Many researchers have argued that the co-movement began to weaken many years before that.

The barrel-of-oil-equivalent price shown in Chart 18 hints at an important principle with regard to natural gas and oil prices co-movements: residual fuel oil and distillate fuel oil (both refined from oil) and natural gas compete as alternative fuel sources in both a business-input and residential-consumption context. The stability of the substitution relationship will ultimately act as the economic mechanism driving the stability of the price co-movement relationship. As discussed above in the context of oil prices, the marginal user's perceived substitution opportunity reacts to—and thereby sets—the market price differential between oil and natural gas.

Economists Stephen Brown and Mine Yücel have documented two rules-of-thumb used in the energy industry: the 10-to-1 rule and the 6-to-1 rule.[35] The former tends to hold up in certain historical circumstances. The latter roughly reflects the energy content differences in a barrel of oil and a natural gas barrel-of-oil equivalent. Oil is typically priced by the barrel (42 gallons) and natural gas is typically priced in units of 1,000 cubic feet. The energy content of 5,800 cubic feet of natural gas approximates the energy content in a barrel of oil (and a barrel of distillate fuel oil); 6,287 cubic feet of natural gas approximates the energy content in a barrel of residual fuel oil—hence the general 6-to-1 price rule. (Chart 18 makes use of this rule.) Neither of these two

Chart 19

U.S. Monthly Natural Gas Consumption and Production



Source: U.S. Energy Information Administration

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[34] BP Statistical Review of World Energy, June 2011

[35] Stephen P.A. Brown and Mine K. Yücel, "What Drives Natural Gas Prices?" *The Energy Journal*, Vol. 29, No. 2, 2008, p. 45-60.

rules-of-thumb predicts natural gas prices with impressive accuracy. The 10-to-1 rule tends to underestimate the actual price and the 6-to-1 rule tends to overestimate the actual price.

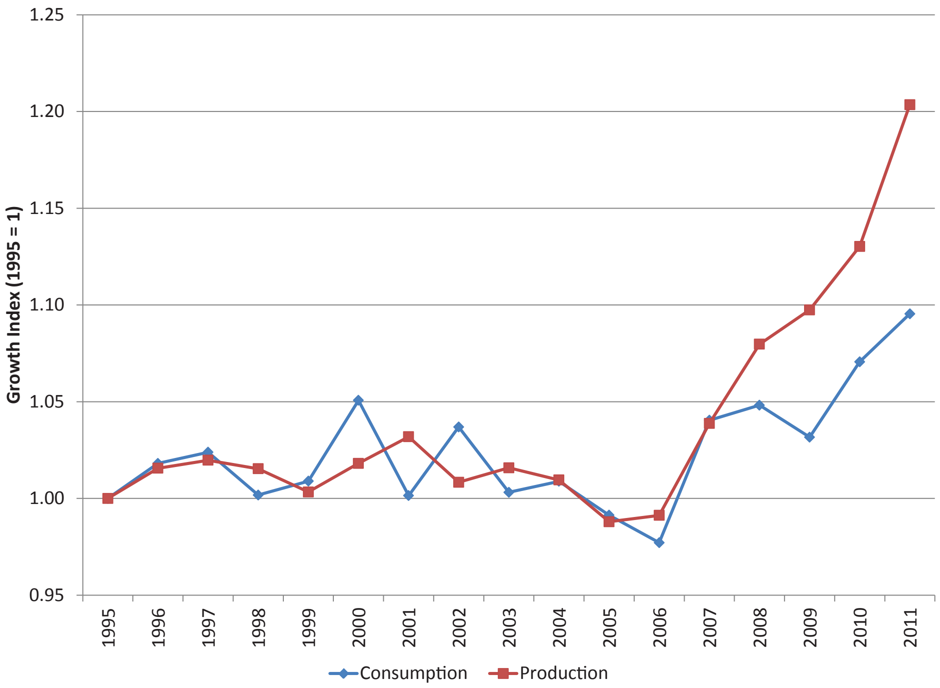
Another basic formula—the burner-tip parity rule—offers a more sophisticated version of the 6-to-1 rule. As discussed above in the context of oil prices, the price of oil (and therefore its influence on the price of natural gas) runs from the end user of the fuel back to the wellhead. The demand is a derived demand, so the burner-tip parity rule idea suggests that each consumer (primarily industrial consumers) assesses the economics of using competing fuels and picks the most cost-effective fuel. The choice works its way back to the wellhead as a price signal. The burner-tip parity rule produces a somewhat tighter co-movement relationship between oil and natural gas relative to the 10-to-1 or the 6-to-1 rule.

Each of the three rules, however, is imperfect—and each completely breaks down in a manner consistent with the break in the co-movement of oil prices and natural gas prices shown in Chart 18. The imprecision occurs because of the substantial amount of short-run volatility in natural gas prices. The structural break occurs primarily in connection with the recent surge in unconventional (shale) natural gas production.

Chart 19 illustrates why the price of natural gas tends to be much more volatile than the price of oil: high levels of imperfectly-predictable seasonality-driven demand. Almost all of the major consumption peaks come in January—the prime heating season. Almost all of the minor consumption peaks come in July—the prime cooling season.

Two additional items punctuate the seasonality of demand (consumption). First, the much wider swings in consumption relative to production imply that natural gas storage plays an important role in the logistics of the physical market for natural gas. Storage acts as a mechanism to buffer against unexpected demand, but storage

Chart 20
Trend in U.S. Natural Gas Consumption and Production



Source: U.S. Energy Information Administration

inventory levels influence the supply and demand conditions perceived by market participants, so these storage conditions have an influence on price. Second, random weather events often punctuate the more predictable patterns of seasonal cyclicality on both the consumption and production side of the market. For example, a cold spell in late spring can create a surge in demand or a storm in the Gulf of Mexico can temporarily disrupt supply. Either event would put upward pressure on natural gas prices in a manner that might deviate from contemporaneous oil price movements.

The preponderance of current evidence suggests that natural gas prices adjust to oil prices. The economics related to fuel substitution, even though such substitution operates on a continuum of end-user choices, creates a relatively stable long-run pattern of co-movement between oil prices and natural gas prices. Yet, many subtleties and complexities in the market for natural gas can generate wide divergence in a short-run context.[36]

The strong break in the oil-natural gas price-link shown in Chart 18 may also have a shorter-run interpretation—although one different in character from a weather event or storage imbalance. This report has marked the break as 2010; other researchers have argued for 2006. Chart 19 provides some support for the early date. Note the trend of increasing production relative to consumption beginning about 2006. This date is consistent with the increasing momentum behind shale gas production—and other horizontal drilling projects.

Chart 20 provides a more vivid year-over-year illustration of the trends shown in Chart 19. Gas production has clearly surged relative to consumption. The surge in supply offers a clear explanation for the declining trend in natural gas prices, in absolute terms and relative to oil prices.

Such price collapses have occurred in past oil or gas booms—and they are not sustainable. Dynamics on both the demand side and the supply side will ultimately drive natural gas prices back toward their historic, long-run relationship with oil prices. First, on the supply side, despite the popular excitement over the new technologies for extracting shale gas, producers have lost a lot of money as the result of the price collapse for natural gas (the core entrepreneurial risk framing this discussion).[37] Consequently, gas producers will keep their gas in the ground if they can and will postpone new gas projects. Producers have turned their focus to using the new horizontal-drilling technologies for producing oil. The greater production of oil relative to natural gas will help bring the two price series back into line with long-run economics. Second, the low natural gas prices will motivate an increase in the quantity demanded relative to future supplies. The higher quantity demanded for natural gas relative to refined petroleum fuels will help bring the two price series back into line with long-run economics.

ENTREPRENEURIAL COST CONTROL THROUGH THE BUSINESS OF SCIENCE AND ENGINEERING

The National Science Foundation categorizes "oil and gas extraction" among the most high-tech businesses in the world.[38] As with many industrial pursuits, the oil and gas industry has always fused together science, engineering, and profit-seeking commerce. Each component helps reinforce the other. The interactions drive productivity: the quest to create ever-greater economic value with ever-fewer resources used in the process. As a general matter, given the price-taking posture of most oil and gas producers, much of the entrepreneurial energy must focus on cost control—with technology acting as a key enabling tool.

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[36] In addition to Brown and Yücel, see: Peter R. Hartley, Kenneth B. Medlock III, and Jennifer E. Rosthal, "The Relationship of Natural Gas to Oil Prices," *The Energy Journal*, Vol. 29, No. 3, 2008; and David J. Ramberg and John E. Parsons, "The Weak Ties Between Natural Gas and Oil Prices," Center for Energy and Environmental Policy Research, Massachusetts Institute of Technology, November 2010.

[37] As Rex Tillerson, Chairman and CEO of Exxon-Mobil, said in June 2012: "We are all losing our shirts today." http://www.cfr.org/united-states/new-north-american-energy-paradigm-reshaping-future/p28630; also see: http://www.zerohedge.com/contributed/2012-06-04/capital-destruction-natural-gas

[38] Science and Engineering Indicators, Table 8-48. http://www.nsf.gov/statistics/seind08/tables.htm.

The geological science related to oil and gas is a fascinating subject that is beyond the scope of this report, except to the extent one understands the enormous challenge and cost associated with finding commercially productive reservoirs. Oil and gas result as a by-product of organic and geologic processes. The creation of (conventional) pools of oil and gas followed from a sequence of random events that generate the necessary and sufficient conditions. Research shows that about 2 percent of organic matter dispersed in permeable rocks becomes petroleum. About one-quarter of such matter will accumulate in a reservoir that has commercial potential.[39] Conventionally (prior to advances in horizontal drilling), oil and gas explorers had to find the places under the earth in which rock formations trapped oil and gas in economically "sufficient" quantities that flowed at "satisfactory" rates.

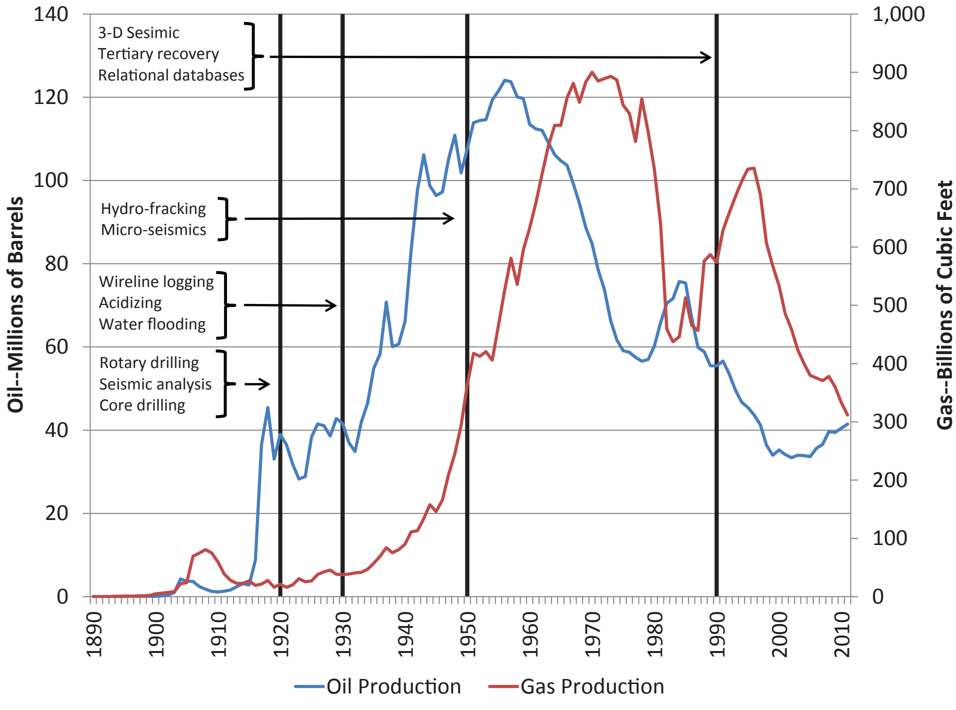
Undertaking the expense of drilling a well presents the only way to confirm these conditions. Consequently, discovering ways to minimize dry holes and maximize the information derived from every well drilled motivated the innovation process.

The Technology of the Upstream Sector

Chart 21 summarizes the annual production history of oil and gas in Kansas, annotated by the dates of key technological advances in rough approximation to when Kansas producers began to apply them. Exploration and technological advancement move through time together. Recall from Chart 1 that Kansas producers, since the 1930s, drilled hundreds of oil and gas wells each year. Consequently, the patterns of annual production do not always show a stark reaction to the introduction of new technologies. The process is symbiotic and evolutionary. A chronology of key events in discovery, science, and technological innovation follows:[40]

Chart 21

Annual Production of Oil and Gas in Kansas, 1890-2011



Source: Kansas Geological Survey

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[39] Forest Grey, *Petroleum Production for the Non-technical Person* (Tulsa: PennWell Publishing Co., 1986), p. 27

[40] The chronology draws liberally from: Daniel F. Merriam, "Advances in the Science and Technology of Finding and Producing Oil in Kansas," *Oil-Industry History*, Vol. 7, No. 1, 2006, pp. 29-46.

1890—Nitroglycerin for well stimulation:
Early wells often needed stimulation to flow better. The art of "shooting" a well involved using explosives to stimulate the well. Shooters often picked nitroglycerin-powered "torpedoes" to do the job.

1913—Surface structural mapping:
These maps resemble contour maps of the surface and the boundary lines of important subsurface geological features that give hints about where oil or gas might reside.

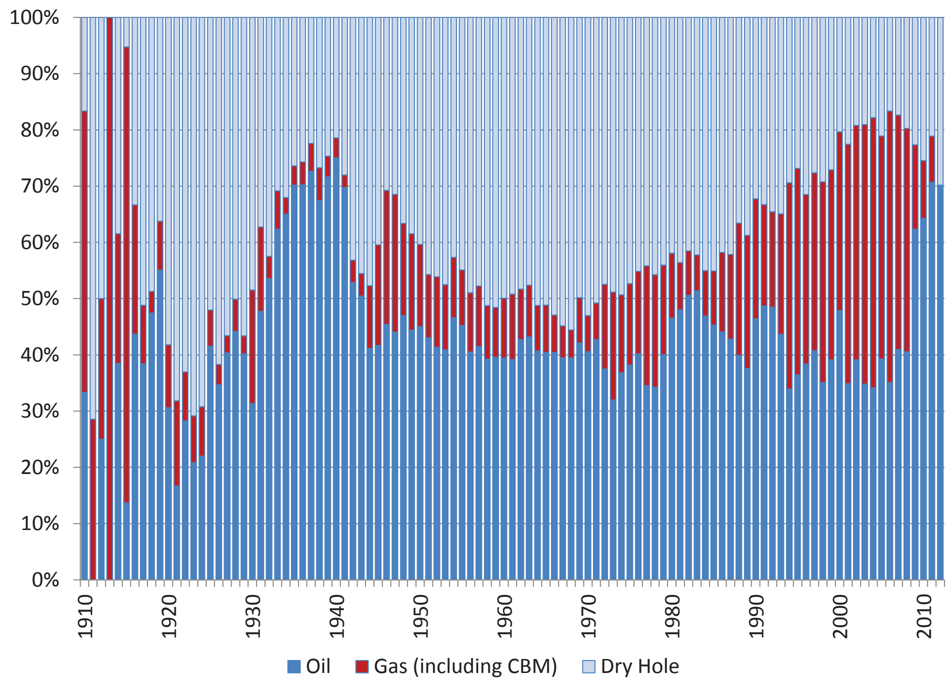
1920s—Introduction of rotary drilling in Kansas:
Early drilling techniques (called cable-tool drilling) used something like a heavy chisel on the end of a line. Raising and dropping the chisel-like drill bit smashed the rock layers. The drilling crew had to periodically use another string tool called a bailer to remove the smashed bits. Certain situations may still call for this process.

The concept of rotary drills had existed for centuries. An experiment with a rotary drill played a central role in drilling the nation's first true gusher in 1901—the famous well in Texas known as Spindletop. Rotary drills, though more expensive to operate, can drill holes many times faster than cable-tool drills. The circulating mud used in the process also helps better control the integrity of the well.

1923—Single-point seismic exploration and core drilling:
A monument outside the Belle Isle Library in Oklahoma City notes that in 1921 scientists in Oklahoma City "confirmed the validity of the reflection seismograph method of prospecting for oil." Originally, seismologists set off a strategically-placed blast in a single location and recorded with seismographs the vibrations that returned from the subsurface. Since different subsurface strata had different "echoes," geologists could study the images to identify structures in which oil or gas may accumulate.

Chart 22

Percentage of Kansas Wells Drilled by Type, 1910-2011



Source: Kansas Geological Survey

(Eventually, the technique evolved to collect over a horizontal distance the data necessary to generate vertical cross-section (2D) “pictures” of the subsurface.)

Core drilling uses specialized drill bits to extract samples of the rock in a well. Geologists inspect the rock for signs of hydrocarbons. They also use the cores to help “map” the subsurface geology.

1930s—Wireline logging and acidizing:
Wireline logging refers to the lowering of measurement instruments down the wellbore. The primary aim of logging is to assess the characteristics of a well in progress. Certain measurements can help provide valuable information about the viability of a well. The sooner such information becomes known, the better from an economic perspective.

Acidizing injects acids into the well to make certain rock formations more permeable to improve the flow of hydrocarbons.

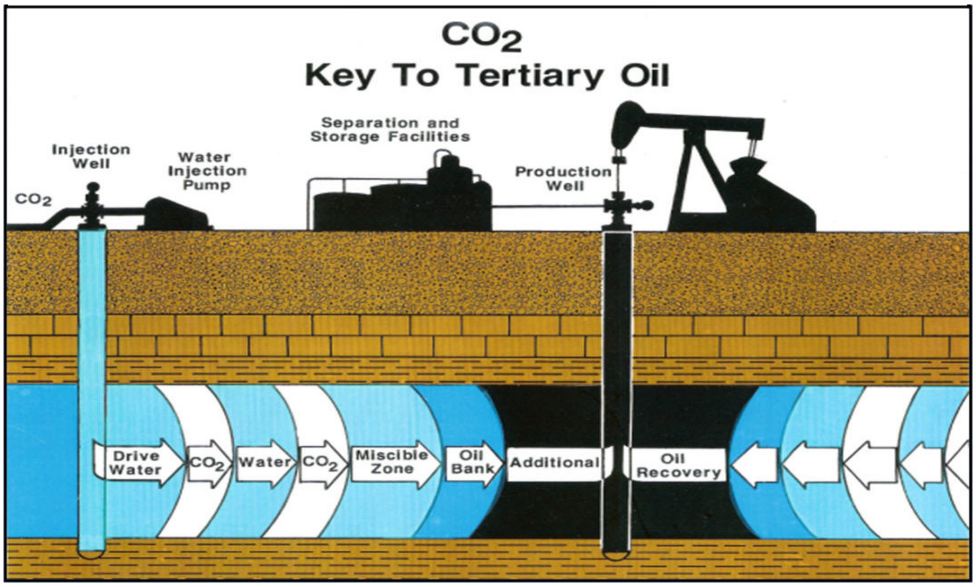
1935—Secondary recovery and water flooding:
Secondary recovery via water flooding is a method to extract additional hydrocarbons from a reservoir once its “natural” production stops. Water is injected into the reservoir from strategically placed wells. Properly executed, the water will flush additional hydrocarbons from the rock.

1950—Micro-seismics and hydraulic fracking:
Micro-seismic was devised as a means to locate the drill bit in real time by using seismic waves generated by the friction between the bit and the rock or sand being drilled. This information aided the drilling process and helped advance innovations related to directional drilling and 3-dimensional imaging (especially in the context of evaluating and controlling the fracture patterns in connection with modern fracking techniques).

Hydraulic fracking pumps fluid and sand mixtures into wells to crack the rock formations as a way to help improve the flow of hydrocarbons into the wellbore. The first test of this method took place in the Hugoton gas field in Grant County, Kansas in 1947. The maturity of the technique is partly responsible for the growth of gas production that followed the introduction of this technology.

Exhibit 3

Tertiary Oil Recovery



Source: http://www.co2storagesolutions.com/

1990s—3-D seismic enhanced (tertiary) oil recovery, integrated petroleum databases, directional drilling, modern hydraulic fracking:
Several technologies began to mature by the 1990s in a mutually reinforcing way. Kansas producers began to make a more determined use of them at about this time.

Beginning in the 1980s, 3-D seismic images improved on the 2-D techniques.[41] 3-D images provide far more detail about the structure of the subsurface, which allows for more informed drilling decisions. As a 2003 Kansas-oriented study stated: "The estimated commercial success rate for wells drilled with 3-D seismic is 70%, compared to an average success rate of approximately 30%-35% for wildcat wells drilled in Kansas over the past 3 years. 3-D seismic has been particularly useful for delineating small structural highs and narrow channels that can be significant drilling targets, but cannot be identified with well-control alone or even using 2-D seismic data."[42]

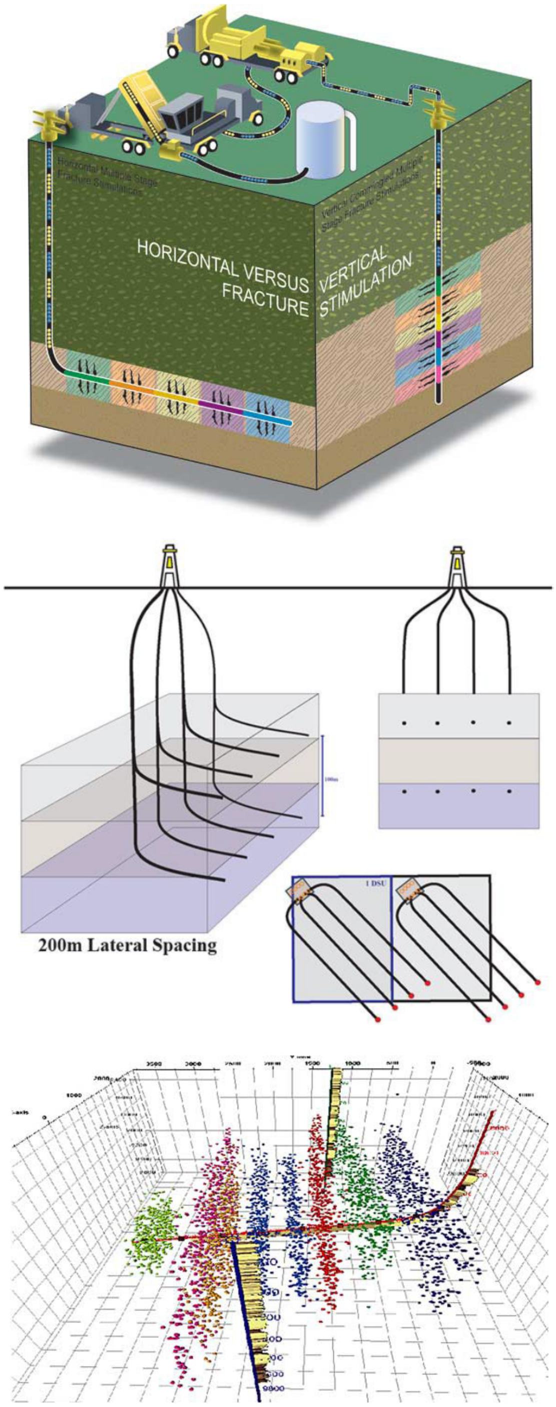
Chart 22, which is an alternative way to view the information presented in Chart 1, documents that Kansas producers have had increasing success rates with their drilling activity since the mid-1960s. The implementation of 3-D seismic reinforced the trend.

Tertiary oil recovery with CO_2 began as experiments in the 1970s. Tertiary oil recovery has the same goal and techniques as secondary recovery—except that gases (like CO_2 or steam), chemicals, or microbes become an added stimulant injected into the reservoir. The additional stimulants help lower the viscosity of the oil so that it flows better. CO_2 does this job well. (See Exhibit 3.) The development of 4D seismic has begun to compliment tertiary recovery in mature fields. The fourth dimension is time, which allows geologists to monitor the flow patterns of specific reservoirs so as to better stimulate them.[43]

Beginning in the 1980s, producers began to increase their use of directional (horizontal) drilling techniques. The concept and technology for directional drilling dated back decades, but it did not become economic until

Exhibit 4

Key Elements of Modern Drilling Technology



Source: http://www.neb.gc.ca/clf-nsi/rnrgynfmtn/nrgyrprt/ntrlgs/prmrndrstndngshlgs2009/prmrndrstndngshlgs2009-eng.html

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[41] http://www.rri-seismic.com/Frame Pages/Tech Pages/Seismic/seismic.htm

[42] Susan Nissen, et al. "3-D Seismic Applications by Independent Operators in Kansas," Petroleum Technology Transfer Council, January 2003, p. 1.

[43] Ayyoub E. Heris, et al., "Study Integrates Flow Simulation, 4D," *The American Oil & Gas Reporter*, July 25, 2012.

the 1980s. Directional drilling, which often produces a smaller environmental footprint, may have several operational and economic advantages because it can mean better production rates from fewer wells drilled. Kansas producers have drilled, on average, a few horizontal wells each year since 1990.

The advancement of computing technology has allowed for improvement in all of the above technologies. In Kansas, the advancement of computing technology has also allowed the Kansas Geological Survey to develop integrated databases for use by the independent producers of Kansas. The Robert F. Walters Digital Geological Library, which resides in Wichita and is managed by the Kansas Geological Society, makes available a vast reserve of data related to oil and gas wells. The improved access to information allows for better decision making.

Exhibit 4 allows for the visualization of three key elements of modern drilling processes that have made "unconventional" sources of oil and gas commercially viable. As discussed above, the various technologies had been under development for decades. Their confluence in the context of producing commercially viable shale gas (and later, shale oil) dates to 1997 when Texas-based Mitchell Energy (after years of research and development partnerships with the Department of Energy, the Gas Research Institute, and other private firms) drilled a successful horizontal well in the Barnett Shale in the vicinity of Fort Worth, Texas.

The top image in Exhibit 4 illustrates the fracking process in both a vertical and a horizontal well. Directional-drilling technologies enable the drilling of horizontal wells. Some oil and gas rich geologic structures have a vertical thickness of only a few dozen feet—but they can cover a vast geographic area. Horizontal- drilling techniques allow producers to tap into that vastness. Notice the different colored zones in the image. Each one of these zones may represent an isolated fracking process: multi-stage fracking. Perfecting the multi-stage process as a horizontal well bores ever deeper into a formation represents one of the many advancements that enables the success of the modern techniques.

The middle image in Exhibit 4 shows how a producer might maximize production from a single well site by strategically spacing many horizontal wellbores. Each wellbore might be fracked.

The bottom image of Exhibit 4 shows a 3-D microseismic image of a fracked horizontal well. This technology allows for frack mapping. A seismic instrument is lowered into the wellbore, and the resulting seismic feedback allows producers to see patterns of fractures in the rock formation. Each color represents a different level of the multi-stage fracking operations. This type of mapping technology made the teams at Devon Energy (which had acquired in 2002 Mitchell Energy, the pioneer in shale-related horizontal fracking) realize the extent to which horizontal drilling combined with multi-stage fracking of each wellbore made all the difference for success.[44]

THE BUSINESS OF THE UPSTREAM SECTOR

Exhibit 5 presents a schematic of the upstream oil and gas sector. The front-end of the process involves an iterative process of business negotiation and scientific investigation—an iterative process that (1) endeavors to define the economic prospects of a potential oil or gas property and (2) creates a mutually-advantageous contractual arrangement with regard to the consenting parties who will share the actual costs and benefits related to the prospect. Once the parties involved have made a contract, the engineering processes related to drilling proceeds. Of course, the engineering process is itself an interlocking network of business arrangements. As two industry experts have noted: "The world of petroleum is a world of contractors and subcontractors."[45] Specialization abounds.

As detailed later in the report, on average, over the past decade, Kansas has employed almost 14,000 private-sector people in the upstream activities depicted in Exhibit 5. Thousands of those counted represent single-person businesses. Of the roughly 1,000 businesses with employees, the average job count per business equals eight. A large number of small, specialist enterprises comprise the upstream business ecosystem in Kansas.

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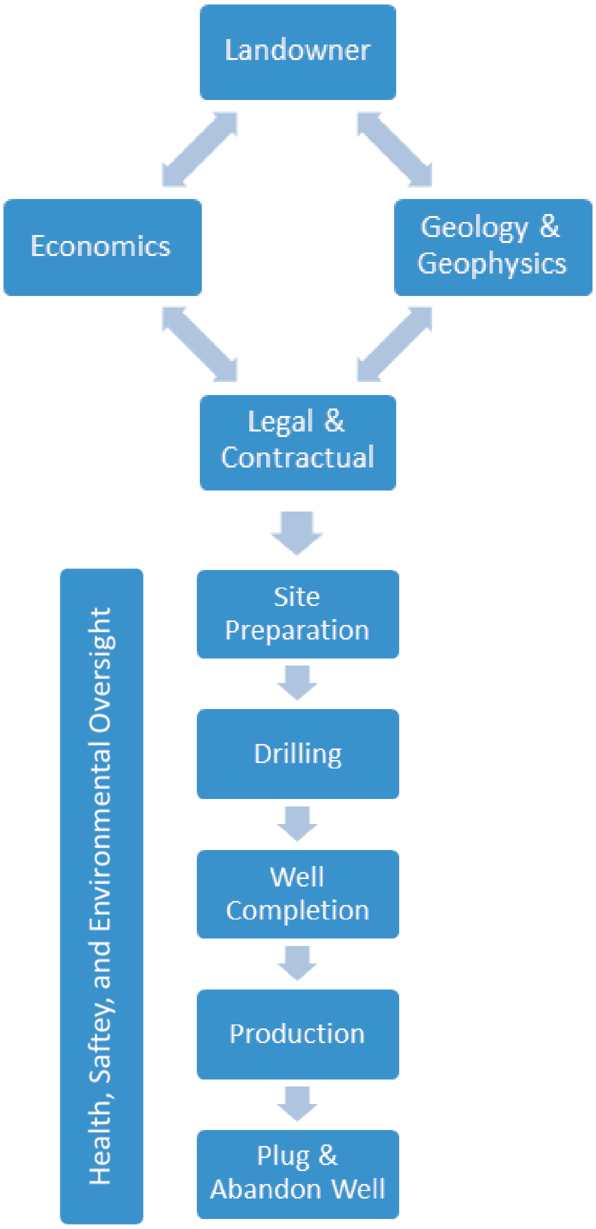
[44] http://thebreakthrough.org/blog/2011/12/interview_with_dan_steward_for.shtml

[45] Bill D. Berger and Kenneth E. Anderson, *Modern Petroleum: A Basic Primer of the Industry*, 3rd Edition (Tulsa: PennWell Publishing Company, 1992), p. 118.

Landowner
In the United States, the landowner(s) holds a prominent place because he or she has the legal property rights to the oil and gas. However, the legal rights can be split between (a) the surface rights to use of the land and (b) the mineral rights to use of the land. Often the same person or legal entity owns both rights. Each set of rights may also be split in fractional shares among many different persons or legal entities. The owner(s) of the surface rights must cooperate in the exploration and extraction process. The owner(s) of the mineral rights must cooperate in the extraction process. The "landman" employed by an oil or gas company has the duty to determine the ownership rights and manage the negotiations among the various owners. With many legal interests in play, the structure of negotiations can become complicated.

Exhibit 5

A Sketch of the Upstream Oil & Gas Industry



Legal counselors to landowners usually advise them to put legal agreements in place before allowing any type of scientific investigation to take place on their property. Typically, in Kansas, landowners will secure a formal lease contract before granting access to their land. The lease gives the lessee the right to explore. The payments made to the lessor under the contract, in part, compensate them for any damage that might occur on the land during the exploration process.

Geology and Geophysics
Geoscientists study subsurface materials, structures, and processes using drill cuttings, gravity, magnetic, electrical, and seismic methods. In brief, they try to scientifically determine where to drill and evaluate the volumes of hydrocarbons that may exist in a particular drilling zone.

Economics
Reservoir engineers use the scientific information compiled and analyzed by the geoscientists to develop economic estimates related to drilling costs and projected payoffs based on the estimated volume of recoverable oil or gas. They also work with other experts to continually assess and improve the cost-benefit equations related to alternative drilling plans or methods. In brief, reservoir engineers help make the decision about whether or not to undertake the cost of drilling a well.

Legal & Contractual
Once the evaluation process has advanced far enough for the relevant parties to make a decision to drill a well, legal negotiations must take place related to how the surface rights owner will be accommodated and compensated during the production process and the owner(s) of the mineral rights, via a lease contract, will share in whatever economic gain results from the well. The mineral lease has several components:[46]

- Bonus payment—an up-front payment for signing the lease, often negotiated as a fixed dollar per acre.
- Royalties—a share of the proceeds from producing and selling the oil or natural gas.
- Time limits related to how long a lessee can explore and drill, along with specific definitions related to exploration, drilling, and quantities produced.
- Directives related to the protection and proper stewardship of the minerals.
- Penalty clauses.
- Pooling clauses that allow oil and gas companies to form partnership agreements with other leaseholders in a geographic area for the purpose of improving the cost-effectiveness of operations.
- Clauses related to operating restrictions and satisfactory performance.

Oil and gas companies that initiate a project (by acquiring a lease) often try to spread their risk by selling fractional interests to other investors. The contractual arrangements make explicit how the parties will share the costs and revenues. Royalty interests differ from mineral interests.

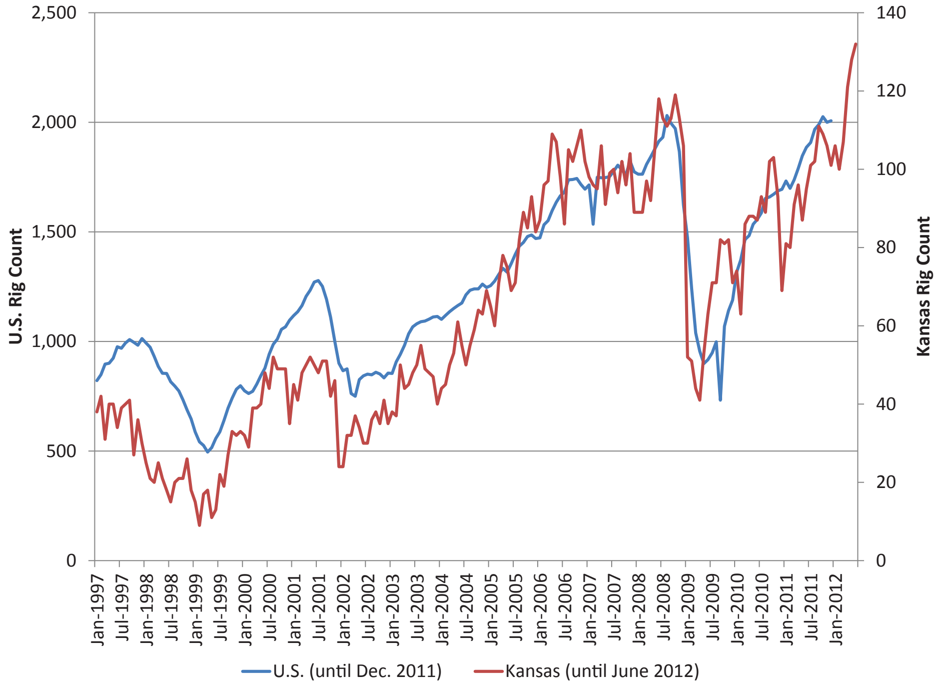
SITE PREPARATION, WELL DRILLING, AND WELL COMPLETION

As already mentioned, the upstream oil and gas business represents an interlocking network of contractors and subcontractors. All of the high-tech elements related to oil and gas extraction represent professional specialties. Entire businesses may specialize in one part of the intricate overall process.

Chart 23 shows that, on average, since 1997, Kansas has more than 60 drilling rigs operating. Since 2004, the

Chart 23

U.S. and Kansas Count of Active Drilling Rigs



Source: Independent Oil and Gas Service, Inc. (Red Top News); U.S. count from Baker-Hughes

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[46] Berger and Anderson, Chp. 4.

time of a general escalation in oil prices, the average has exceeded 85 rigs per month. The trend in Kansas rigs in operation matches closely the U.S. trend. As discussed in detail above, global oil markets have a tight integration; all producers respond to the same set of price signals.

The list below provides a cursory overview of the semi-skilled and highly-skilled people involved with drilling rigs, well completions, and on-going production. According to data compiled by the Independent Petroleum Association of America, among the producing states, Kansas typically ranks third or fourth in oil wells drilled and seventh or eighth in natural gas wells drilled. (See Chart 8.) All of the drilling activity has established a pool of talent in Kansas that is broad and deep. From a producer's perspective, all operating costs associated with employing these specialized people (and well operations in general) are significant—and present elements of entrepreneurial risk.

Petroleum engineers: Devise methods to improve oil and gas extraction and production.

Rig operators: Set up or operate a variety of drills and pumps to circulate mud through a drill hole.

Fluid engineers: Manage appropriate drilling fluid specifications for a drilling operation.

Wireline operators: Use of cabling technology to lower equipment or measurement devices into a well.

Well loggers: Detailed recordkeeping (a well log) of the geologic formations penetrated by a borehole.

Casing: Placement of pipe into a recently drilled section of a borehole.

Cementing: Securing casing pipe with advanced cementing techniques. Note that casing and cementing protocols play an integral role in the structure of the well—and work simultaneously to protect underground water supplies, as shown in Exhibit 6. Not every well follows each of the cementing steps shown in Exhibit 6—especially in Kansas. Conductor casing is used in a low percentage of Kansas wells. Kansas producers also rarely use intermediate casing. In Kansas, surface casing is typically set to the depth necessary to protect fresh water; on productive wells, production casing is set to the well's total depth and then cemented at the bottom of the hole to case off zones that have productive potential and at the top of the hole to protect "usable water" (water that is not fresh enough to be used without treatment).

Perforating: Techniques used to create a hole in the casing through the cement and into the rock formation to allow (and enhance) oil and gas to flow into the completed well.

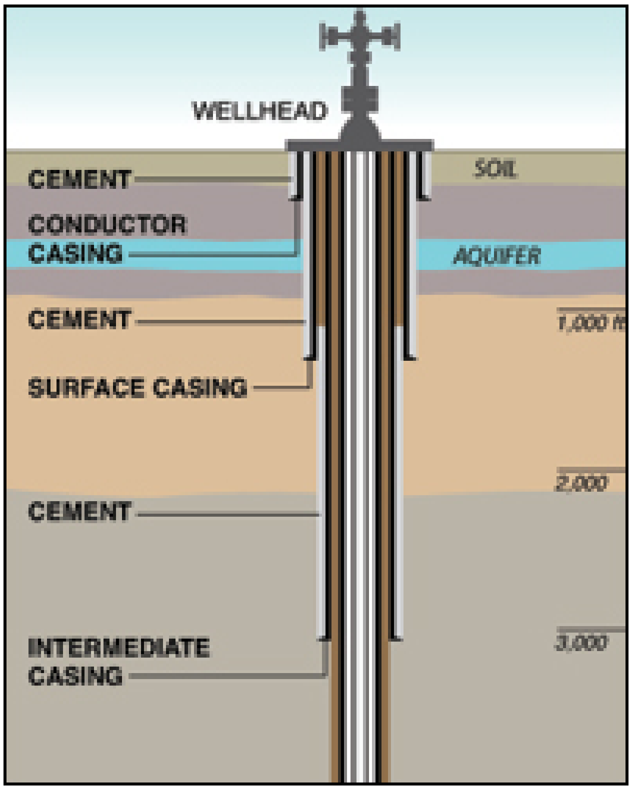
Stimulation: Specialized techniques used to improve well flow or enhance oil and gas recovery, such as acidizing, fracking, swabbing, hot oiling, snubbing, and coil tubing.

Acidizing: The use of hot hydrochloric acid to remove substance build-up—like limestone, dolomite and calcite cement—that can impede the flow of a well.

Fracking: The propagation of fractures in a rock layer that results from injecting highly-pressurized fluid mixtures into a well.

Exhibit 6

Drill Casing and Cementing



Swabbing: Removal of liquids that were instrumental to the drilling process but must be removed for proper well operation. Specialists place a rubber plunge down the well bore. The swab is then pulled back up towards the top of the well bore. As the swab moves up the well the pressure below it is reduced and liquids are sucked out behind it.

Hot Oiling: Circulation of heated fluid, typically oil, to dissolve or dislodge paraffin deposits from the production tubing. Such deposits tend to occur where a large variation in temperature exists across the producing system.

Snubbing: Also known as hydraulic workover, this procedure involves forcing a string of pipe into the well against wellbore pressure to perform the required tasks. The rigup is larger than for coiled tubing and the pipe more rigid.

Coil Tubing: Coiled tubing is used when producers desire to pump liquids directly to the bottom of the well, such as in a circulating operation or a chemical wash. It can also be used for tasks normally done by wireline if the deviation in the well is too severe for gravity to lower the toolstring and circumstances prevent the use of a wireline tractor.

Pumper: A pumper gauges (measures) the tanks daily, performs routine maintenance, and reports any problems that may arise to his superintendent.

Salt Water Disposal: Salt water produced by a well is frequently hauled to a distant disposal well if a lease does not have its own disposal facilities—or is not connected to a nearby disposal well.

Miscellaneous Services: If a well doesn't produce gas, it is either served by a propane supplier or it is tied in to an electrical system. Repairs to the engine or motor powering the pumping unit periodically occur. Repairs also occur to the pumping unit and tank battery. Wells need to have their rods and tubing pulled periodically to repair parts in the rod string or leaks in the tubing.

Plugging Wells: When a well's production has declined to the point where its production revenues will no longer cover its operating costs, the well is said to have reached its economic limit, even if the well may still have recoverable oil or gas. At this point, a producer will most likely choose to plug the well, remove the equipment, and forfeit the leasehold interest. Any operator of a well is ultimately responsible for plugging it. The Kansas Corporation Commission will look to the most recent operator first; only when it cannot identify a potentially responsible party will it designate a well as an "orphan well" and plug it at the expense of the state government. The financing for state-sponsored plugging of orphan wells comes from two funds maintained by the Kansas Corporation Commission. The primary contribution to those funds, in turn, comes from the oil and gas industry through (1) the conservation fee (production tax) and (2) the financial assurance payments made when operators renew their licenses. Additional funds come from the Kansas Water Plan and from the state share of oil and gas royalties on Federal lands. Kansas law also provides for a $400,000 annual transfer from the State General Fund (about 25 percent of the total). However, State General Fund transfers have not occurred in recent years.[47]

Health, Safety, and Environmental Oversight

The Kansas Corporation Commission (Conservation Division) is the primary government agency charged with regulating oil and gas activities in Kansas. The functions of the Commission have grown significantly over time.

In the earliest days of the Kansas oil and gas industry, before producers and consumers understood how to steward the oil and gas resources properly, the Commission protected correlative rights (the rights to oil and gas reserves underneath adjacent properties with different owners) and promulgated rules to help prevent waste. This focus resulted in well-spacing orders to protect the rights of offsetting landowners and to prevent over drilling. Another remedy involved rules related to "production allowables," or limits on the rate of production from a given well.

In one way or another, the Kansas Corporation Commission (in conjunction with federal regulators like the Environmental Protection Agency and the Department

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[47] See K.S.A 55-192, K.S.A 55-193 and FY 2013 Governor's Budget Report—Volume 1, p. 77.

of Labor's Occupational Safety and Health Administration), oversees almost all of the steps and processes related to producing oil and gas, as depicted in Exhibit 5. The Conservation Division of the Kansas Corporation Commission is staffed by professionals with backgrounds in geology and law, and many of the professionals have industry experience. The staff maintains an open dialogue with industry through the Oil & Gas Advisory Committee, which represents industry, landowners, and other interested parties. The Conservation Division has a history of professionalism and of timely responses to filings, which serve to adequately regulate the industry without undue cost or delay. The Kansas Corporation Commission has formal rules, procedures, and (as appropriate) penalties related to:

- Notice of intention to drill.
- Classification of wells.
- Procedures for determining the location of wells using global positioning system.
- Application for well spacing.
- New pool applications.
- Operator or contractor licenses.
- Assignment of allowables.
- Preservation of well samples, cores, and logs.
- Unlawful production.
- Prevention of waste, protection of correlative rights, and prevention of discrimination between pools.
- Well construction requirements.
- Well casing and cementing.
- Mechanical integrity requirements.
- Mechanical integrity testing.
- Tests of wells.
- Shut-off tests.
- Completion reports.
- Drilling through gas storage formations.
- Drilling through CO2 storage facility or CO2 enhanced oil recovery reservoirs.
- Dual or multiple-completed wells.
- Surface commingling of production.
- Vacuum and high volume pumps applications.
- Transfer of operator responsibility.
- Pollution prevention.
- Venting or flaring of gas.
- Sensitive groundwater areas.
- Spill notification and clean-up.
- Disposal of hazardous materials.
- Leak detector inspections and testing.
- Reporting of leaks, potential leaks, or loss of containment.
- Notice of intention to abandon a well.
- Temporarily abandoned wells.
- Plugging methods and procedures.
- Tank and truck identification.
- Documentation required for transportation and storage.
- Storage facility requirements.
- Storage facility monitoring and reporting.
- Safety inspection and annual review of safety plans.
- Temporary abandonment of a storage facility.
- Application for decommissioning and abandonment of storage facility.

The growing use—and public awareness—of hydraulic fracturing has raised public concerns related to its potential to degrade water supplies. To protect fresh and usable groundwater, the Kansas Corporation Commission has promulgated regulations dealing with the casing of wells, cementing that casing, the use of surface pits and the plugging of wells. Any spills of oil or salt water are required to be reported to the Commission which will provide guidance for cleanup activities. As most oil and gas wells produce a certain amount of salt water waste, the Commission has rules for its safe disposal into non-usable water bearing geological formations and for the testing of the mechanical integrity of the salt water disposal wells. The casing and cementing rules serve to protect water resources from both the disposal of waste water and from hydraulic fracturing. Each operator must be licensed by the Commission and is subject to fine or revocation of license for acts of non-compliance.

ASSESSING THE FUTURE: HOW "UNCONVENTIONAL" OIL AND GAS PLAYS MAY CONTRIBUTE TO THE KANSAS ECONOMY

The definition of "unconventional" oil or gas systems typically relates to their economics.[48] "Unconventional" oil and gas plays cost more to develop than "conventional" plays. That general, but not necessarily universal, definition explains why hydrocarbons trapped in shale or coalbeds often qualify as unconventional oil or gas resources. Historically, producers faced much higher extraction costs for these resources (if they could indeed actually extract them) than they did for oil or gas trapped in, say, sandstone. Scientific and technological advancement may have lowered the production costs, but the definitional classifications remain.

The Mississippian Lime Play

The Mississippian Lime play in south central Kansas (and perhaps much of western Kansas) fits into the "unconventional" category primarily because the horizontal-drilling techniques being employed are the same ones used to extract oil and gas from shale. Kansas producers have extracted oil and gas from the Mississippian Lime formation for decades using "conventional" techniques (like basic vertical well drilling).

Nevertheless, because of the new techniques, the Mississippian Lime may yield a substantial amount of oil and gas that more conventional techniques (seemingly) could not access. That makes the play sit comfortably in this report's model of an industry defined by enduring high-tech entrepreneurship.

The portfolio of horizontal-drilling technologies discussed above resulted from the entrepreneurially energies of a collection of Mid-Continent firms. The earliest efforts of these entrepreneurs benefitted from a shale gas research and development project in the New England area initiated in the mid-1970s the then newly-created Department of Energy. But the Mid-Continent firms (with the early aid of a few risk-sharing grants and technological assistance from government agencies) conducted the trial-and-error work required to make unconventional oil and gas sources commercially viable. A 1997 well drilled by Mitchell Energy into the Barnett Shale underneath the area of Fort Worth, Texas typically marks the breakthrough point. Advances and refinements continued thereafter.

The smaller, independent companies entrepreneurially pursued the unconventional oil and gas sources for the same primary economic reason smaller, independent companies dominate Kansas production: The projected profits on specific projects do not rise to the dollar levels required by larger companies.

Harvard researcher Clayton Christensen established this general point in the work that led to his iconic book, *The Innovator's Dilemma*. He has summarized the point this way: "One of the bittersweet results of success is that as companies become large, they lose sight of small, emerging markets."[49]

The major oil companies had the human and financial capital to pursue and develop the disruptive technologies so-far discussed, but they did not have a compelling financial incentive to pay attention. Most of the major oil companies had their focus on finding large, conventional sources of oil and gas outside of the United States (except for the Gulf of Mexico).[50] Rex Tillerson, Chairman and CEO of Exxon-Mobil, speaking before an audience associated with the Council on Foreign

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[48] B.E. Law and J.B. Curtis, "Introduction to Unconventional Petroleum Systems," AAGP Bulletin, Vol. 86, No. 11, November 2002, pp. 1851-1852.

[49] Clayton M. Christensen and Michael Overdorf, "Meeting the Challenge of Disruptive Change," *Harvard Business Review*, March-April 2000, p. 70.

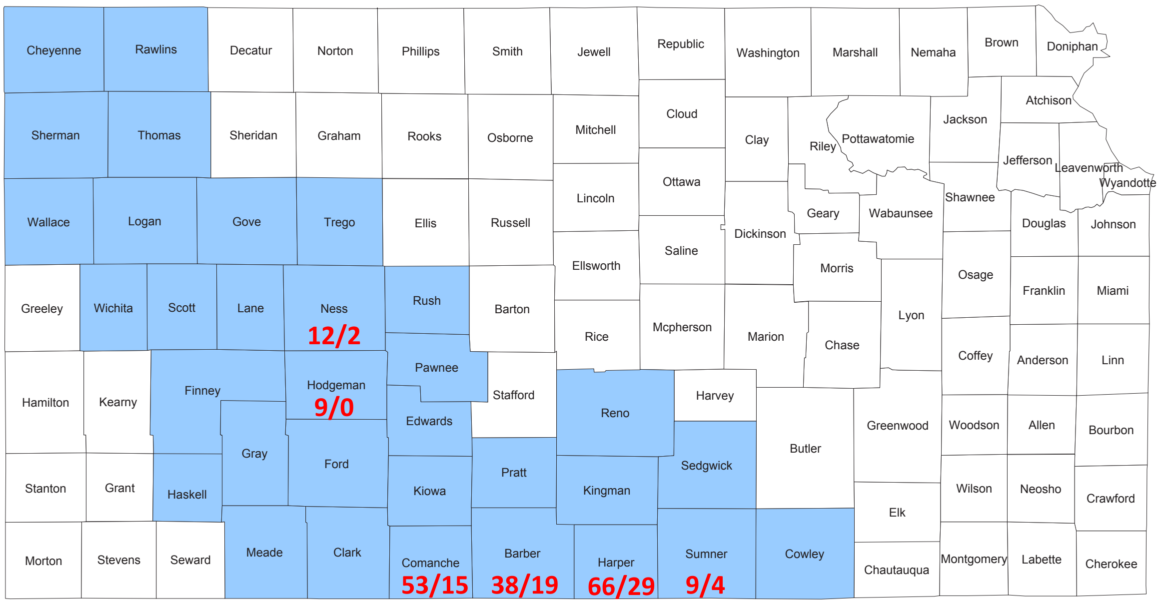
Relations, recently said: "And I would be less than honest if I were to say to you, and we saw it all coming, because we did not, quite frankly. We did recognize the potential of the shale resources in North America. We recognized there were technology solutions to a portion of that. We grossly underestimated the capacity of both the rocks, the capacity of the technology to release the hydrocarbon, natural gas from the shale gas and now oil from tight oil rocks. We underestimated just how effective that technology was going to be, and we also underestimated how rapidly the deployment of that technology would occur -- again, all in response to fairly high prices."[51] With the technology and production potential proven, Exxon-Mobil addressed its lack of foresight by acquiring XTO Energy in 2010, in a deal valued at $41 billion.[52]

The economic potential made possible by the new technologies has brought a major oil company back to Kansas. The Shell Oil Company recently purchased large tracts of leased acreage in Kansas related to the Mississippian Lime formation. Prior to this investment, records from the Kansas Geological Survey indicate that Shell Oil last completed a well in Kansas in 1984 (with most activity before that pre-dating 1950). Two Oklahoma-based companies, Sandridge Energy and Chesapeake Energy, have also leased large amounts of acreage related to the Mississippian Lime play.

Map 2 indicates the approximate geography of the Mississippian Lime (which extends down two-counties deep into Oklahoma) and the Kansas counties that have attracted the most intent-to-drill permits for horizontal wells. Intent-to-drill represents a permitting process not a guarantee to drill a well. Producers, as a matter of operational planning, often register an intent-to-drill that does not ultimately materialize as an actual well drilled. The left-hand number shown in the select counties on Map 2 indicates the count of intent-to-drill permits; the right-hand number indicates the count of well completions. The counts represent permit and drilling activity

Map 2

Approximate Area of Interest Related to the Mississippian Lime Formation and Count of Horizontal Well Permits vs. Wells Drilled (2010 through July 2012) in the Top-6 Counties



Source: Sandridge Energy, Public Presentation; Kansas Geological Survey

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50 Verleger, "The Amazing Tale of U.S. Energy Independence," p. 54.

[51] http://www.cfr.org/united-states/new-north-american-energy-paradigm-reshaping-future/p28630

[52] http://news.exxonmobil.com/press-release/exxon-mobil-corporation-and-xto-energy-inc-announce-agreement

that took place from 2010 through July 2012. In that time frame, Barber County (at 50 percent) experienced the highest conversion rate from intent-to-drill to well-drilled. Only time will tell if the conversion rates increase from those reported on the map.

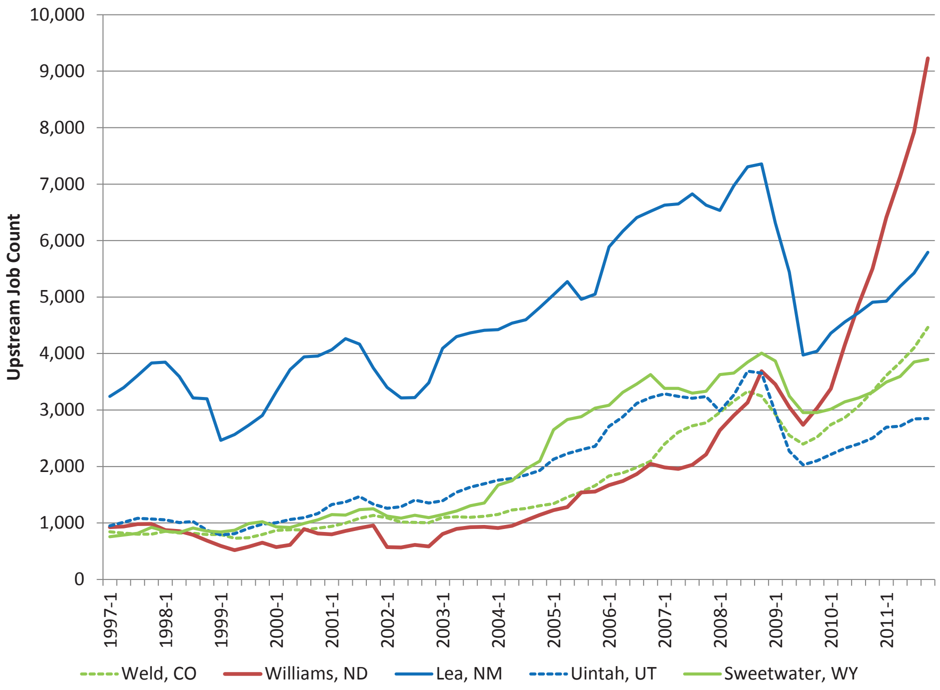
To further clarify, the figures on Map 2 represent horizontal wells only. The intent-to-drill horizontal versus vertical wells is a relevant distinction separating the Mississippian Lime play from the regular patterns of exploration and production. Map 2 shows the number of horizontal well permits from 2010 through July 2012 for the top-6 counties only: 187 out of a total of 260. Most of the other permits, but not all, specified counties in the Mississippian Lime zone on the map. Over the same time period, however, the Kansas Corporation Commission issued 20,958 intent-to-drill permits that did not have a horizontal specification. The Mississippian Lime play has stimulated interest and received attention form the news media, but the independent producers of Kansas continue to explore and drill in 92 of the state's 105 counties. (Table B5 in Appendix B shows that independent oil and gas producers, over the state's history have drilled 97 percent of the wells, produced 93 percent of the oil, and produced 63 percent of the natural gas.)

Beginning in 2012, blog posts appeared comparing the Mississippian play in Oklahoma and Kansas to the Bakken shale play in North Dakota.[53] Such comparisons should consider several different perspectives and caveats. The comparisons have two fundamental elements: (1) the potential growth of oil and gas related jobs supported by drilling and production and (2) the potential size of recoverable oil and gas reserves. The potential drilling-and-production-related job growth, in turn, has implications for the transportation and housing infrastructure required to accommodate such growth.

To put the infrastructure issue in perspective, Chart 24 illustrates upstream (exploration, drilling, and drilling-support services) job growth in select counties that have experienced recent oil or gas "booms." Chart 25 helps provide further perspective by illustrating upstream jobs

Chart 24

Quarterly Upstream Job Count in Select "Boom" Counties



Source: U.S. Bureau of Labor Statistics

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[53] See, for example: http://seekingalpha.com/article/322155-investing-in-the-mississippi-lime-is-it-the-new-bakken

Chart 25

Upstream Jobs as a Share of Total Jobs (implied by Chart 1)

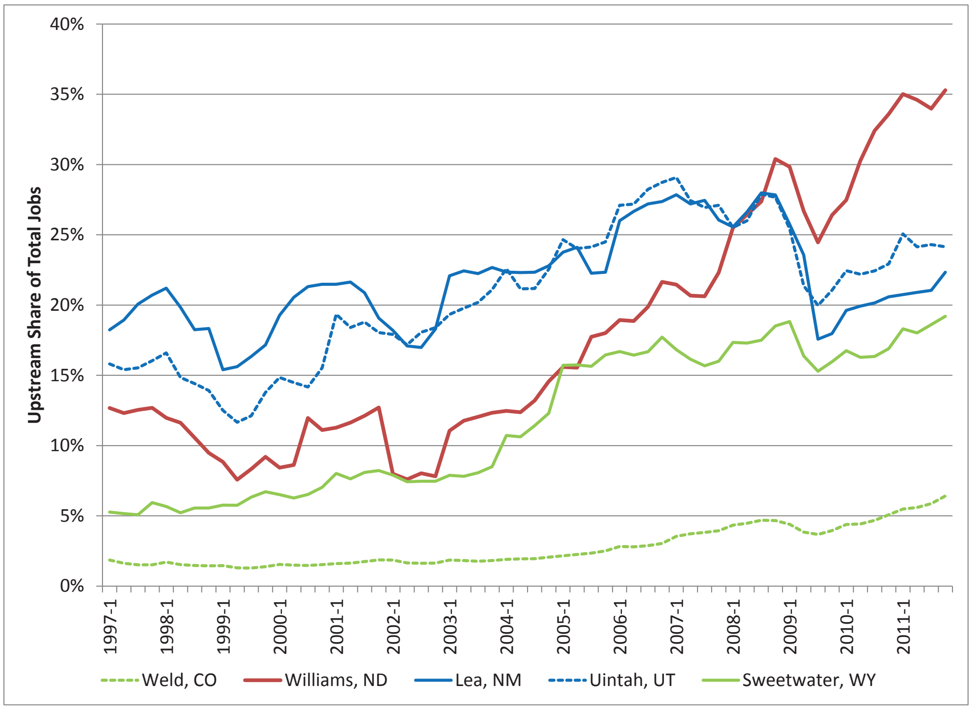
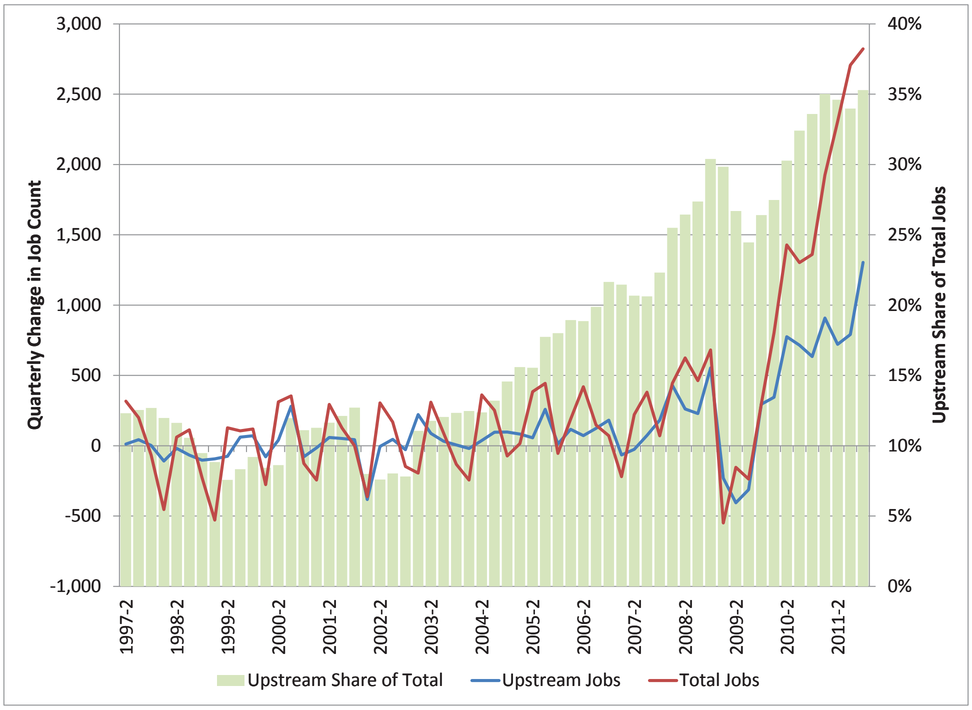


Chart 26

Quarterly Change of Upstream and Total Jobs (along with Upstream Job Share) in Williams County, North Dakota



Source: U.S. Bureau of Labor Statistics

as a share of total jobs. Contrast Weld County, Colorado with the other counties. Weld County had the upstream job count and job growth of many of the other boom counties, but the share of upstream jobs was much smaller. Weld County hosts several sizable cities (Greeley has a population of about 92,000) and is within close driving proximity from the Denver metro area. This type of context matters. The more remote counties can expect to exhibit much more severe infrastructure strain as part of the growth process. Proximity to larger population centers can help ameliorate the strain—a relevant point in the context of the Kansas portion of the Mississippian Lime, since Oklahoma City, Tulsa, and Wichita have close proximity to the current target counties shown on Map 2.

Notice that both the job counts and the job growth illustrated in Chart 24 number in the thousands. Williams County, North Dakota (which has received most of the recent news media attention) represents an extreme case. It has exhibited explosive growth. And it has experience noteworthy infrastructure strains as a result. From 1997 to 2012, Williams County experienced 300 percent growth in its count of total jobs; two thirds of that growth took place from 2010 to 2012. At the beginning of this growth phase, officials estimated the need to build homes for 23,000 new permanent residents—and the utility infrastructure required to service those homes. Before the boom, this area of North Dakota typically experienced at most a few dozen housing starts per year.[54]

Chart 26 illustrates the quarter-over-quarter progression of the growth phenomenon in Williams County, North Dakota. It also reveals some of the growth dynamics related to upstream jobs and total jobs. The steady net growth in upstream jobs eventually triggered enough critical mass to support the growth of a large number of other jobs. To put the Williams County growth into context, consider that, on average, over the period from 1998 to 2010, Kansas has supported about 7,000 upstream jobs. The upstream job growth in Williams County represents the equivalent of the entire Kansas upstream job base rapidly converging on a relatively rural Kansas county like Dickenson County, Seward County, or Sumner County. So far, no evidence indicates that Kansas will experience job count numbers of this magnitude.

The Mississippian Lime activity in Oklahoma offers perhaps the best evidence for setting expectations in Kansas. Essentially, nine counties in north central Oklahoma encompass the Mississippian Lime formation. Table 5 reports the number of horizontal wells drilled in those counties from 2009 through June of 2012. Note that the Oklahoma counties registering the highest count of well completions: Woods, Alfalfa, and Grant, are, respectively, roughly contiguous to the Kansas counties of Comanche, Barber, and Harper, the counties on Map 2 registering the most interest.

Table 5

Horizontal Wells Completed in Oklahoma Mississippian Lime Counties

County	2009	2010	2011	2012*
Alfalfa	1	18	91	70
Garfield	2	3	12	5
Grant	0	2	58	42
Kay	1	4	6	4
Major	1	0	0	0
Noble	0	0	5	4
Pawnee	0	1	2	1
Payne	3	5	9	12
Woods	13	30	40	62
Total	21	63	223	200

*Through June of 2012

Source: Oklahoma Corporation Commission

Two companies dominate the production activity implied by Table 5: Chesapeake Energy and Sandridge Energy. These companies accounted for more than 98 percent of the horizontal well completions in Alfalfa and Woods; with Sandridge completing at least 70 percent of the wells in Alfalfa and Chesapeake completing at least 75 percent of the wells in Woods. Sandridge accounted for at least 85 percent of the wells completed in Grant County.

The price of oil or gas drives drilling. Oil and gas prices collapsed in 2008. Oil prices bottomed-out in 2009 and began to escalate rapidly. Gas prices remained near post-collapse levels. (See Chart 3.) The favorable trend in oil prices helps explain the upward trend in number of wells drilled shown in Table 5—and why a Sandridge executive has made public statements suggesting that the company

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[54] Danny Boyd, "Oil Boom Creates Infrastructure Needs," *The American Oil and Gas Reporter*, February 2011.

may drill as many as 200 wells in Kansas in 2013.[55] Of course, as all veterans of the oil and gas industry know, favorable price trends can quickly turn unfavorable.

The Potential for Infrastructure Strains in Kansas

The drilling operations in the Mississippian Lime play will likely put strains on infrastructure in rural Kansas. In other states, the infrastructure strain from increased horizontal drilling activity has come in two general forms: truck traffic and housing for upstream workers. The truck traffic is unavoidable and will be a function of drilling requirements and the rate at which producers drill wells. The issue of housing accommodations for upstream workers carries more uncertainty; the Kansas locations currently attracting interest from producers with plans to drill horizontal wells are rural but not necessarily desolate. Commuting from urban areas offers options.

Truck traffic has placed a significant burden on the rural roads in North Dakota and certain counties in Texas (related to the Eagle Ford Shale). For example, in North Dakota, each well requires approximately 1,000 truck trips to the well and 1,000 truck trips from the well.[56] The well-drilling activity in Kansas could match those truck numbers for several years. The Mississippian Lime is much more shallow and easier to hydraulically fracture than the Bakken Shale and Eagle Ford Shale. However, the Mississippian Lime produces much more salt water than the shale formations. In the case of shale, producers truck water in; in the case of the Mississippian, producers will likely truck water out—until they become confident enough with the particulars of the Mississippian's production potential to invest in water-related pipeline or disposal-well infrastructure. (However, the CEO of Sandridge Energy has made public statements expressing that company's intention to develop salt water disposal systems ahead of the drilling program, and thereby eliminate or mitigate the need for trucking salt water: "The mystery of the play that was unlocked . . . is that high enough oil prices and drilling a horizontal well that can get enough volume can make money, can have a rate of return. If you have the belief that you can move 3,000 barrels of water a day and get 200 or 300 barrels of oil with it, and do that over a large area, you'd be inclined to go ahead and spend the tens of millions of dollars up front for a water disposal system."[57])

The outlook for the Mississippian Lime play remains uncertain. Success in the Mississippian Lime could lead to hundreds of horizontal wells being drilled each year. But "success" is the operative word.

Disappointing exploration outcomes and shifting economic conditions are an inherent part of the model of high-tech entrepreneurship that characterizes the oil and gas industry. The current explorations in Kansas could disappoint with regard to recoverable oil and gas. Alternatively, the economics of the Mississippian Lime play could change—either in absolute terms (because of, say, a collapse in prices) or in relative terms (because of, say, new plays in other locations with better expected investment returns). The economics matter somewhat more in the Mississippian Lime context than in other shale plays around the country because three companies hold most of the leases related to the Mississippian Lime play; the turnover of activity related to alternative resource-allocation decisions that these three leaseholders might make could be much slower than in regions with dozens of leaseholders and production companies (like the Bakken or Eagle Ford Shale regions).

The "baseline" production scenario described below assumes "success," and defines it in a particular way: the average number of horizontal wells drilled *per quarter* begins at 75 and grows to 300 over a 10-year period. If all of that activity happened to take place in, say, two counties instead of several counties, the road infrastructure in the two counties could experience between 150,000 and 600,000 more truck trips than otherwise. Even if the drilling activity becomes much more dispersed, certain road corridors could act as primary traffic

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[55] Dan Voorhis, "Oil Exec: SandRidge Finding Increasing Success in Horizontal Drilling in Kansas," *Wichita Eagle*, August 20, 1012. http://www.kansas.com/2012/08/20/2456786/oil-exec-sandridge-finding-increasing.html

[56] Danny Boyd, "Oil Boom Creates Infrastructure Needs," p. 2.

[57] Dan Voorhis, "2012 May Reveal Future for Oil in Kansas, *Wichita Eagle*, March 5, 2012. http://www.kansas.com/2012/02/24/2224606/2012-may-reveal-future-for-oil.html

ways. (In the most optimistic scenario contemplated below, the number of wells could increase by 114 percent over the baseline scenario, implying between 320,000 and 1,280,000 more truck trips than otherwise.)

Insufficient housing accommodations have placed stress on municipal government resources in North Dakota and Wyoming. First, upstream activity in both these states required the creation of "man camps," which can lead to increased demand for local government services, especially emergency responders related to health and safety. Second, the relatively high wages paid to the upstream workers can serve to bid up the price of housing, food, and other amenities—thereby increasing the overall cost of living for long-time residents that may not have the resources to bear it.

The demand for temporary housing will depend on many factors. However, the "baseline" production scenario discussed below contemplates 60 workers per well that will require temporary housing accommodations. Combined with the baseline assumptions about the (escalating) number of wells drilled per quarter, localities could experience a demand to accommodate between 4,500 and 18,000 temporary workers per quarter. A change to the scenario assumptions could potentially double those numbers.

Based on Map 2, Barber, Comanche, and Harper Counties have attracted the most intent-to-drill applications. Those three Kansas counties have a combined population of about 12,800. That number is less than the combined number of about 19,000 for the Oklahoma counties of Alfalfa, Grant and Woods. The drilling activity represented in Table 5 indicates that the Oklahoma counties have experience relevant for Kansans. The workforce and infrastructure issues should share similar characteristics.

The clear lesson learned from the experience of other oil and gas boom localities is the importance of planning and working collaboratively—among governments and between governments and industry. The state of Kansas has put in place the foundations of a planning process by forming an Inter-Agency Working Group that includes representatives from the Departments of Agriculture, Transportation, Revenue and Health and Environment; the Kansas Corporation Commission (KCC); the Kansas Water Office; the Attorney General's Office; and the Kansas Housing Resources Corporation. The Group has sent delegates on fact-finding missions to North Dakota and Mississippian-Lime areas of Oklahoma. Local Kansas governments in counties along the Kansas and Oklahoma boarder have also held cooperative planning meetings.[58]

One key element of planning is to clearly delineate roles and responsibilities. For example, says one of the delegate reports: "North Dakota took the position that the government's job is to help plan/facilitate housing, run sewer lines, and lay roads. The role of building new housing stock should be the job of private industry."[59] Cooperative planning between government and business can apply to road infrastructure just as easily as it can apply to housing infrastructure. As the city administrator for Kiowa City, Kansas said in a Kansas-Oklahoma planning meeting: "There is merit in coming together. Oil companies are not the big bad wolf. They are businesses."[60]

Many businesses have learned as much as governments with regard to past oil boom experiences—and choose to take a proactive approach to the known infrastructure issues. For example, Shell Oil, one of the three major leaseholders associated with the Mississippian Lime play, has a policy of proactively coordinating its transportation plans with local government officials. When Shell enters into a new county to conduct it exploration work, company officials meet with the county road and bridge department and county commissioners to explain its business goals and to seek opportunities to work with the county to ensure that both parties interests are considered in the company's business plans. Shell will also work with the road and bridge department within the county to identify the safest routes for Shell's employee's and contractor's vehicles to travel. Shell will then file an approved route map with the county and will require all

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[58] Yvonne Miller, "How to Prepare for and Capitalize on the Oil Boom?" *Alva Review-Courier*, February 8, 2012

[59] http://www.kansascommerce.com/DocumentView.aspx?DID=1057

[60] Yvonne Miller, "How to Prepare for and Capitalize on the Oil Boom?" *Alva Review-Courier*, February 8, 2012

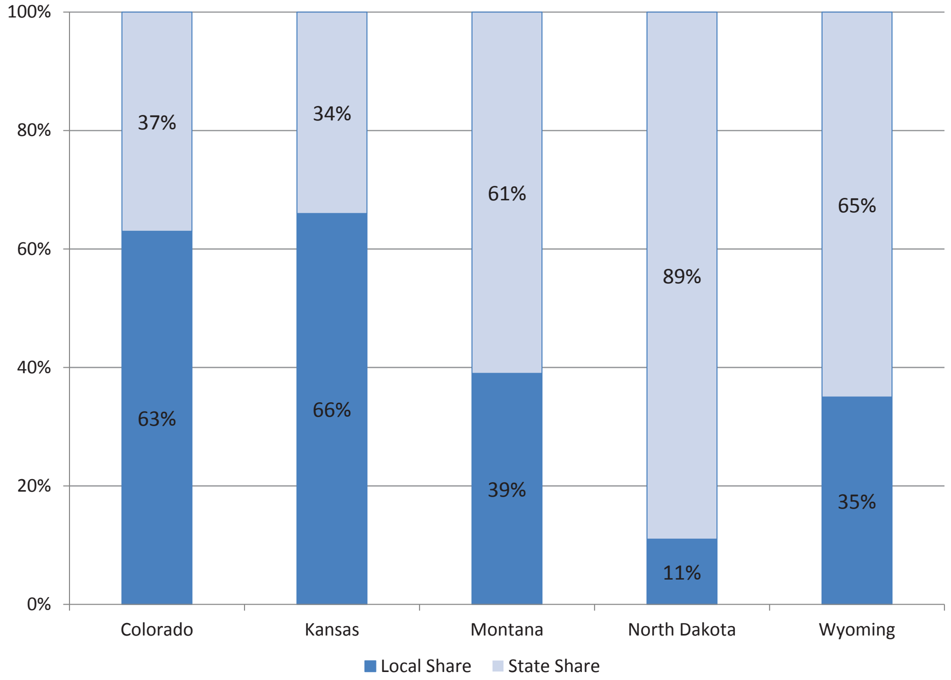
of its employees and contractors to travel only on the approved route. Failure to do so will result in corrective action. If required, Shell will also make safety enhancements to the approved routes to include the addition of safety signage and road/bridge upgrades. Shell regularly follows up with the county to maintain an open channel of communication and to address concerns and unforeseen issues, if they arise. Shell monitors road conditions daily along the approved routes and will work closely with the county to maintain a safe roadway for Shell and the community. If the company negatively impacts a road, the company will work in coordination with the county to repair the road at Shell's cost.[61]

Delineating roles between different jurisdictions of government may be more important than delineating roles between industry and government. Headwaters Economics, a non-profit organization that studies rural economies and land planning issues, has undertaken several studies related to the impact on local communities related to oil and gas booms. A prominent position taken by this group concerns the split between local and state government with regard to oil and gas tax revenue. Since most of the real impact falls under the jurisdiction of local government, Headwaters Economics criticizes fiscal systems that distribute a disproportionate share of tax revenues away from local government toward state government (especially if the state government does not have clear policies related to how it will reallocate the money to local governments, as demand requires).[62]

One news report related to the Eagle Ford Shale in Texas illuminates the importance of the point. In LaSalle County, Texas, heavy truck traffic has severely degraded the county's "farm-to-market" road network. The chief administrator for LaSalle County estimates that upgrading the county's 230 miles of roads to withstand the drilling-related traffic would cost $100 million. Yet the county's entire budget is about $6 million.[63] The worsening road conditions and surge in traffic have caused a

Chart 27

Local versus State Government Shares of Oil and Gas Related Taxes and Royalties, Select States



Source: Headwaters Economics; Center for Applied Economics, KU School of Business

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[61] Author's communication with officials from Shell Oil.

[62] See, for example: "Benefiting from Unconventional Oil: State Fiscal Policy is Unprepared for the Heightened Community Impacts of Unconventional Oil Plays," April 2012. http://headwaterseconomics.org/

spike in traffic accidents in several counties in the Eagle Ford Shale region. Another news report said: "County judges in five counties—Frio, LaSalle, Zavala, Dimmit and Webb—were added to TxDOT's energy task force in May [2012]. The counties hope to have more of a voice in state decisions, including how to get more tax revenue from drilling to pay for road upkeep."[64] (Related: A study focusing on DeWitt County, Texas projected, as an average, that road upgrade costs related to the life of the Eagle Ford Shale could sum to approximately $133,000 per well.[65])

Chart 27 replicates research published by Headwaters Economics, with Kansas added for comparison.[66] Local governments in Kansas retain more oil and gas related taxes than do local governments in the comparison states. Based on the Headwaters Economics metric, local governments in Kansas would seem to have better control over the challenges that may arise from development of the Mississippian Lime. The comparatively sound fiscal arrangement in Kansas—combined with proactive cooperation with producers—should work to smooth the planning process and facilitate better stakeholder cooperation than has existed in other states. (Note that metrics like those promoted by Headwaters Economics, while useful, do not necessarily have a straight forward interpretation. They require a detailed knowledge of a particular state's fiscal system. In Texas, for example, the state government collects the severance tax—but current law dedicates the funds, in part, to the state's Permanent School Fund; in effect, an allocation to "local government." A change in allocation requires legislative approval.[67])

Estimating Potential Economic Impacts in Kansas

In 2011, Governor Brownback and the Kansas Legislature (via SB 198) designated 50 counties as Rural Opportunity Zones. New residents moving into these counties, assuming they meet specific criteria, become eligible for a zero income tax rate for up to five years or assistance paying off student loans. To qualify as a Rural Opportunity Zone, counties had to have experienced population loss of at least 10 percent between the 2000 Census and the 2010 Census. With reference to Map 2, 75 percent of the Mississippian Lime counties also qualify as Rural Opportunity Zones—including the current target counties of Barber, Comanche, and Harper. Combined with the Rural Opportunity Zone policies, the Mississippian Lime could act as a powerful catalyst to the economic development sought by Kansas lawmakers and citizens.

Attempting to estimate the economic impact of the Mississippian Lime play on the state of Kansas requires assumptions related to several uncertainties. For example:

- What percentage of the geography shown in Map 2 will warrant drilling?
- How many wells will producers choose to drill? At what rate will they drill them?
- To date, the primary producers with lease contracts reside outside of Kansas. How many well-related jobs will consist of out-of-state workers versus in-state workers? How much will the out-of-state workers spend on the goods and services offered by Kansas-based businesses?
- How much oil or gas will the average well produce? What percentage of each well's production will consist of oil versus natural gas?
- What price will the oil or gas fetch? Will the price stay high enough to warrant horizontal drilling costs? Will the relative price of oil and gas change in a way that makes other plays more economic than the Mississippian Lime play?

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[63] Ana Campoy, "Drilling Strains Rural Roads," *Wall Street Journal*, July 27, 2012, p. A3.

[64] http://www.mysanantonio.com/news/local_news/article/Drilling-takes-its-toll-on-roads-and-people-s-3690962.php#page-2

[65] http://www.caller.com/news/2012/jul/02/study-shows-one-eagle-ford-shale-countys-road/

[66] "Benefiting from Unconventional Oil: State Fiscal Policy is Unprepared for the Heightened Community Impacts of Unconventional Oil Plays," April 2012, p. 16.

[67] http://www.co.dewitt.tx.us/ips/export/sites/dewitt/downloads/Press_Release_Road_Damage_Cost_Allocation _Study_final.pdf

- What share of the royalty revenue generated from production will circulate in the Kansas economy?
- How much will tax revenues increase as the result of the drilling and production processes?

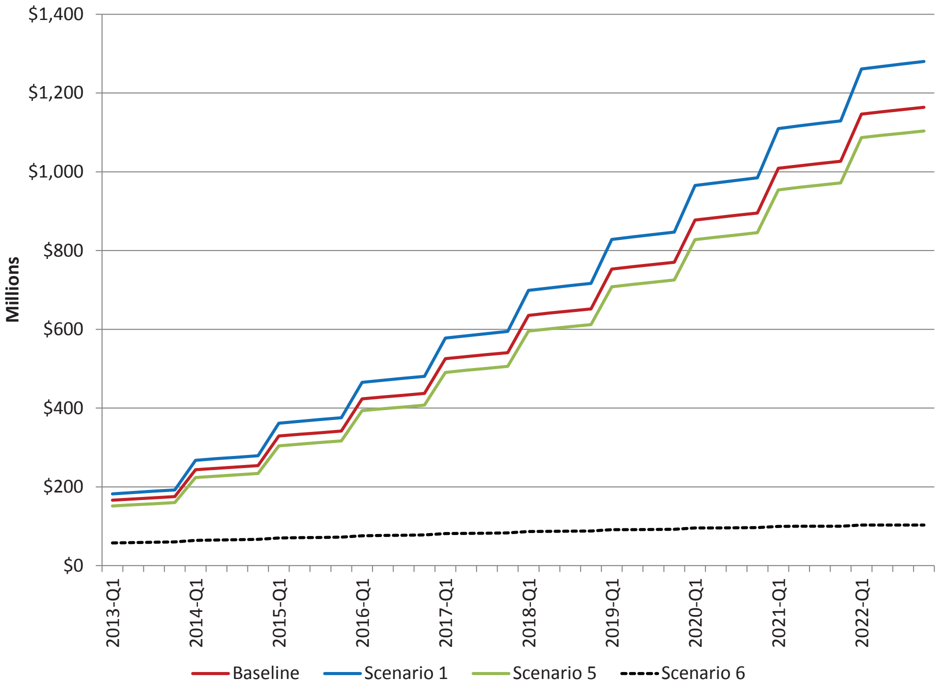
A simulation model developed by the Center for Applied Economics at the University of Kansas School of Business provides some insight into these questions. The discussion below outlines the framework and the results related to select scenarios. Appendix A offers additional details about the simulation model and the economic impact estimation procedures.

The simulation model, which reports inputs and outputs on a quarterly basis, begins with the following Baseline Scenario (which is based on 10 calendar years, beginning in January of 2013 and ending in December of 2022):

- In 2013, producers will drill 75 wells per quarter. Each year, the number of wells drilled will increase by an average of 25 per quarter. So, producers will drill 100 wells per quarter in 2014, 125 per quarter in 2015, and so on until the pace reaches 300 per quarter in the last scenario year of 2022. This step change implies a total of 7,500 wells—less than half the projected number of potential wells (see Appendix A).
- Because out-of-state companies currently control most of the leases related to the horizontal Mississippian Lime play, the baseline number of Kansas-based well-drilling jobs begins at zero in 2013 and grows by 2.5 percent each year, implying that 22.5 percent of well-drilling jobs will be Kansas-based jobs by 2022. (A Kansas-based job is one in which the income earned can be legitimately counted as belonging to a Kansas resident. Jobs executed in Kansas by residents of another state do not count as Kansas-based jobs.)
- The Baseline Scenario—and every other scenario—assumes a total of 60 drilling-related jobs per well, with each well taking one month to complete.

Chart 28

Growth of Kansas Income Resulting from Select Scenarios Related to the Mississippian Lime Play



Source: Center for Applied Economics, KU School of Business

- All jobs not considered Kansas-based jobs assume a per diem per worker of $125 per day. The hotel sector of the Kansas economy receives $100 per day from each out-of-state worker and the restaurant sector receives $25 per day. The expenditures equal new economic activity that would not occur without the horizontal-drilling Mississippian Lime play.
- The Baseline Scenario assumes that each well supports 80 jobs related to the construction sector of the economy. It counts 100 percent of these jobs as Kansas-based jobs.
- The Baseline Scenario sets the price of oil at $90 per barrel and sets the price of natural gas at $3.50 per thousand cubic feet. Additionally, it sets the production from each well at 55 percent oil and 45 percent natural gas.
- The Baseline Scenario assumes that 100 percent of the royalties earned from each well will remain in Kansas as Kansas-based income. It sets the royalty rate at 20 percent of the production value from each well.

To build intuition about how changes to particular variables will influence the economic impact of the Mississippian Lime play, a description of six scenarios follows. Each scenario makes a 10 percent change relative to the baseline level of one particular variable. The scenario numbering scheme ranks them from the most positive to the least positive economic impact relative to the Baseline Scenario.

Chart 28 illustrates how the Baseline Scenario, Scenario 1, Scenario 5, and Scenario 6 would influence the growth of aggregate Kansas income. Each scenario except Scenario 6 assumes a steady increase in the pace of well drilling. Scenario 6 offers one definition of a pessimistic scenario: it includes all elements of the Baseline Scenario, except that the pace of well drilling equals 25 wells per quarter for 10 years.

The Baseline Scenario would add an additional $166 million to the Kansas economy in the first quarter of 2013. As producers drill an annually-increasing number of wells (in stepwise fashion as per assumption) and market the oil and gas, Kansas income begins to accumulate each quarter. By the first quarter of 2022, the direct jobs, indirect jobs, and royalties associated with the Mississippian Lime play contribute about $1.15 billion each quarter to total Kansas income. Scenario 1 escalates income growth more quickly than the Baseline Scenario and adds about $1.3 billion to Kansas income by the first

Table 6

Economic Impact Metrics Resulting from Select Scenarios Related to the Mississippian Lime Play (Dollars in Millions)

		Scenario					
Performance Metric	**Base**	**1**	**2**	**3**	**4**	**5**	**6**
Avg. Increase in In-State Job Count per Quarter	1,908	2,100 (1,717)	1,954 (1,863)	1,930 (1,886)	1,886	1,790	161
Avg. Increase in In-State Income per Quarter	$29.0	$31.8 ($26.0)	$29.7 ($28.1)	$29.4 ($28.4)	$28.4	$27.4	$2.5
Avg. Increase in State Severance Tax per Quarter	$4.4	$4.9 ($4.0)	$4.4 ($4.4)	$4.9 ($4.0)	$4.4	$4.4	$0.40
Avg. Increase in O&G Property Tax per Quarter	$42.8	$47.1 ($38.6)	$42.8 ($42.8)	$47.3 ($38.4)	$42.8	$42.8	$3.6
Avg. Increase in Other State & Local Taxes	$3.6	$3.9 ($3.3)	$3.7 ($3.5)	$3.7 ($3.6)	$3.6	$3.4	$0.31

Source: Center for Applied Economics, KU School of Business
Notes: Oil and gas property tax calculations follow the Kansas Department of Revenue protocols using a discount rate of 15% and an average annual operating cost per well of $500,000 in year one; $250,000 in year two; and $125,000 thereafter. The property tax calculations also assume 140 total mills, which is the average total mills levied within the Mississippian Lime counties identified in Map 2 from 2005 to 2010. Estimates for Other State & Local Taxes exclude state corporate income taxes and property taxes levied on properties classified as commercial/industrial due to unmanageable estimation uncertainties.

quarter of 2022. Scenario 6 escalates income growth less quickly than the Baseline Scenario and adds about $1.0 billion to Kansas income by the first quarter of 2022. Scenarios 2 and 3 fit between the Baseline Scenario and Scenario 1. Scenario 4 fits between the Baseline Scenario and Scenario 5.

By design, Scenario 6 is a significant outlier. It basically assumes that the Mississippian Lime play will gain no more drilling-related momentum than it has experienced to date. A "slow" pace of drilling is the best way to quantify the economic impacts associated with a pessimistic scenario (regardless of why that outcome occurs). Scenario 6 adds about $58 million to the Kansas economy in the first quarter of 2013. By the first quarter of 2022, the direct jobs, indirect jobs, and royalties associated with the Mississippian Lime play contribute about $103 million each quarter to total Kansas income. (A complete abandonment of horizontal drilling related to the Mississippian Lime play would result in zero economic impact.)

Table 6 reports additional information related to the economic impact of each scenario. To help facilitate comparisons among the scenarios, Table 1 reports average increases per quarter for the various metrics. (Note from Chart 28 that each year produces a significant step change because of the assumption about how the pace of change in well drilling takes place. The major step change in each year is a straightforward part of the calculated 10-year quarterly average.) Each scenario has a linear character based on a 10 percent change, so the reader can adjust the average quarterly change upward or downward in proportion to different rates of change in the variable. For example, with regard to Scenario 2, a 10 percent increase in the growth rate of in-state drilling jobs results in a quarterly-average job count that is 2.3 percent higher than the baseline count and a quarterly-average income accumulation that is 2.8 percent greater than the baseline accumulation. An additional 10 percent increase in the growth of in-state drilling jobs will double the percent changes from baseline—or, put another way, a 20 percent increase in in-state drilling jobs would increase the quarterly-average job count by 4.6 percent higher than baseline count and a quarterly-average income accumulation that is 5.6 percent greater than the baseline accumulation. (The variables will interact if one assumes that they change simultaneously. However, as a rough approximation, adding the quarterly averages for each variable will provide intuition about how different combinations of variables and different growth rate assumptions will contribute to the overall economic impact.)

Scenario 1: *Increase (decrease) the pace of well drilling by 10 percent per year from baseline.*

Not surprisingly, the pace of well drilling generates the largest (positive or negative) economic impact of the six scenarios, relative to the Baseline Scenario. Well drilling supports jobs (directly and indirectly) and generates income from royalties and business profits. The stream of royalty incomes and business profits, in turn, support additional jobs and business profits as it circulates in the Kansas economy. The income generated from jobs, commerce, and production supports additional tax revenue for state and local government.

Scenario 1 (a 10 percent increase in wells drilled) results in 8,250 wells drilled relative to the baseline level of 7,500 (a 10 percent decrease results in 6,750 wells). As explained in Appendix A, however, the Mississippian Lime might yield a projected maximum number of 16,069 horizontal wells. If true, in the context of the scenario framework, that would imply a 114 percent rate of increase in the number of wells drilled. Such a rate of increase would roughly double the figures reported in Table 6.

Scenario 2: *Increase (decrease) the pace of Kansas-based drilling jobs by 10 percent per year from baseline.*

The second-place rank of this scenario (based on job and income growth) underscores the point that job creation drives the economic impact estimates more than the royalty income generated by production. This scenario, relative to Scenario 1, also helps to illustrate another (obvious) point: the incomes generated by job creation helps support Other Taxes but production value drives Severance Taxes and Oil and Gas Property Taxes.

Scenario 3: *Increase (decrease) the baseline price of oil and gas by 10 percent.*

This scenario ranks third in economic impact from an overall job count and income perspective. However, it has roughly the same impact as Scenario 1 from the perspective of Severance Taxes and Oil and Gas Property Taxes, underscoring the importance of market prices for Kansas producers and Kansas governments.

Related to oil and gas property taxes, the table below provides estimates for the assessed value implied by the simulations model's representative well for three different prices: the baseline price of $90 per barrel of oil and $3.50 per thousand cubic feet; the baseline price plus 10 percent; and the baseline price minus 10 percent. The reader can use these estimates to calculate the property tax revenue potential per well in a specific taxing jurisdiction.

	Baseline	+10%	-10%
Year 1	$428,337	$468,066	$380,208
Year 2	352,672	385,651	312,778
Year 3	294,252	322,018	260,715
Year 4	240,319	263,275	212,651
Year 5	189,086	207,470	166,994
Year 6	141,137	155,244	124,263
Year 7	96,803	106,954	84,753
Year 8	56,852	63,438	49,150
Year 9	21,845	25,310	17,954

Scenario 4: *Decrease the royalties that remain in state by 10 percent from baseline.*
This scenario, relative to the Baseline Scenario, illustrates the relatively small jobs impact that royalty income generates in the economic impact simulation.

Scenario 5: *Decrease the Kansas-based construction-related jobs per well by 10 percent from baseline.*

As discussed in connection with Scenario 2, job creation generates the strongest economic impact. The more well-drilling jobs and well-support jobs that become Kansas-based jobs, the more the overall Kansas economy will benefit from the Mississippian Lime play.

Scenario 6: *Hold wells drilled to 25 per quarter for 10 years (and retain all other Baseline Scenario assumptions).*

As discussed above, this scenario is intended to illustrate that the Mississippian Lime play may not fulfill the optimistic expectations held by many stakeholders. Producers in Oklahoma have reported successful outcomes—and Sandridge Energy has publicly communicated with potential investors that the Kansas geology holds similar promise. But the Kansas-based activity still needs to prove itself.

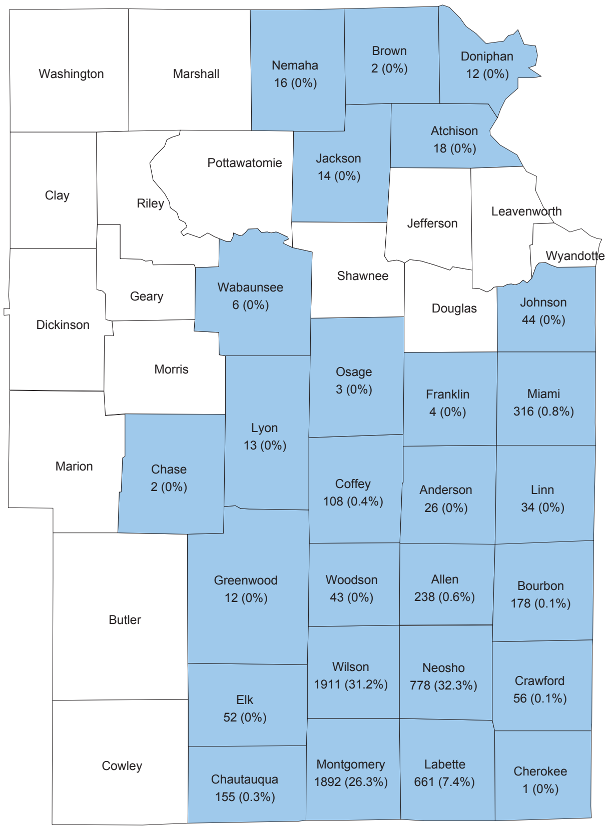
COALBED METHANE IN EASTERN KANSAS

The well-known phrase "canary in a coal mine" derived from the known hazards of noxious gas that could imperil coal miners. Miners would carry caged birds into mines with them. If harmful gas filled the air, the birds would succumb before the miners, providing a warning signal.

Methane (and other gases) enters coal through a process of absorption. The gas lines the pores of the coal in a near-liquid state.[68] The gas often leaks from naturally-occurring fractures in coal formations.

Map 3

Coalbed Methane Activity in Eastern Kansas, Wells Drilled (Share of Cumulative Production)



Source: Kansas Geological Survey

Chart 29

Kansas Coalbed Methane Wells Drilled and Kansas Natural Gas Price, 1981-2011

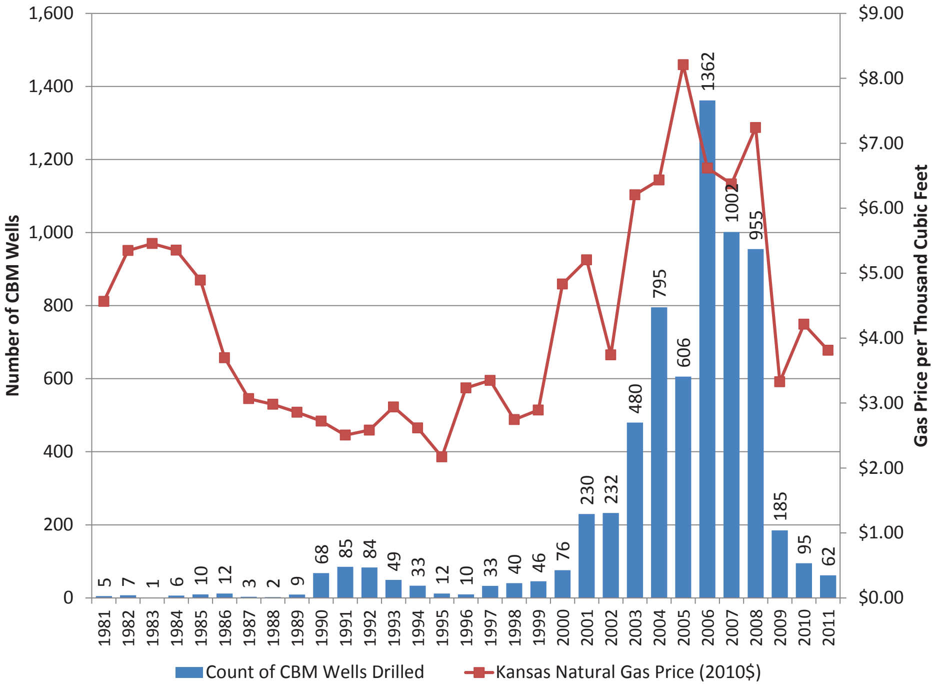
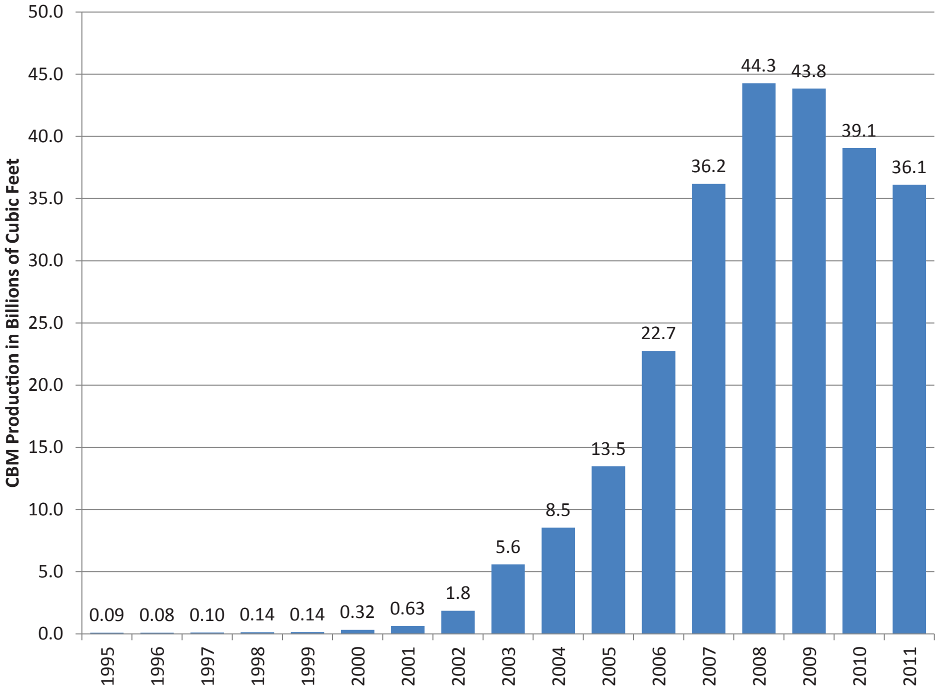


Chart 30

Kansas Coalbed Methane Production, 1995-2011



Source: Kansas Geological Survey; Independent Oil & Gas Services (Red Top News); U.S. Energy Information Administration

Coalbed methane, or CBM, counts as an "unconventional" hydrocarbon source because producers must access it in ways technically different from (and typically more costly than) the techniques used to produce natural gas from "conventional" source rocks (like sandstone). Coal has much lower permeability than conventional source rocks. A significant element of stimulating gas production deals with dewatering the coalbed to relieve the pressure that traps the gas in the pores of the coal.

Two coal basins—known as the Forest City and Cherokee basins—lie underneath the eastern quarter of the state of Kansas.[69] With reference to Map 3, the Forest City Basin generally encompasses the upper half of Coffey, Anderson, and Linn Counties and the counties north of those; the Cherokee Basin generally encompasses the counties south of those. (A formation known as the Boubon arch overlaps the two basins.) These basins contain many different strata of coal of varying depths and breadths. A typical wellbore can encounter up to 14 different coal beds, each of which may yield methane.[70] According to geologists at the Kansas Geological Survey: "The gas storage capacity of a coal is a complex function of reservoir temperature and pressure, composition, micropore structure, and molecular properties of its absorbed gas."[71]

The historical record indicates that producers in southeastern Kansas had some commercial success with CBM production from the 1920s into the 1930s.[72] Despite this early record of success, the CBM resource did not attract serious attention until the 1980s. The Kansas Geological Survey only has records of CBM wells dating back to 1981. This date marks the beginning of a federal government tax incentive related to CBM production from new wells, which operated until 1992. The federal government extended the tax incentive from 1993 to 2002—but the extended incentive applied to gas produced from "recompleted" wells rather than new well.

Map 3 illustrates that four counties within the Cherokee Basin—Labette, Montgomery, Neosho, and Wilson—account for about 80 percent of the CBM wells drilled and about 97 percent of the cumulative production. However, exploration has taken place in all of the blue-colored counties on the map.

Chart 29 and Chart 30 reveal that, although interest in CBM dates back to 1981, notable progress with developing this resource did not begin until about 2000. The uptick in drilling activity in the early 1990s seems coincident with the up-coming termination of the federal tax credit program. Not surprisingly, the most concerted effort coincides with the escalation of natural gas prices. (However, a substantial amount of learning no doubt accrued in the two decades prior to the price escalation that allowed Kansas producers to confidently respond to the price signals.[73]) The rapid escalation in drilling illustrated by Chart 29 had an obvious outcome on the amount of annual coalbed methane production shown in Chart 30. For perspective, despite the impressive boom in the cumulative production of coalbed methane, it amounted to 9.4 percent of total natural gas production over the 2005-to-2011 time period, with the highest percentage equaling 12.2 percent in 2009.

The U.S. Energy Information Administration tracks coalbed methane production among the states. Records for most states begin in 2005. However, the records for three states begin in 1989: Alabama, Colorado, and New Mexico got a head start in meaningful CBM production. Despite the head start, those states' production seems to have peaked. Alabama's CBM production peaked in 1998; Colorado's in 2002; and New Mexico's in 1997.

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[68] http://en.wikipedia.org/wiki/Coalbed_methane

[69] K. David Newell, et al., "Geological and Geochemical Factors Influencing the Emerging Coalbed Gas Play in the Cherokee and Forest City Basins in Eastern Kansas," Kansas Geological Survey, Open-File Report 2004-17. http://www.kgs.ku.edu/PRS/publication/2004/AAPG/Coalbed/P1-02.html.

[70] K David Newell, et al., "Coalbed Gas Play Emerges in Eastern Kansas Basins," *Oil and Gas Journal*, December 23, 2002, p. 36.

[71] *Ibid*., p. 37.

[72] William T. Stoeckinger, "Kansas Coalbed Methane Comes on Stream," *Oil and Gas Journal*, Vol. 88, No. 23, June 1990, 88-90.

[73] K. David Newell, "Communications from Individuals Regarding Their Role in the History of the Coalbed Natural Gas Play in Eastern Kansas, circa 1990 to 2010," Kansas Geological Survey, Open-File Report 2010-15, November 17, 2010. http://www.kgs.ku.edu/PRS/publication/2010/OFR10_15/KGS_OFR_2010-15.pdf

Table 7 reports the cumulative production for those states with records of CBM production. Colorado, Wyoming, and New Mexico produce significantly more CBM than the other states. By the U.S. Energy Information Administration's reckoning, Kansas ranks 8th out of 13 states. (The EIA figure of 211 bcf contrasts with the figures reported in Chart 30, which sum to 200 bcf.)

Table 7

State-by-State Cumulative Coalbed Methane Production, 2005-2010, Billions of Cubic Feet

State	Cumulative Production 2005-2010	Share of U.S. Cumulative Production 2005-2010
Alabama	655	5.95%
Arkansas	17	0.15
Colorado	3,039	27.62
Kansas	211	1.92
Louisiana	2	0.02
Montana	73	0.66
New Mexico	2,695	24.49
Oklahoma	377	3.43
Pennsylvania	43	0.39
Utah	422	3.84
Virginia	531	4.83
West Virginia	149	1.35
Wyoming	2,789	25.35
U.S.	11,003	100.0%

Source: U.S. Energy Information Administration

Scientists at the Kansas Geological Survey estimate that the coalbeds of Kansas may contain about one trillion cubic feet of natural gas.[74] At the rate of production shown in Chart 30 for 2008 and 2009, Kansas could produce coalbed methane for about 22 years. However, based on current economics, as suggested by the pattern of drilling and production illustrated by Chart 29 and Chart 30, natural gas prices need to be at least $5.00 per thousand cubic feet for this level of production to sustain itself.

ASSESSING HISTORY: HOW THE OIL AND GAS INDUSTRY HAS CONTRIBUTED TO THE KANSAS ECONOMY

Entrepreneurial success often results from serendipity. New value propositions frequently emerge through accidental discoveries about how to create value for people. Native Americans had long attributed healing properties to the petroleum that seeped out of the ground. But no one attributed to it much commercial potential except as a medicine until around 1850s. People used whale oil to light their lamps. In fact, about 1830, an enterprising Johnson County man had a successful business helping to supply pioneers heading out on the Santa Fe Trail. The slick sheen of petroleum on the water in his well disappointed him—because he thought of value as supplying fresh water—until he discovered that he could sell the slick stuff as lubricant for wagon wheels.[75]

The oil industry began as the result of similar serendipity—serendipity related to the mining of salt. Salt had a known commercial value, and the production of salt from salt water wells had an annoying byproduct in northwestern Pennsylvania: petroleum seepage. A man named Samuel Kier had to dispose of the petroleum that seeped into his salt well. When he discovered that it caught fire, his entrepreneurial urges drove him to experiment with various petroleum-based products. Petroleum jelly (an ointment used in a medicinal manner familiar to Native Americans) remains with us today, but it did not sell well then. Kier's development of a cost-effective method for producing kerosene had more success. Kerosene became an excellent substitute for whale oil as a lamp fuel. In 1853, in order to market kerosene, Kier created the first oil refinery, which he located in Pittsburg, Pennsylvania, and refined the oil gathered from area salt mines.[76]

The commercial potential of kerosene motivated people to search for oil for its own sake. A man named Edwin Drake (along with a technically competent assistant named "Uncle Billy" Smith) had the idea that the methods used for salt water well drilling could be used for oil well drilling. He was partly right. The problem came when the wells would fill with water and collapse. He innovated by first driving an iron pipe to the bedrock and then drilled inside the pipe to prevent collapse. It worked—and the technique became a standard feature of drilling operations—the same feature (dramatically

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[74] Private conversation with Dr. David Newell of the Kansas Geological Survey.

[75] Craig Miner, *Discovery!* (Wichita, Kansas: KIOGA, 1987), p. 13.

[76] http://en.wikipedia.org/wiki/Samuel_Martin_Kier

advanced) that also protects drinking water supplies during current-day drilling operations. Historians typically credit Drake as drilling the nation's first commercial oil well in Titusville, Pennsylvania in 1859.[77] The first shipment of oil from that well reportedly went to Samuel Kier's refinery in Pittsburg.[78]

The success of Drake's drilling method and Kier's marketing innovations drew people into the oil industry. The first oil boom happened in northwestern Pennsylvania from 1859 to 1870.[79] Talented men began to learn the risks and rewards of the oil business.

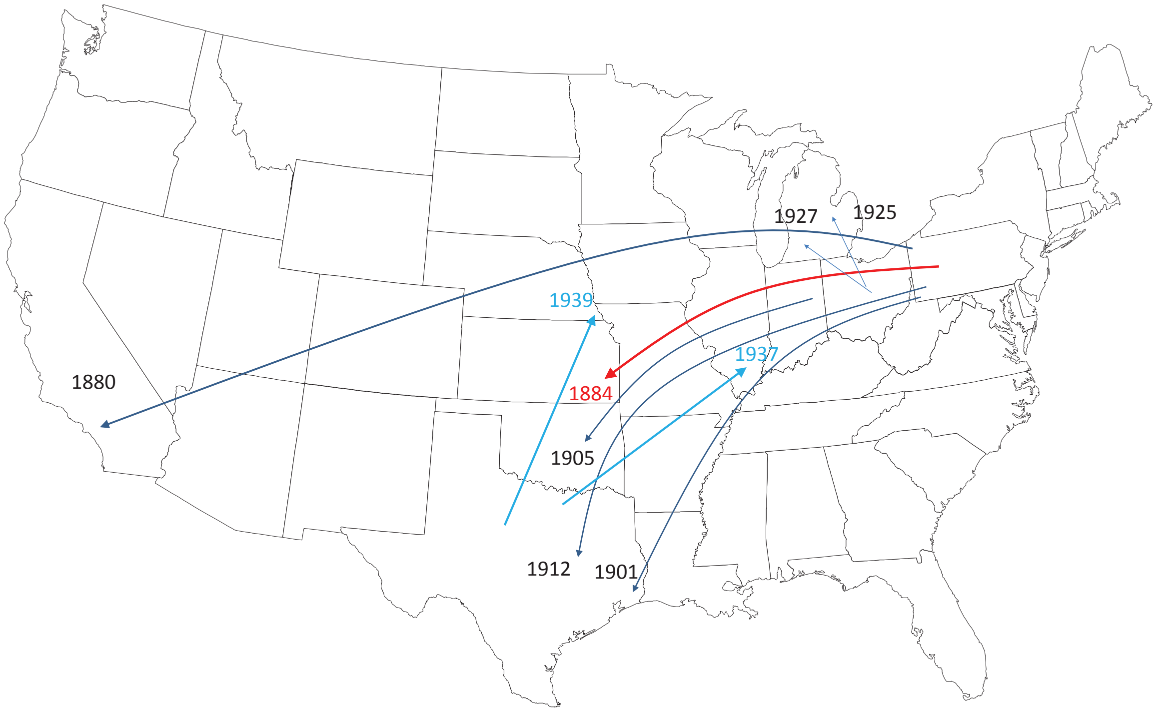
A Brief Economic History of Oil and Gas in Kansas

Map 4 shows that those talented men began to migrate to other oil-rich locations—Kansas being among the first. Oil entrepreneurs knew Kansas had potential because the first attempt at drilling for oil in Kansas occurred near Paola, Kansas in 1860.[80] By the mid-1860s, Fort Scott, Kansas had become one of the state's first "boom" towns, and began piping natural gas to homes.[81]

George W. Brown, editor of a Lawrence, Kansas newspaper known as the Herald of Freedom, became a key figure in early Kansas oil and gas history. He had come to Kansas in 1854 from Pennsylvania where he had edited a newspaper. Brown's Pennsylvania roots and connections gave him a keen awareness of the seminal oil activity taking place there, and he understood what it implied for Kansas. Brown organized the drilling of the Paola well in 1860, along with many other wells thereafter.[82]

Map 4

Major Migrations of Oil Men



Source: Samuel W. Tait, Jr., *The Wildcatters: An Informal History of Oil-Hunting in America*, p. xiv.

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[77] http://en.wikipedia.org/wiki/Edwin_L._Drake

[78] http://en.wikipedia.org/wiki/Samuel_Martin_Kier

[79] http://en.wikipedia.org/wiki/Pennsylvanian_oil_rush

[80] Miner, *Discovery!*, p. 16.

[81] *Ibid*., p. 47

William M. Mills came to Kansas from Pennsylvania in 1884 (the man represented by the arrow on Map 4). His central role in the successful development of Kansas oil and gas fields earned him the respectful moniker: "the Drake of the western field."[83] Mills had all the attributes of an iconic entrepreneur and pioneer. He made and lost a fortune in Pennsylvania before he decamped to eastern Kansas to put in the grinding due-diligence and relationship-building necessary to rebuild the fortune he lost. Before ultimately settling in the town of Paola, Mills (and his wife) explored as far west as Salina and as far south as Coffeyville. He became as knowledgeable as anyone at the time about oil and gas prospects in Kansas.

Mills' explorations and partnerships facilitated the iconic status of two other partnerships in Kansas petroleum-industry history: McBride & Bloom and Guffey & Galey. Albert McBride (Miami County) and Camden Bloom (Montgomery County) were two Kansas boys that, despite their youth, had proficiency in the art and science of well drilling. They became the contractors of choice in their era; and drilled Norman #1 (in Neodesha in 1892), which, according to the National Historic Landmarks Program, signifies the beginning of development of the Mid-Continent oil field.[84] Mills made the acquaintance of James Guffey and John Galey while in Pittsburg, Pennsylvania on a trip to recruit venture capital partners. Guffey and Galey had wildcatter blood in their veins and seized the opportunity. As Kansas petroleum industry historian Craig Miner put it: "Guffey and Galey had more than experience: they had also the daring necessary to plunge into Kansas without hesitation. The two were described as 'extensive and daring operators' in the Pennsylvania field, and there was no question that their vision and determination corresponded well with Mills' own. An observer at the time commented of the association between Mills, Guffey, and Galey that 'These men, taken together, were the embodiment of American vigor and push.'"[85]

Natural gas had a better commercial market than oil when Mills got started in Kansas. Town people understood the utility of gas for lighting, cooking, and heating (both residentially and industrially). But Mills and his associates systematically (and relatively inexpensively) acquired land leases and drilled oil wells, often plugging them once they discovered oil-producing wells.

Of course, Mills and associates were not alone; many other entrepreneurs had entered the business. However, the overall development of the market took place slowly. Producers faced a chicken-and-egg problem. Commercially viable oil production required an infrastructure; infrastructure required commercially viable oil production.

The arrival of John D. Rockefeller's Standard Oil (via its Forrest Oil subsidiary) in the mid-1890s, which bought holdings from Guffey and Galey, resolved the chicken-and-egg problem. It brought investment capital, access to markets, industry know-how, and plans to build a refinery in Neodesha (1897), which ended up refining about 3,000 barrels a day by 1903.

The result was "the boom of 1903." Craig Miner's description of the boom in 1903 sounds just like stories about Williston, North Dakota in 2012. (Multiply each dollar figure in Miner's description by 25 to approximate today's dollars.) [86]

> The growth of towns in the oil and gas belt seemed magic. Iola built some of the largest gas engines in the world in 1903, boasted one of the most complete cement plants west of the Mississippi, the largest number of zinc smelting retorts in the U.S., and probably the only sulphuric acid works in the world where natural gas was used in the reduction. In six years, Iola had grown from 1,500 to 10,000 and had a monthly payroll of $100,000. It was constructing an $80,000 water works and an electric light plant, and had a $150,000 electric interurban running

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[82] *Ibid*., p. 14.

[83] *Ibid*., p. 32.

[84] http://en.wikipedia.org/wiki/Norman_No._1_Oil_Well

[85] Miner, *Discovery!*, p. 38.

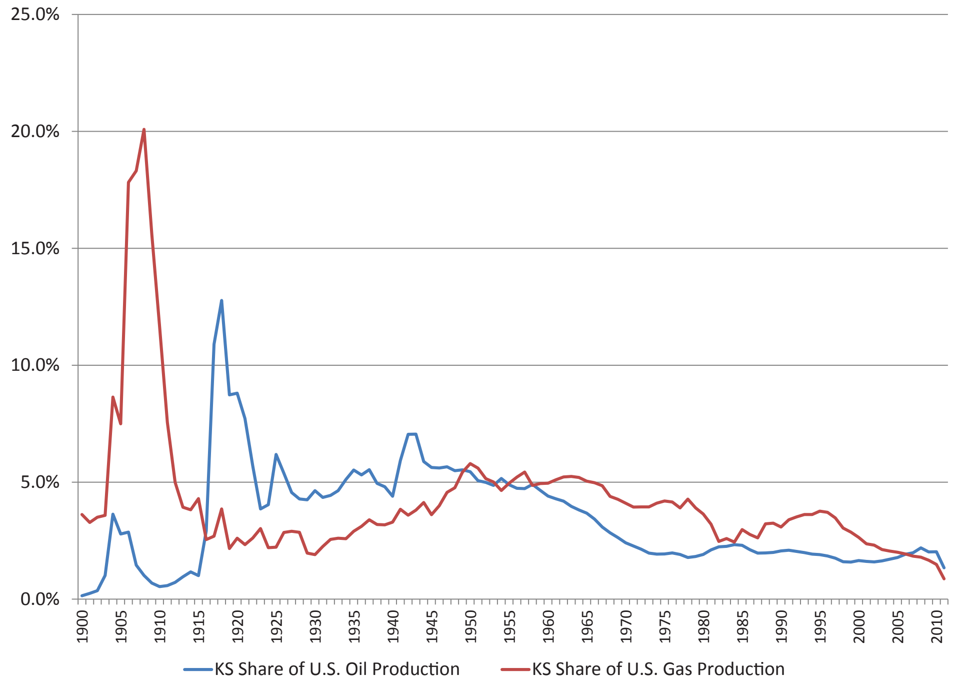
[86] http://www.minneapolisfed.org/community_education/teacher/calc/hist1800.cfm

from the Neosho River through Iola and on to Gas City, Lanyonville and LaHarpe. Manufacturing included an ice plant and cold storage company with a daily capacity of 50 tons, an iron foundry, a planning mill, a creamery, flour and feed mills and a saw mill. Independence in 1903 opened the Carl-Leon Hotel at a cost of $50,000 for the building and $15,000 for the furnishings. It had a spacious office complete with a massive fireplace of Independence bricks, fired using the town's natural gas, and rooms equal to anything in Kansas City. There were electric bells in the Carl-Leon, fire alarms, bell boy service and reading and writing rooms. Chanute in 1903 established a stock exchange at the Hetrick opera house, primarily to aid promoters in placing the stock of new oil companies. Oil roads and electric traction lines into the oil fields were suggested daily. All this, most thought, was courtesy of oil and gas combined with the "energy and hustle of fore-sighted businessmen" who could see that "there are other very good opportunities for making money in the Kansas gas and oil field apart from getting it from under the surface of the ground."

Economic statistics seemed like fantasy. In 1905, it was estimated that the oil and gas industry had added $50 million to the value of Kansas property. It had "doubled the population of nearly every town in the oil region and brought many men of national reputation in the field of finance within her borders. The industry has transformed an agricultural state into a commercial and industrial empire." In November, 1903, there were 200 drilling rigs at work in Kansas, manned by 400 drillers and 400 tool dressers. Supply houses serving the Kansas oilpatch were making $200,000 a month, and hotel receipts in the Iola area were about $500,000 a year…[87]

Chart 31

Kansas Oil and Gas Production as a Share of U.S. Production



Source: Kansas Geological Survey; U.S. Energy Information Administration

Chart 31 illustrates the 1903 booms in Kansas in the context of the central role Kansas played in the birth of the U.S. oil and gas industry. As a share of U.S. production, natural gas grew from 3.5 percent to 8.6 percent and oil grew from 0.4 percent to 3.6 percent. (Table 8 provides additional details about the time line of key events influencing the movement of the curves in Chart 31.)

The gas share kept growing because the year 1903 foreshadowed another major Kansas oil boom—much more substantial than the first, illustrated by Chart 31 as the oil production boom starting in 1915. In 1903, four businessmen in Augusta, Kansas met to discuss the prospect of drilling for gas in order to heat and light the city. To execute their plans, they formed the Augusta Oil, Gas, Mining and Prospecting Company. A rig builder and tool dresser recently recruited from Ohio to Kansas got the business to drill a well. In July of 1903, the crew hit gas at 1,356 feet.[88]

Another entrepreneurial effort born of the new-found understanding of how to create commercial value from natural gas helped advance the industry in Kansas. Much like Rockefeller's insight that the oil industry could benefit from disciplined management in a consolidated holding structure, a man named Henry L. Doherty began to acquire many dozens of city gas services under the company name of Cities Service. Such an operation required reliable supplies of gas. Mr. Doherty invested in trained geologists to help. A geologist named Charles Gould (with a partner) took on the task in 1913 of exploring around the existing gas pipelines in Butler County, Kansas. They produced a scientifically detailed, color-coded contour map that represented an important innovation at the time.

Table 8

Select Events in Early Kansas Oil & Gas History

1860	First oil well drilled near Paola (Miami County)
1873	Gas discovered at Iola (Allen County)
1886	Small refinery erected at Paola
1892	First commercial well (Norman #1) at Neodesha (Wilson County)
1897	Standard Oil refinery completed at Neodesha
1903	First 1,000 barrel/day well, Bolton field (Montgomery County)
1914	Discovery of Augusta field (Butler County)
1915	Discovery of El Dorado field (Butler County)
1917	Discovery of "Golden Lanes" (Greenwood County)
1922	Discovery of Hugoton gas field (Seward County)
1923	Discovery of Fairport field (Russell County)

Source: Daniel F. Merriam, "Exploring for Petroleum in the Flatlands: History of Oil and Gas Exploration in Kansas," *Oil-Industry History*, Vol. 3, No. 1, 2002, p. 56.

As with so many technological advancements, the skeptics abounded initially (Cities Service directors among them).[89] But the science behind the color-coded maps worked—beginning the long process discussed above related to innovations that worked to minimize the drilling of dry holes. The science found the gas—and it found the oil (which had a lower priority at the time).

In 1914, the city fathers of El Dorado decided that they wanted to drill for the city's own gas source. After some false starts, the new geological science worked in El Dorado just as it had worked in Augusta. In 1915, crews had discovered oil in a well called Stapleton #1. No one realized it at the time, but they had discovered one of the largest pools of oil in the continental United States.

The El Dorado boom commenced—aided strongly by the demand for oil generated by World War I. Leases in El Dorado reached $3,750 per acre. (In today's dollars, that would be 25 to 30 times more than current-day leases fetch in relation to the Mississippian Lime play!) The population of Butler County exploded, increasing from 23,059 in 1910 to 43,842 in 1920, with most of the surge happening after 1915.

Historian Craig Miner provides the following account from a contemporary writing in the advanced stages of the El Dorado oil boom, which significantly aided the war effort: "Standing on an eminence at the western edge

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[87] Miner, *Discovery!*, pp. 93-94.

[88] *Ibid*., p. 120.

[89] *Ibid*., pp. 120-123.

of the city, the spectator can look for miles at an endless field of derricks set out in rows with all the regularity of a new apple orchard. Up hill and down hill, the rows run until they are lost in the distance. As a matter of fact, there are more than a thousand derricks in sight, each one pumping from mother earth the liquid that is destined to play the biggest part in reclaiming the world for democracy."[90]

Chart 32 converts the production data illustrated in Chart 21 (and implied by Chart 31) into inflation-adjusted dollars based on production volumes and prevailing prices. Kansas offered an excellent platform from which to initiate the oil boom in the Mid-Continent because much of the gas and oil resided in relatively shallow depths which wildcatters could reach with early drilling technologies.[91] As Chart 31 implies, however, other states have more petroleum resources than Kansas. After the steady depletions of the early oil discoveries and the Hugoton gas field, Kansas has consistently produced less than five percent of U.S. oil and gas volumes.

Table 9

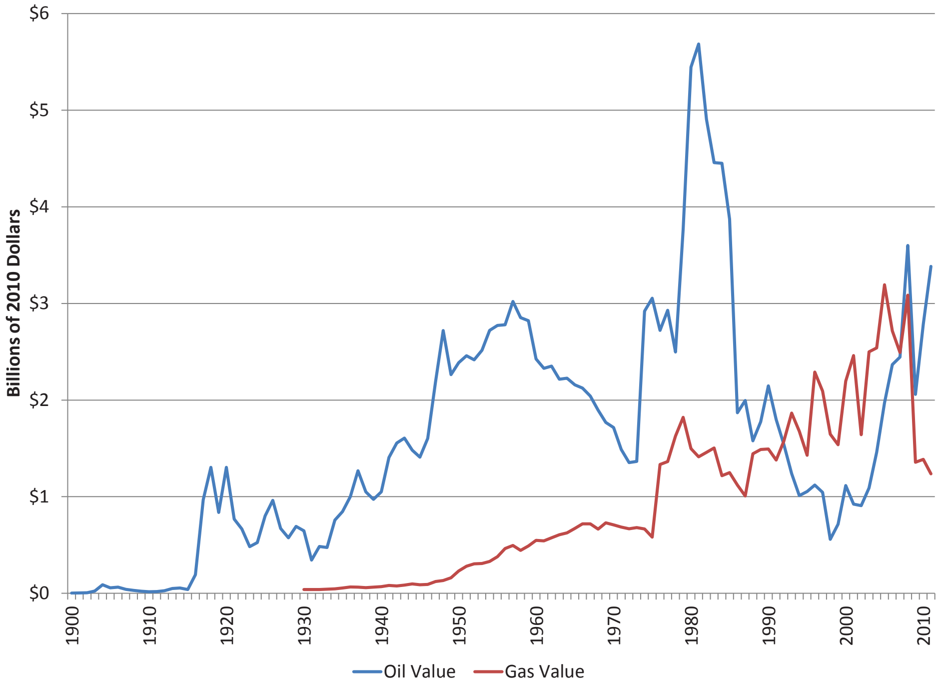
Top-15 States, as Ranked by Upstream Industry Average Share of State Gross Domestic Product, 1965-2010

		Avg. Share of State GDP (%)			
Rank	**State**	**1965 to 2010**	**1965 to 1970**	**1985 to 1990**	**2005 to 2010**
1	Alaska	26.3	12.4%	33.8	28.7
2	Wyoming	24.4	21.1	23.0	31.6
3	Louisiana	19.8	21.5	21.5	19.1
4	New Mexico	12.2	11.8	9.3	15.6
5	Oklahoma	10.8	8.9	9.8	14.5
6	Texas	9.8	9.2	9.6	11.3
7	North Dakota	4.8	2.6	6.8	5.2
8	Montana	3.4	2.7	3.5	4.3
9	Colorado	3.0	1.2	2.1	5.0
10	Utah	2.1	2.0	2.7	2.7
11	Kansas	2.0	4.1	2.5	1.6
12	Mississippi	1.9	2.6	2.6	1.7
13	Arkansas	1.7	1.1	1.1	3.1
14	West Virginia	1.6	1.2	1.6	2.4
15	Alabama	1.2	0.2	0.6	2.1

Source: U.S. Bureau of Economic Analysis; U.S. Census Bureau; U.S. Bureau of Labor Statistics; Center for Applied Economics, KU School of Business

Chart 32

Annual Market Value of Kansas Oil and Natural Gas (2010$)



Source: Kansas Geological Survey

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[90] *Ibid*., p. 118.

[91] Merriam, "Advances in the Science and Technology of Finding and Producing Oil in Kansas," pp. 30-33.

The Upstream Sector and Kansas Gross Domestic Product

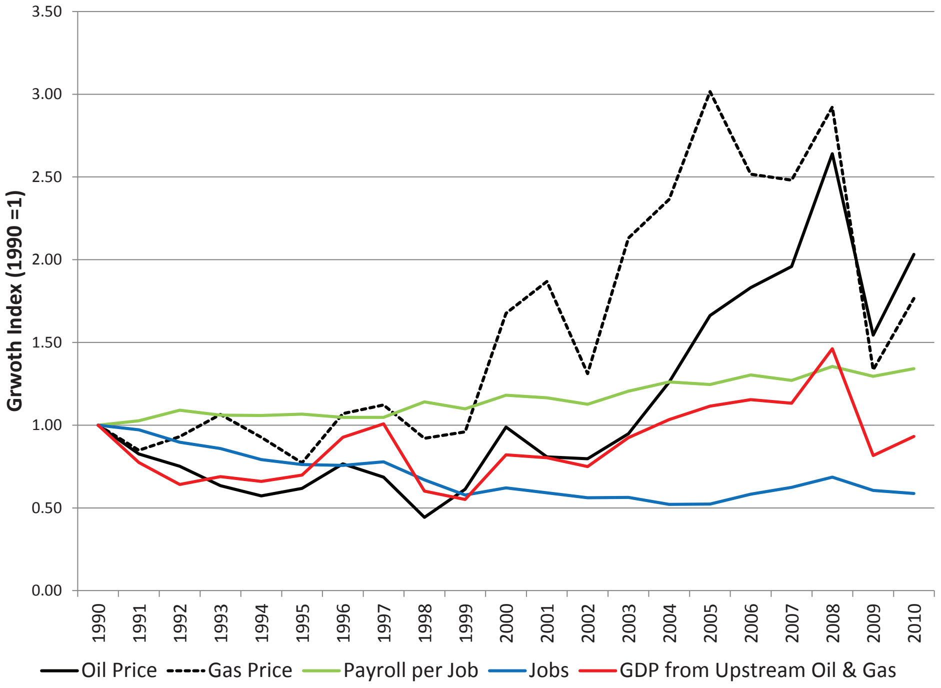
Nevertheless, the dollars earned on Kansas production have consistently made healthy contributions to the value created in the Kansas economy. Table 9 provides a snapshot of the top-15 states with regard to the contribution made to total state gross domestic product (GDP) by oil and gas extraction activity (essentially, a significant fraction of the upstream sector, as defined in this report) from 1965 to 2010. The table also compares 5-year average GDP shares for select time periods.

Note the significant variation among the states and the select time periods. These variations relate to the patterns of exploration, discovery, production, and price. Nine of the 15 states show a higher average GDP share for the 2005-2010 period than the 1985-1990 period. These increases capture the surge in activity related to the widespread unconventional (shale) oil and gas plays along with the significant price surge beginning in 2004 and ending in 2009. (See Table B6 and Table B7 in Appendix B for state-by-state data related to oil and gas production volumes.)

Kansas producers benefited from the price surge. However, the state did not rank among the states with an increased share of GDP related to oil and gas extraction. Perhaps the Mississippian Lime plays will change that in the next several years. More importantly, however, a declining share of upstream-related GDP does not necessarily convey a negative message. The Kansas oil and gas industry has made a steady contribution to the Kansas economy, but the state has increased its GDP in other areas, thereby shrinking the stable contribution made by oil and gas extraction. For example, a substantial amount of economic growth in Kansas has taken place in the Northeast corner of the state—around the Kansas City area—a region with few oil and gas resources. This growth has reduced the measured statewide economic contribution made by the oil and gas industry, but it in no way diminishes the regional (or statewide) importance of the industry.

Chart 33

Growth Trends of Oil and Gas Prices and Components of GDP



Source: U.S. Energy Information Administration; U.S. Bureau of Economic Analysis; Center for Applied Economics, KU School of Business

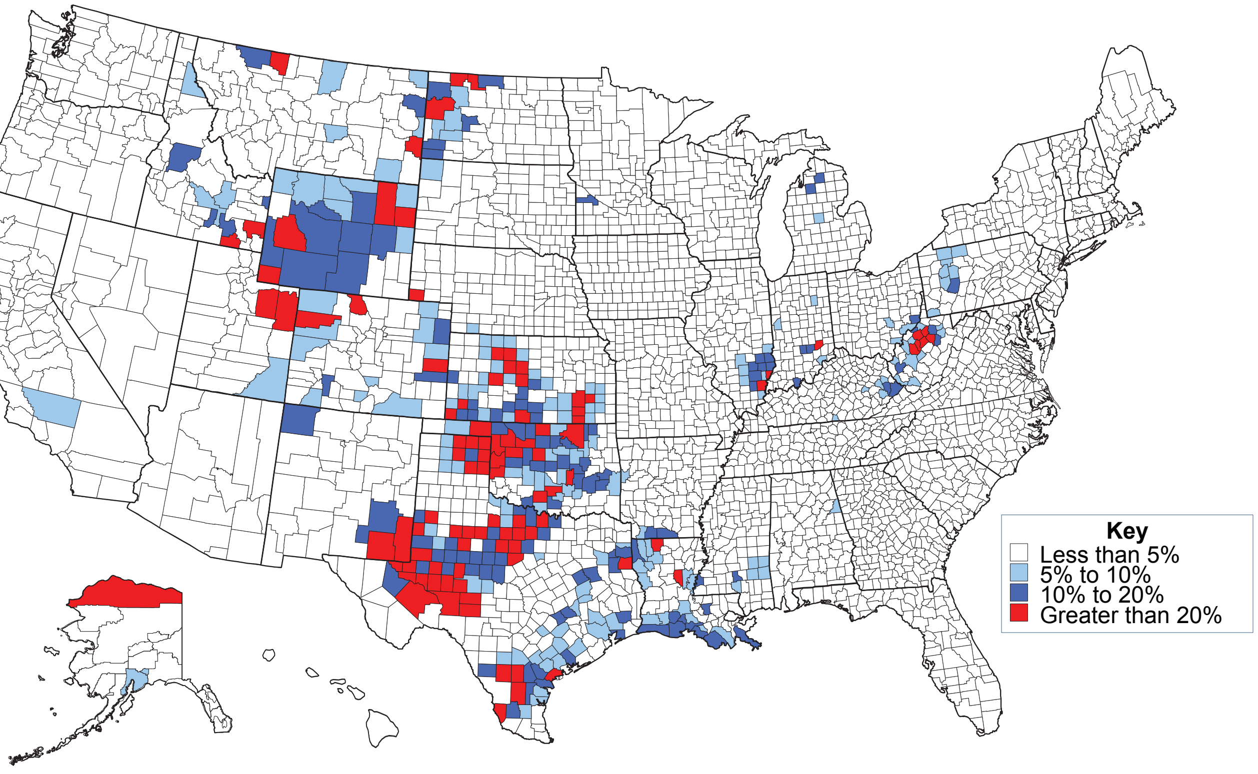
Chart 33 provides a brief tutorial on the interaction of oil and gas prices and the gross domestic product generated by oil and gas extraction activity over the past two decades. Recall that Kansas oil and gas producers behave as price takers: their production activity has essentially no influence on market prices and their exploration, drilling, and production activity essentially reacts to the production economics dictated by changing market prices. The chart shows relative growth trends among inflation-adjusted: Kansas oil and gas wellhead prices, the GDP from oil and gas, and the payroll (wages plus benefits) per job for the people employed in the sector. (Unlike elsewhere in the report, Non-employer businesses and their revenues are not included in the payroll and jobs computation, but will be embodied in the GDP trend line.)

GDP is a measure of the market value of production. As a practical matter, the government measures it with reference to employee compensation and before-tax business profits. Chart 33 shows that GDP tends to track closely with changes in the level of oil and gas prices. Statistically, for the years shown, changes in Kansas GDP in the oil and gas extraction sector and the price of oil or gas have a correlation coefficient of about 0.85, indicating a tight co-movement. Naturally, a significant amount of that extra GDP goes to producers as before-tax profit. But also note the trend in "Payroll per Job." It has a tight co-movement with the price of oil or gas, with an oil-price correlation coefficient of 0.89 and a gas-price correlation coefficient of 0.81. As in almost all sectors of a well-functioning market economy, employees share in the economic value they help create.

The "Jobs" trend in Chart 33 has a more nuanced economic story. Jobs trended upward beginning in 2005 as oil and gas prices rose, but overall the trend in Jobs shows an inverse co-movement (a negative statistical relationship) with oil and gas prices over the time period illustrated. Production—not price—drives jobs. The

Map 5

County-by-County Share of Jobs in the Upstream Sector



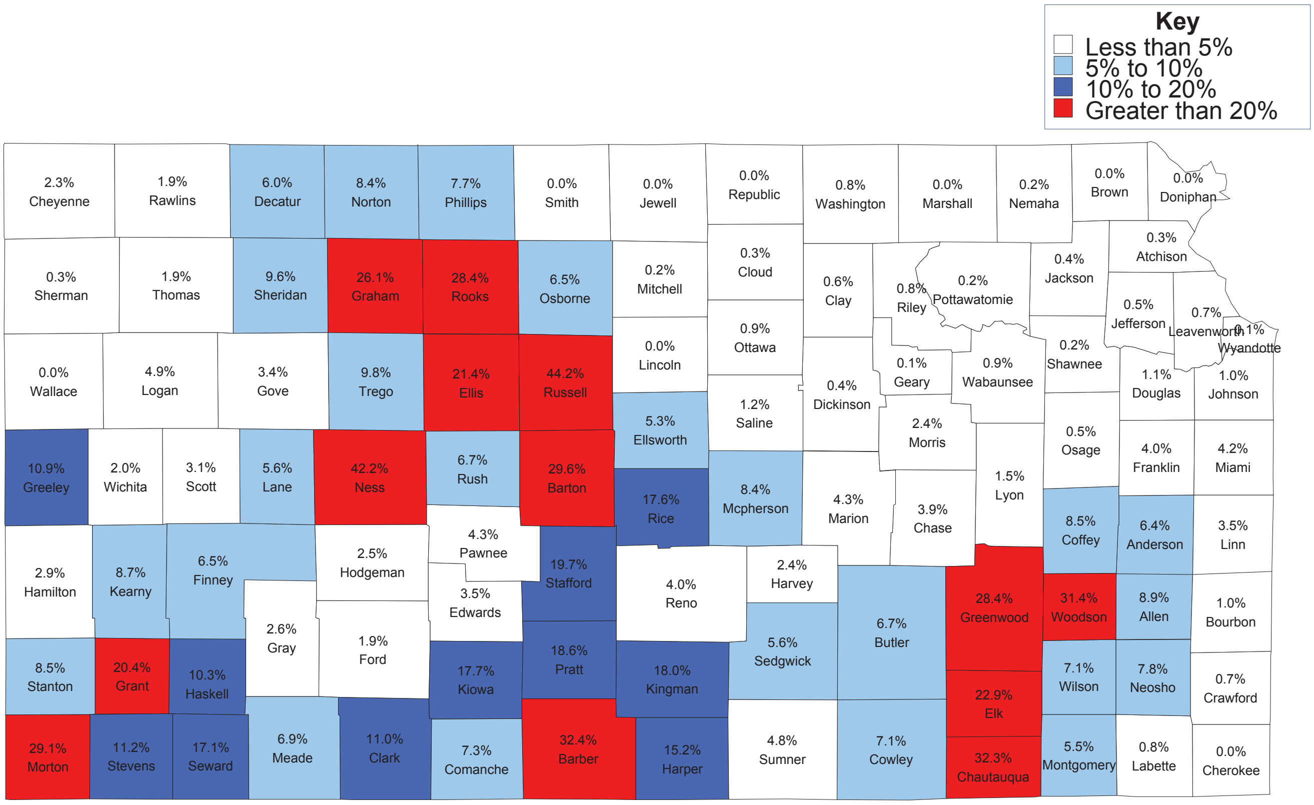
Source: U.S. Bureau of Labor Statistics; U.S. Census Bureau *change* in jobs has a tight co-movement with the *change* in oil or gas production (not illustrated): Jobs and oil production has a correlation coefficient of 0.92; Jobs and gas production has a coefficient of 0.77. The upward trend in Jobs in 2005 resulted from the upward trend in oil prices because the substantial price increases made it economically worthwhile to increase production. (Gas production did not increase. Despite the surge in natural gas price that motivated a surge in drilling, as illustrated in Chart 1, and especially the increase in coalbed methane production illustrated in Chart 30, the added natural gas production could not offset the declining production from the Hugoton Gas Area, which represented about 45 percent of Kansas gas production during this time frame.)

Map 5 helps provide a nationwide perspective about the location of jobs in the oil and gas upstream sector. Map 6 provides a Kansas close-up of Map 5. The maps record the county-by-county average share, from 1998 to 2010, of all jobs in the upstream sector relative to all jobs in the private sector. (The definition of the upstream sector is described below.)

As referenced above in connection to Kansas GDP, the upstream sector makes a significant contribution to the GDP generated in most parts of the state—except for the northeast part of the state. As a simple illustration, imagine drawing a line on Map 6 from the top corner of Saline County to the Middle of Johnson County. Every county that touches the line or is north of the line will represent the northeast. On average, from 2005 through 2010, those counties represented about 53 percent of Kansas GDP. With reference back to Table 9, removing the northeast GDP from the calculation would increase oil and gas extraction from 1.6 percent of Kansas GDP to 3.4 percent. For the 2005 to 2010 time period that

Map 6

Kansas Close-Up County-by-County Share of Jobs in the Upstream Sector

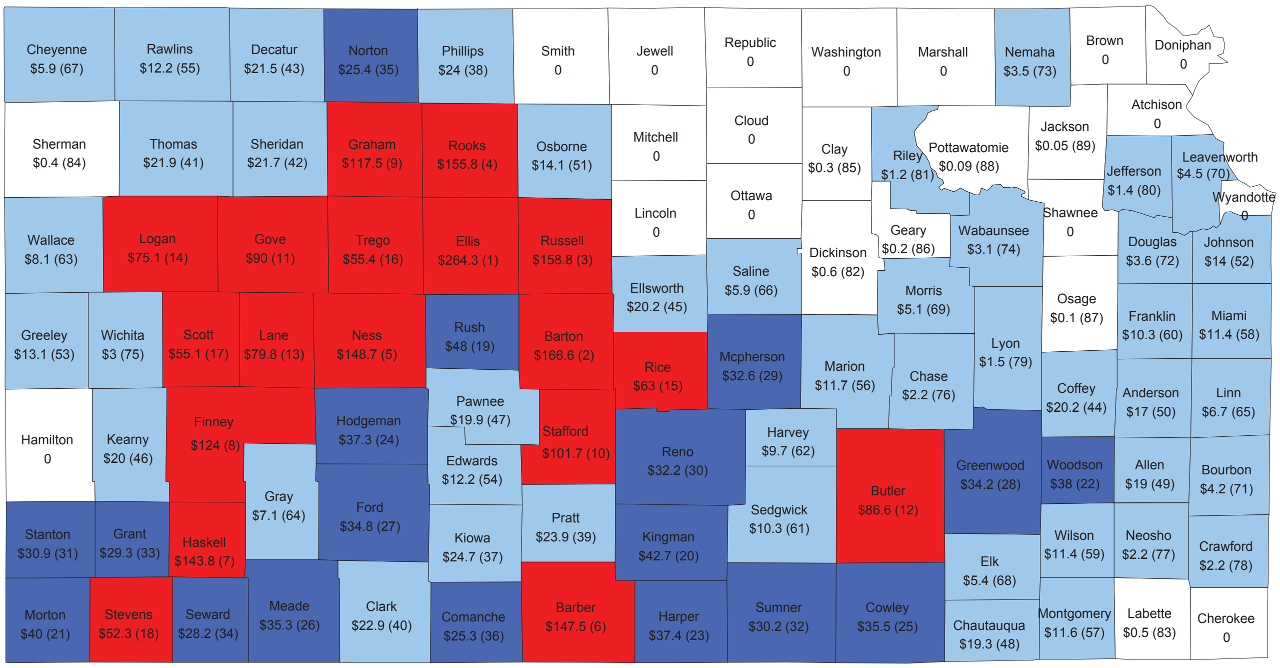


Source: U.S. Bureau of Labor Statistics; U.S. Census Bureau

Map 7

County-by-County Value of Oil Production (and Rank) in 2011, $Millions

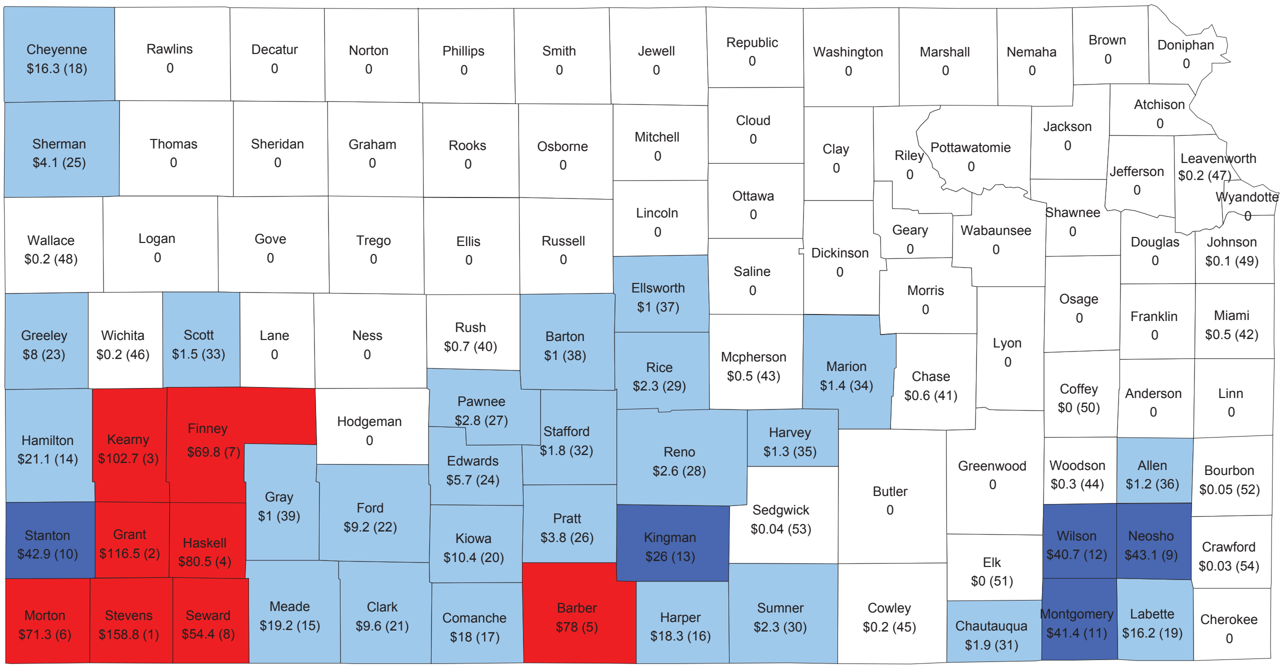
Key
☐ $0.0 to $1.0
🟦 $1.0 to $25.0
■ $25.0 to $50.0
🟥 More than $50.0



Map 8

County-by-County Value of Gas Production (and Rank) in 2011, $Millions

Key
☐ $0.0 to $1.0
🟦 $1.0 to $25.0
■ $25.0 to $50.0
🟥 More than $50.0



Source: Kansas Geological Survey; Independent Oil & Gas Services (Red Top News) would change the Kansas rank among the listed states to 10th from 15th.

Map 7 and Map 8 report the county-by-county distribution of oil and gas value for the 2011 production year. Note from Map 8 the prominence of gas production from the Cherokee Basin coalbeds in the southeast. (See Tables B8, B9, B10, and B11 in Appendix B for historical data on county-level oil and gas production.)

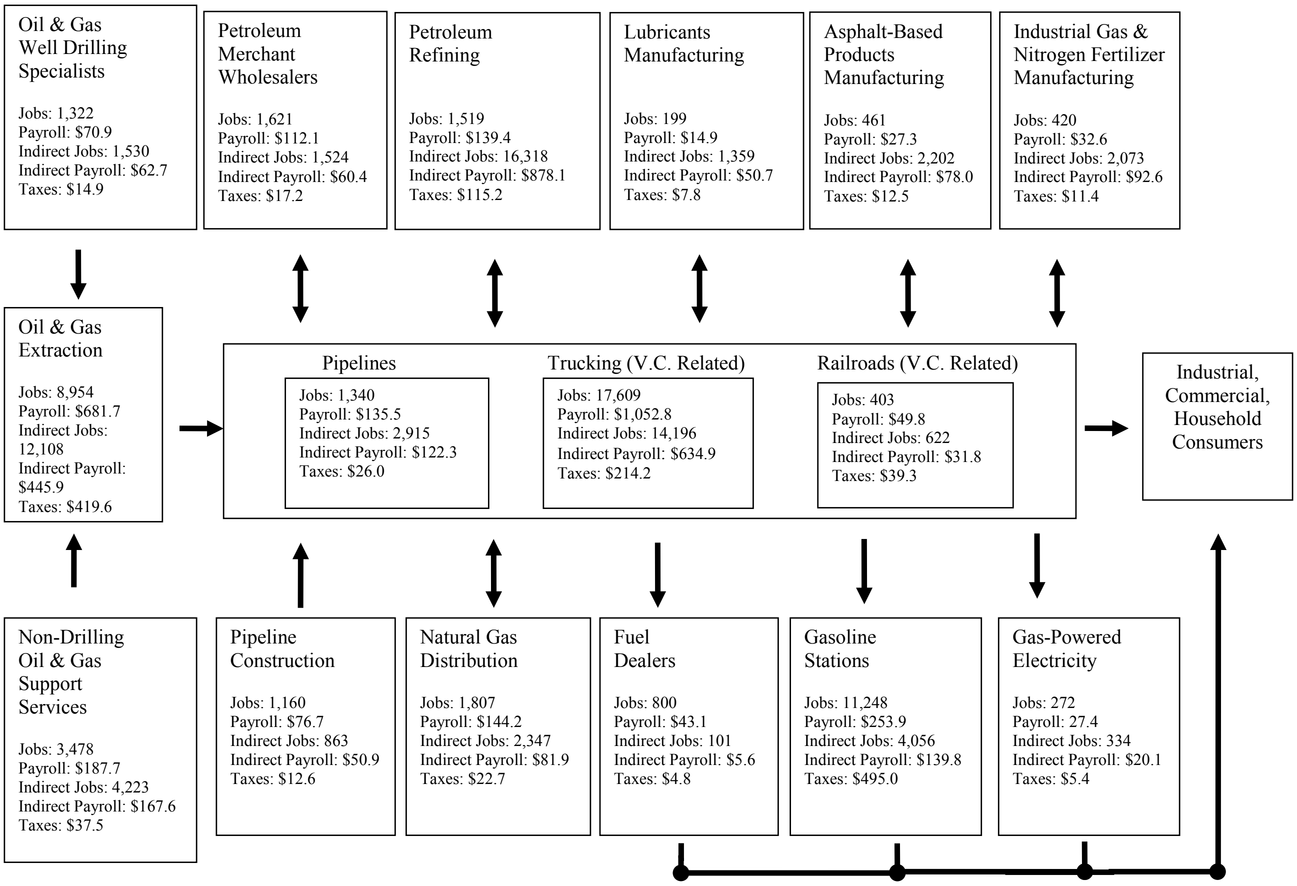
THE OVERALL OIL AND GAS VALUE CHAIN IN KANSAS

The upstream sector is a key wealth-creating sector of the Kansas economy. However, the oil and gas industry represents more to the Kansas economy than just the contribution of the upstream sector. Exhibit 7 illustrates the broader oil and gas value chain, and documents the average annual economic contribution to the Kansas economy made by each component. Oil and gas resources form the foundation for many products and service businesses. In turn, the jobs and corresponding income derived from the production of products and service made possible by oil and gas helps support a broad array of economic opportunities across many dozens of non-oil-and-gas-related industry sectors in the state of Kansas.

This report defines the upstream sector as: development of oil and gas field properties (extraction), specialists in the drilling of oil and gas wells, all non-drilling support activities associated with the stewardship of safe and productive oil and gas properties, the construction of oil and gas pipelines, and the transportation by pipeline of oil and gas. The categories correspond to specific industry codes used by the government to track economic activity. The employment count includes owners

Exhibit 7

A Representation of the Oil and Gas Value Chain for the State of Kansas (Average Annual Economic Contribution from 1998 to 2010; Millions of 2010 Dollars)



of non-employee businesses—the inclusion of which makes a significant contribution to the overall count.

This report defines the downstream sector as any business sector in the value chain that is not part of the upstream sector. Some analyses distinguish among the upstream, midstream, and downstream, and, unlike this report, typically put pipeline and certain other transportation activity in the "midstream" sector. Table B12 in Appendix B provides more detail about the classifications and the associated jobs and payroll data.

Exhibit 8 provides a map of Kansas pipelines and refinery locations.

Each component of Exhibit 7 lists five items: Jobs, Payroll, Indirect Jobs, Indirect Payroll, and Taxes. The reported measures of these items constitute the annual average levels from 1998 through 2010. The year 1998 marked a low point for oil prices and, coincidentally, marks the year of a major change in the way the government classifies industry sectors. Items reported in dollars have been adjusted for inflation, with 2010 as the base year. Descriptions and summary charts related to the five different components in each box of Exhibit 7 follow.

The Jobs and Payroll items reflect actual industry data collected by the U.S. Bureau of Labor Statistics and the U.S. Census Bureau. The Center for Applied Economics at the KU School of Business made special estimations or data collection efforts in cases where data gaps appeared or unique parts of an industry component required a special focus.

Chart 34 and Chart 35 summarize the jobs and payroll data from Exhibit 7. These represent the jobs and payroll directly related to each of the specific business categories in the upstream and downstream sectors. The Jobs and Payroll data have two components: businesses with employees and businesses without employees. The payroll estimated for the businesses with employees

Exhibit 8

Kansas Refineries and Pipelines

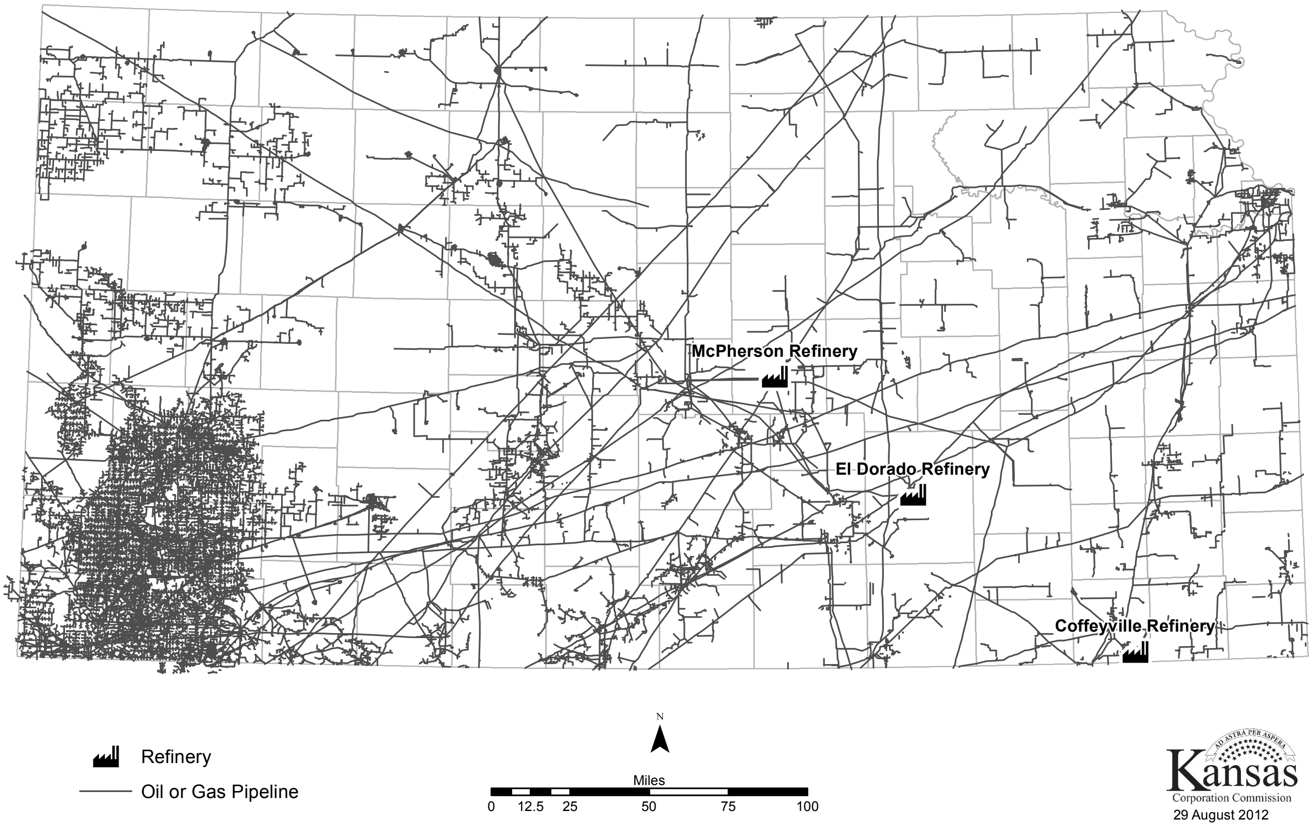


Chart 34

Avg. Annual Direct Jobs, Upstream & Downstream, 1998-2010

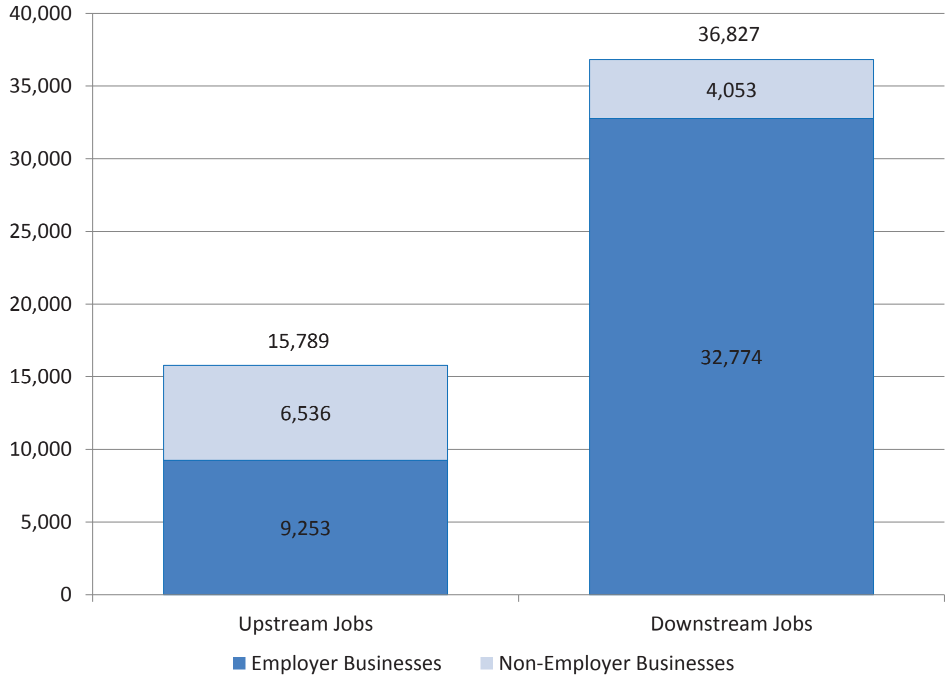
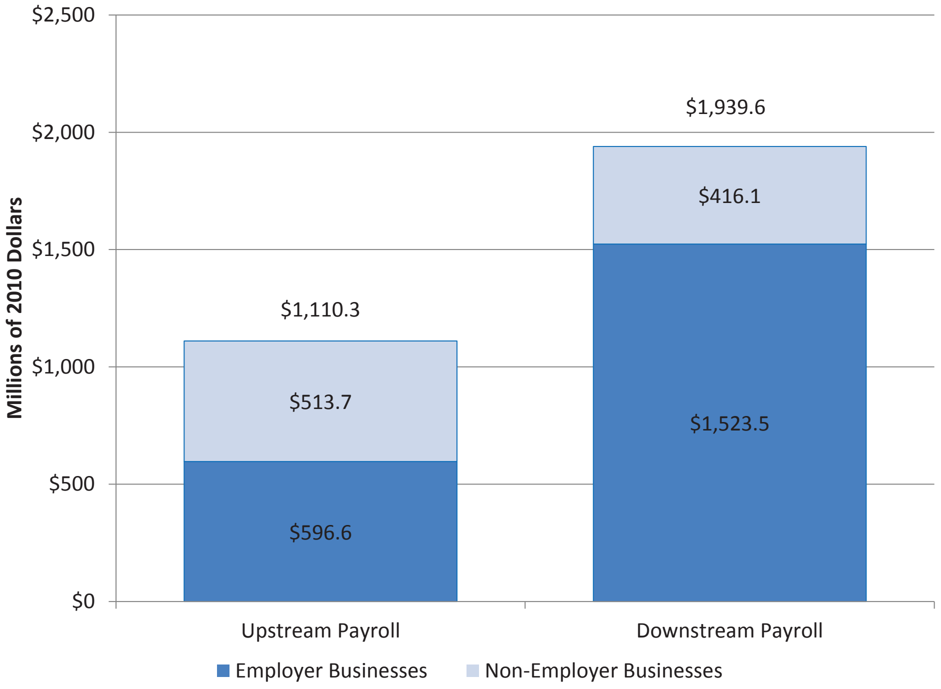


Chart 35

Avg. Annual Direct Payroll, Upstream & Downstream, 1998-2010



Source: U.S. Bureau of Labor Statistics; U.S. Census Bureau; Center for Applied Economics, KU School of Business

Chart 36

Avg. Annual Direct Jobs by Business Establishment Job Count, Upstream & Downstream, 1998-2010

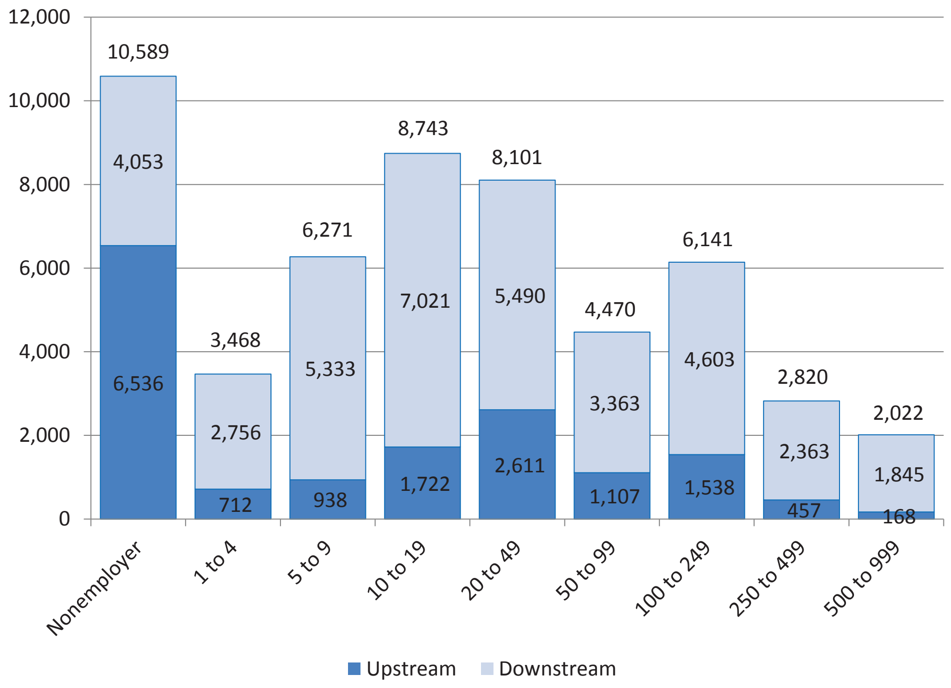
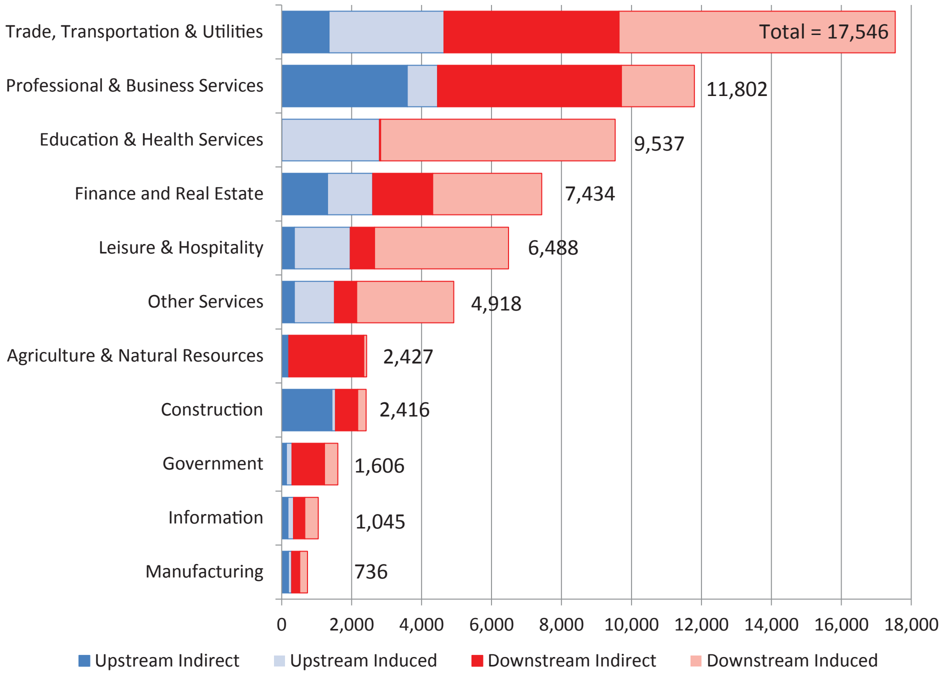


Chart 37

Avg. Annual Indirect and Induced Jobs by Sector, Upstream & Downstream, 1998-2010



Source: U.S. Bureau of Labor Statistics; U.S. Census Bureau; IMPLAN; Center for Applied Economics, KU School of Business includes estimates for fringe benefits, since that is a major form of compensation. For the businesses without employees, each business in a respective component of the value chain counts as one job and the receipts of the business count as "payroll." Non-employee businesses play a significant role in the upstream segment of the industry: many of these businesses constitute the lessors and royalty owners of the land and mineral rights. (The items for Trucking and Railroads represent estimates to account for the number of jobs and related payroll specifically interacting with the oil and gas value chain, as represented in Exhibit 7.)

Chart 36 provides job estimates based on the size of the business establishments involved. From a data presentation perspective, "establishments" differ from "firms." A large firm with thousands of employees may operate a branch office or production facility. Government statisticians treat the branch as an establishment. That said, most of the establishments represented by the data in Chart 36 probably also qualify as stand-alone firms.

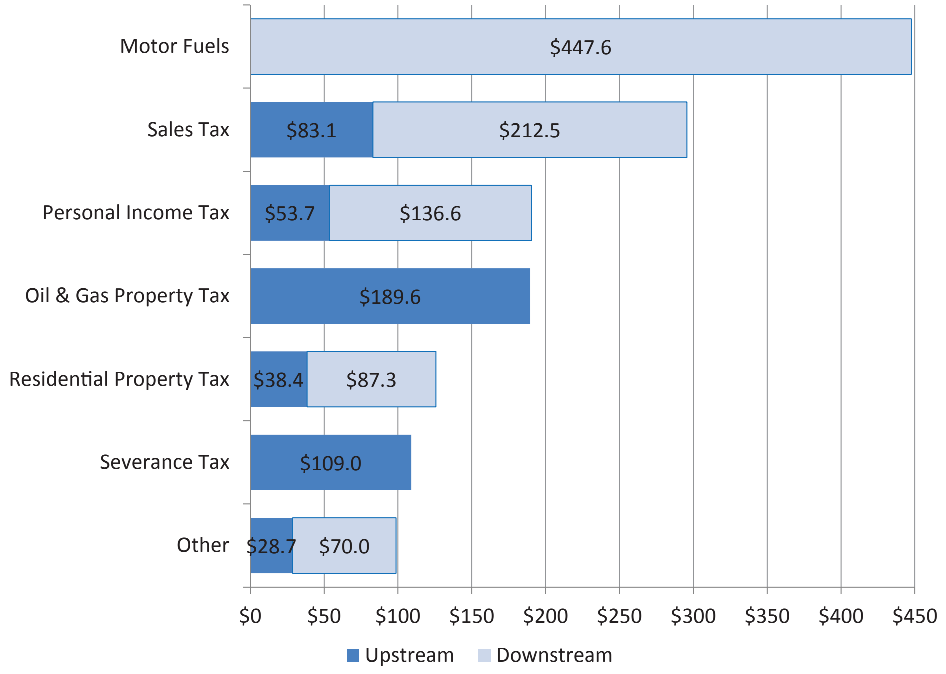
The Indirect Jobs and Indirect Payroll items in Exhibit 7 reflect estimates made by using input-output analysis, a traditional approach for conducting economic impact evaluations. Input-output analysis uses the historical pattern of industry-to-industry interactions to assess how economic activity in one sector spills over to other sectors.

The input-output analysis represented in Exhibit 7 relied on the databases and software developed by the Minnesota IMPLAN Group, Inc. (www.implan.com). IMPLAN is an industry standard because of the work the firm does to make the data as current as possible.

IMPLAN generates two types of information in response to economic impact investigations: (1) indirect effects and (2) induced effects. Indirect effects measure the economic activity related to the direct interaction of one industry segment with another—for example, the jobs and related payroll specifically associated with a business in the Oil & Gas Extraction sector hiring the services of a firm in the Drilling sector. Induced effects,

Chart 38

Avg. Annual State and Local Taxes by Type Supported by the Upstream & Downstream Sectors, 1998-2010, Millions 2010$



Source: U.S. Bureau of Labor Statistics; U.S. Census Bureau; IMPLAN; Center for Applied Economics, KU School of Business in turn, measure the economic activity made possible by the income earned by personnel in each of the sectors—for example, the array of jobs supported by the income spent by the families supported by jobs in the Oil & Gas Extraction sector and the Drilling sector, like food, clothing, housing, transportation, and entertainment.

Chart 37 provides a summary of the estimates, by sector, for the indirect and induced jobs created by the upstream and downstream business sectors. For convenience, the "Indirect Jobs" and "Indirect Payroll" items listed in the components of Exhibit 7 add together the indirect and induced effects generated by the IMPLAN input-output calculations. The IMPLAN analysis relies for its results on the actual jobs and payroll data presented in Table B12 of Appendix B.

The Taxes item in Exhibit 7 reflects a large subset of state- and local-level taxes. The estimates exclude only two major categories of taxation: (1) corporate income taxes and (2) commercial property taxes paid by businesses that do not face an explicit property tax levied on lands with oil and gas resources. Corporate income taxes and commercial property taxes—especially those on many of the downstream businesses sectors—are substantial omissions. However, there is no credible way to make estimates of these taxes without having widespread access to proprietary data.

Chart 38 summarizes the major taxes used in Exhibit 7. Table B13 in Appendix B provides a more detailed list of the taxes and Table B14 provides county-by-county data on oil and gas related property taxes. With two exceptions, each category of tax is estimated separately based on the job count and take-home pay associated with each upstream and downstream sector. Severance Tax and Oil and Gas Property Tax are allocated to the Oil and Gas Extraction sector. Motor Fuels Tax is allocated to the Gasoline Stations sector.

A PRIMER ON THE KANSAS SEVERANCE TAX (K.S.A 79-4217)

- Enacted in 1983. (The Kansas Supreme Court ruled as invalid a 1957 version of a severance tax.)
- The tax is levied on the gross value of oil and gas at the time it is severed from the earth.
- The statutory tax rate equals eight percent. (A property tax credit of 3.67 percent, per K.S.A. 79-4219, makes the effective severance tax rate equal to 4.33 percent.)
- Seven percent of the severance tax is dedicated to a Special County Mineral Production Tax fund for counties and school districts in producing areas. The remaining 93 percent of the tax is dedicated to the State General Fund.

Exemptions for Oil Wells:

- Oil wells of 2,000 feet or less that produce 5 barrels per day or less.
- Oil wells deeper than 2,000 feet, are allowed exemptions according to the following schedule:

Price per Barrel	Normal Exemption	Water-Flood Exemption
More than $16.00	6 barrels/day or less	7 barrels/day or less
$15.01 to $16.00	67barrels/day or less	8 barrels/day or less
$14.01 to $15.00	8 barrels/day or less	9 barrels/day or less
$13.01 to $14.00	9 barrels/day or less	10 barrels/day or less
$13.00 or less	10 barrels/day or less	10 barrels/day or less

- All oil production from tertiary recovery processes.
- All new pools discovered are exempt for the first two years, unless (as of July 1, 2012) the new pool produces more than 50 barrels per day.
- All oil production from (certified) 3-year inactive wells for 10 years from the date of certification.
- All incremental oil produced from a "production enhancement project" for 7 years following the project start date.

Exemptions for Gas Wells:

- Gas wells that have an average daily production value of less than $87.
- Gas used for the aid of gas production.
- Gas used for domestic or agricultural purposes.
- Prior to July 1, 2012, gas from a new pool for a period of two years.

- All gas production from (certified) 3-year inactive wells for 10 years from the date of certification.
- All incremental gas produced from a "production enhancement project" for 7 years following the project start date.

A Primer on Kansas Ad Valorem Taxation of Oil and Gas Property

- The Kansas Constitution (Article 11) classifies oil and gas leases (and all associated improvements represented by a well and production equipment) as tangible personal property.
- Like a home or business, appraisers estimated a market value for a lease. The market value is then assessed at 25 percent of market value for oil leases that produce 5 barrels a day or less and gas leases that produce 100,000 cubic feet per day or less. Leases that produce more than these thresholds are assessed at 30 percent of appraised market value.
- Like a home or a business, the assessed value of an oil or gas property are subject to the property tax rates levied by all relevant jurisdictions (e.g., city, county, school district, special district, state).
- The appraised valuation of an oil or gas property follows a multi-step process:
    - The Kansas Department of Revenue's Division of Property Valuation annually sets the price of oil for assessment purposes. It also sets the price of natural gas (through a process more complicated than that for oil). During the annual price-setting process, the Division of Property Valuation invites and considers input from outside parties like county appraisers, industry associations, and other interested parties. The Division uses standardized formulas to determine a decline rate for the underground oil and gas reserves associated with a well because these reserves (in addition to the well and the production equipment) create the tax base: the tax applies to the value of oil or gas in the ground.
    - Once the Division of Property Valuation sets a price for oil and gas to use for the prospective tax year, it applied that price to a well's production rate less the expenses incurred for that production. The net figure determines an income level for the production.
    - The income calculation, in turn, determines the value of the oil or gas resources in the ground. The property tax rate (millage rate) levied by each taxing jurisdiction applies to the calculated value.
- K.S.A. 79-201t exempts from property or ad valorem taxes: "All oil leases, other than royalty interests therein, the average daily production from which is three barrels or less per producing well, or five barrels or less per producing well which has a completion depth of 2,000 feet or more." This law took effect in the 1998 tax year.

APPENDIX A:

TECHNICAL DETAILS OF MISSISSIPPIAN LIME SIMULATION MODEL AND ECONOMIC IMPACT ESTIMATES

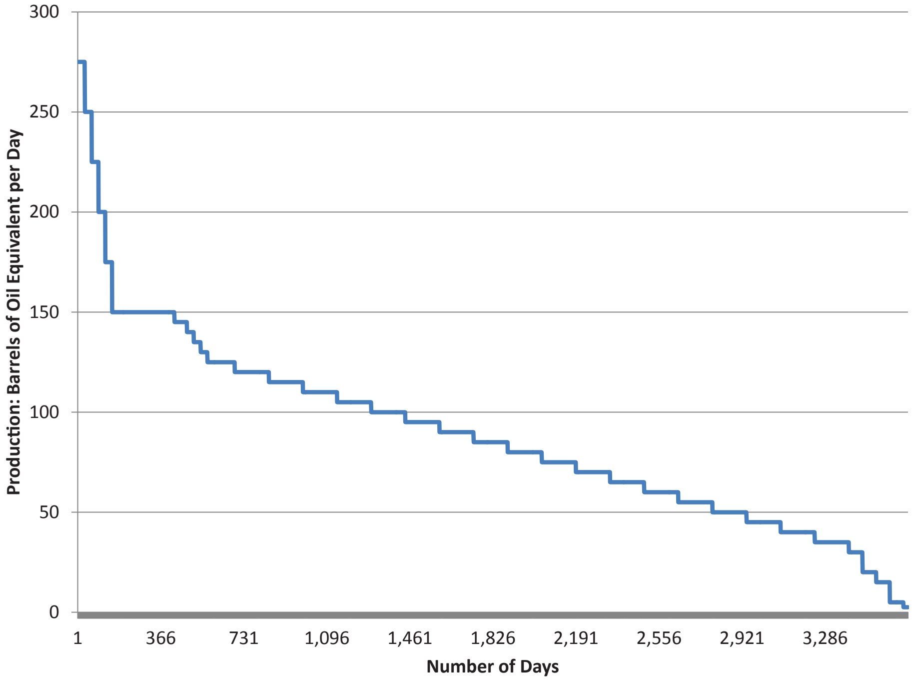
The representative well forms the foundation for the simulation model related to the potential economic impact of the Mississippian Lime play. The representative well helps define the workforce required to drill and complete it, as well as defining a realistic production profile to establish production-related income streams. Data developed and reported for investors by Sandridge Energy (February 2012), one of the prominent leaseholders involved in the Mississippian Lime play, provided the empirical basis for the representative well depicted in Chart A1. The first 600 days closely conforms to the average experience Sandridge reports for its horizontal Mississippian wells in Oklahoma and Kansas. Sandridge offered 10-year present value estimates to its potential investors, so the simulation uses the 10-year time frame to deplete the representative well. The decline pattern in Chart A1 implies a well that will produce about 324,000 barrels of oil equivalent. Public statements by Sandridge Energy officials indicate that the average well produces about 55 percent oil and 45 percent natural gas.

The economic impact estimates rely on the IMPLAN input-output model (as described in the text of this report related to the contribution of the oil and gas industry to the Kansas economy). The inputs into the IMPLAN model are:

- The number of workers required to drill and complete a well;
- The number of construction-related workers required to support a well;
- The transportation-related workers required to support a well and its subsequent production volumes;

Chart A1

Production Profile of a Representative Horizontal Well Related to the Mississippian Lime Play



Source: Sandridge Energy, Public Presentation; Center for Applied Economics, KU School of Business

- The per diem per worker spent in the hotel and restaurant sectors by out-of-state (visiting) workers;
- The income (defined as "proprietor" income) generated as production royalties.

These inputs into the IMPLAN model generate "indirect" job counts, "induced" job counts, labor income derived from the job counts, and proprietor income implied by the business activity supporting the job counts.

Table A1

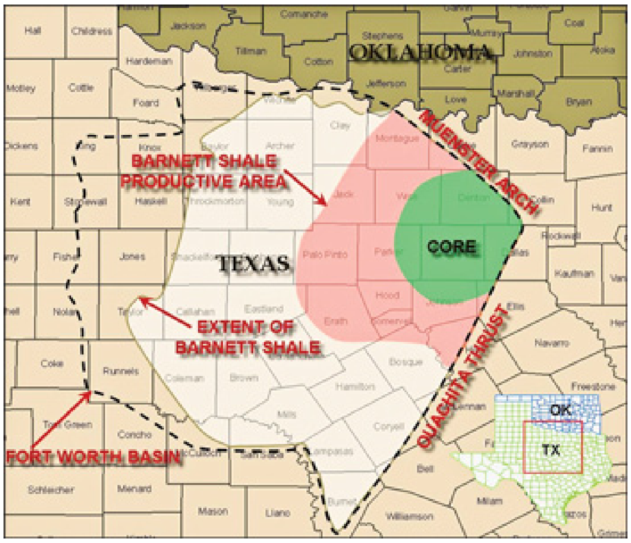
Estimated Potential Well Count by County, Select Scenarios

County	Square Miles (Sections)	Max Wells @ 3 per Section	Wells if 10% of Max	Wells if 18% of Max
Barber	1,134.1	3,402	340	612
Cheyenne	1,019.9	3,060	306	551
Clark	974.6	2,924	292	526
Comanche	788.3	2,365	236	426
Cowley	1,125.8	3,377	338	608
Edwards	621.9	1,866	187	336
Finney	1,302.0	3,906	391	703
Ford	1,098.3	3,295	329	593
Gove	1,071.7	3,215	322	579
Gray	868.9	2,607	261	469
Harper	801.3	2,404	240	433
Haskell	577.5	1,733	173	312
Hodgeman	860.0	2,580	258	464
Kingman	863.4	2,590	259	466
Kiowa	722.6	2,168	217	390
Lane	717.5	2,152	215	387
Logan	1,073.0	3,219	322	579
Meade	978.1	2,934	293	528
Ness	1,074.8	3,224	322	580
Pawnee	754.3	2,263	226	407
Pratt	735.1	2,205	221	397
Rawlins	1,069.4	3,208	321	577
Reno	1,255.4	3,766	377	678
Rush	717.8	2,153	215	388
Scott	717.5	2,153	215	387
Sedgwick	997.5	2,993	299	539
Sherman	1,056.1	3,168	317	570
Sumner	1,181.9	3,546	355	638
Thomas	1,074.7	3,224	322	580
Trego	889.5	2,668	267	480
Wallace	913.7	2,741	274	493
Wichita	718.6	2,156	216	388

The discussion in the simulation scenarios references a projected total number of possible horizontal wells implied by the geography identified in Map 2 of the report. The simulation does not incorporate this projection except to understand scenarios that might exceed the projected maximum number of wells. To generate this projection, industry representatives suggested using the Barnett Shale geography and geology as an analog for the Kansas Mississippian Lime. The counties roughly defining the area of the Barnett Shale depicted in Exhibit A1 comprise about 26,000 square miles. The "core" area, colored in green, comprises about 2,650 square miles (or 10 percent of the total). The core area plus the pink-colored area comprises about 4,700 square miles (or about 18 percent of the total).

Exhibit A1

Texas Counties that Help Define the Geography of the Barnett Shale



Source: http://www.worldoil.com/SHALE-ENERGY-Developing-the-Barnett-Barnett-activity-continuing-despite-environmental-tensions.html

The Kansas Mississippian Lime region depicted by the county geography in Map 2 comprises 29,755 square miles. Applying the Barnett Shale ratios to this area implies a "productive" region of between 2,975 and 5,356 square miles.

The Barnett Shale region supports about three horizontal wells per square mile (defined as a "section" by the oil industry). Using this well count in the Kansas Mississippian Lime context implies a projected range of 8,925 to 16,068 potential wells. Table A1 provides estimates of potential well count by county. Based on the Barnett Shale-related assumptions, some counties could conceivably experience the estimated maximum count. All counties combined cannot.

APPENDIX B

SUPPLEMENTARY DATA TABLES

Table B1

County-by-County Well Count, Average Well Depth, and Maximum Well Depth

	Well Count	Avg Depth	Max Depth
Allen	12,044	846	5,168
Anderson	7,412	816	4,700
Atchison	125	1,984	3,136
Barber	6,628	4,659	9,342
Barton	15,732	3,414	5,090
Bourbon	3,239	626	6,428
Brown	78	3,087	5,772
Butler	13,850	2,351	6,841
Chase	1,110	1,516	4,625
Chautauqua	8,606	1,410	5,502
Cherokee	244	536	1,470
Cheyenne	1,108	2,552	5,803
Clark	1,924	5,515	8,060
Clay	114	2,189	3,664
Cloud	27	3,165	4,046
Coffey	3,086	1,347	4,222
Comanche	1,953	5,430	4,775
Cowley	10,227	2,916	4,573
Crawford	2,660	357	3,097
Decatur	1,718	3,770	5,033
Dickinson	505	2,540	3,550
Doniphan	42	1,968	3,400
Douglas	1,411	857	2,996
Edwards	2,290	4,494	6,070
Elk	3,148	1,593	4,133
Ellis	14,147	3,600	4,858
Ellsworth	3,387	3,228	5,360
Finney	3,542	3,909	7,044
Ford	977	5,013	6,752
Franklin	5,511	732	6,195
Geary	108	2,283	3,638
Gove	2,334	4,368	5,169
Graham	8,148	3,868	5,052
Grant	2,576	3,384	8,000
Gray	421	5,036	7,350
Greeley	900	4,017	5,994
Greenwood	11,233	2,024	5,684
Hamilton	1,157	3,030	6,690
Harper	2,792	4,557	9,060
Harvey	2,026	3,265	4,548
Haskell	3,292	4,505	7,650
Hodgeman	2,521	4,512	6,856
Jackson	138	3,078	3,992
Jefferson	782	1,622	3,615
Jewell	18	3,818	4,437
Johnson	3,428	847	5,370
Kearny	2,749	3,269	7,534
Kingman	4,532	4,172	5,975
Kiowa	2,551	4,829	9,069
Labette	4,022	721	6,250
Lane	2,628	4,558	5,700
Leavenworth	1,291	1,357	3,500
Lincoln	53	3,230	4,306
Linn	4,580	547	2,100
Logan	1,180	4,655	5,756
Lyon	967	2,331	3,484
McPherson	5,504	3,130	6,955
Marion	4,419	2,577	4,613
Marshall	67	1,865	3,973
Meade	2,192	5,720	8,480
Miami	8,344	545	2,740
Mitchell	36	3,860	4,675
Montgomery	14,560	950	4,625
Morris	930	2,110	4,300
Morton	3,655	4,240	7,395
Nemaha	291	3,322	4,183
Neosho	10,132	767	8,270
Ness	6,651	4,397	6,795
Norton	1,219	3,675	4,560
Osage	108	1,880	3,808
Osborne	575	3,520	4,860
Ottawa	28	3,442	4,453
Pawnee	3,307	4,019	5,365
Phillips	1,844	3,485	4,152
Pottawatomie	126	2,437	3,790
Pratt	4,525	4,329	6,709
Rawlins	1,284	4,359	5,361
Reno	3,732	3,671	5,008
Republic	5	3,186	3,565
Rice	9,283	3,320	5,327
Riley	185	1,861	4,440
Rooks	9,037	3,539	5,860
Rush	3,086	3,780	4,802
Russell	12,027	3,164	4,209
Saline	1,488	3,055	5,433
Scott	1,138	4,449	6,432
Sedgwick	4,115	3,273	4,750
Seward	3,419	5,268	9,050
Shawnee	30	2,329	3,329
Sheridan	1,871	4,044	5,001
Sherman	477	2,530	5,913
Smith	34	3,622	4,800
Stafford	10,192	3,845	5,330
Stanton	1,653	4,119	7,507
Stevens	4,020	4,232	8,714
Sumner	6,202	3,567	6,651
Thomas	967	4,618	5,720
Trego	4,349	4,021	5,145
Wabaunsee	539	2,888	3,753
Wallace	433	4,794	6,058
Washington	22	3,270	11,300
Wichita	219	4,672	6,321
Wilson	7,898	1,036	3,352
Woodson	8,599	1,225	8,376
Wyandotte	96	588	1,428

Source: Kansas Geological Survey

Table B2

Total Wells Drilled by State (2005-2009)

	Wells Drilled--Oil			Wells Drilled--Gas			Wells Drilled--Dry Hole		
	Exploratory	Development	Total	Exploratory	Development	Total	Exploratory	Development	Total
United States	3,852	59,484	63,336	10,098	124,835	134,933	6,609	14,604	21,214
Federal Offshore	20	614	634	100	1,034	1,134	551	488	1,039
Alabama	38	48	86	34	1,759	1,793	122	73	195
Alaska	5	620	625	10	67	77	48	26	74
Arizona	-	-	-	-	-	-	3	1	4
Arkansas	7	251	258	423	2,901	3,324	98	168	266
California	20	10,324	10,344	26	587	613	114	301	415
Colorado	19	287	306	375	13,572	13,947	215	368	583
Florida	-	1	1	-	-	-	-	1	1
Illinois	50	1,093	1,143	2	181	183	258	433	691
Indiana	36	254	290	86	124	210	139	126	265
Kansas	**817**	**5,255**	**6,072**	**225**	**4,974**	**5,199**	**1,265**	**2,437**	**3,702**
Kentucky	129	804	933	1,321	2,165	3,486	366	857	1,223
Louisiana	12	1,307	1,319	73	4,638	4,711	206	1,229	1,435
Maryland	-	-	-	-	-	-	-	-	-
Michigan	40	157	197	23	1,707	1,730	106	157	263
Mississippi	10	338	348	33	639	672	133	178	311
Montana	483	733	1,216	235	1,799	2,034	168	143	311
Nebraska	30	74	104	32	229	261	116	107	223
Nevada	-	1	1	-	-	-	13	1	14
New Mexico	118	2,844	2,962	167	4,884	5,051	124	268	392
New York	19	500	519	143	596	739	63	38	101
North Dakota	711	1,569	2,280	9	101	110	91	71	162
Ohio	64	1,205	1,269	268	1,894	2,162	57	158	215
Oklahoma	366	4,121	4,487	1,347	9,400	10,747	432	1,346	1,778
Oregon	-	-	-	-	4	4	-	1	1
Pennsylvania	338	4,144	4,482	2,582	10,517	13,099	61	202	263
South Dakota	10	83	93	11	20	31	25	4	29
Tennessee	15	138	153	306	183	489	41	235	276
Texas	339	20,978	21,325	892	35,352	36,244	1,907	5,080	6,987
Utah	94	1,312	1,406	197	2,601	2,798	95	111	206
Virginia	-	-	-	81	2,689	2,770	-	-	-
West Virginia	9	147	156	964	6,448	7,412	24	69	93
Wyoming	63	732	795	206	14,467	14,673	175	301	476

Source: IHS Energy; Independent Petroleum Association of America

Table B3

Total Footage Drilled by State (2005-2009)

	Footage Drilled--Oil (thousand feet)			Footage Drilled--Gas (thousand feet)			Footage Drilled--Dry Hole (thous feet)		
	Exploratory	Development	Total	Exploratory	Development	Total	Exploratory	Development	Total
United States	27,496	274,710	302,206	60,163	815,630	875,793	39,265	71,532	110,796
Federal Offshore	293	6,706	6,999	913	10,467	11,379	6,849	4,256	11,105
Alabama	435	547	982	168	4,281	4,449	1,108	269	1,377
Alaska	57	3,814	3,871	88	567	654	313	163	475
Arizona	-	-	-	-	-	-	15	1	16
Arkansas	41	986	1,027	2,812	20,613	23,425	584	945	1,529
California	89	24,073	24,162	141	3,807	3,948	771	1,496	2,266
Colorado	117	1,886	2,003	2,072	88,333	90,404	976	1,662	2,599
Florida	-	3	3	-	-	-	-	1	1
Illinois	143	2,695	2,837	4	172	176	664	1,018	1,682
Indiana	86	462	548	195	158	353	271	214	485
Kansas	**3,423**	**15,302**	**18,724**	**959**	**9,284**	**10,243**	**5,357**	**8,934**	**14,290**
Kentucky	214	1,210	1,425	4,531	8,309	12,840	564	2,282	1,846
Louisiana	91	6,883	6,974	652	48,590	49,242	1,730	10,199	11,928
Maryland	-	-	-	-	-	-	-	-	-
Michigan	193	631	825	126	2,824	2,950	407	421	829
Mississippi	103	2,619	2,721	198	5,342	5,540	1,108	1,453	2,561
Montana	5,288	6,814	12,102	529	2,811	3,340	802	410	1,213
Nebraska	133	362	495	98	576	675	523	461	984
Nevada	-	5	5	-	-	-	72	6	78
New Mexico	554	17,698	18,252	1,262	28,675	29,937	673	1,554	2,227
New York	37	813	850	838	1,868	2,706	480	140	619
North Dakota	9,053	18,699	27,752	104	289	393	806	547	1,353
Ohio	249	4,745	4,994	1,112	7,222	8,334	211	609	821
Oklahoma	2,806	20,548	23,354	13,078	68,927	82,005	2,844	6,822	9,667
Oregon	-	-	-	-	12	12	-	2	2
Pennsylvania	705	7,434	8,138	12,250	41,417	53,667	232	584	816
South Dakota	87	504	591	23	35	57	55	29	83
Tennessee	35	222	257	1,260	660	1,920	79	394	473
Texas	2,297	121,471	123,768	8,188	344,768	352,956	14,694	29,002	43,696
Utah	664	8,214	8,878	1,714	22,327	24,041	662	346	1,008
Virginia	11	1,077	1,088	443	6,343	6,787	11	1,077	1,088
West Virginia	35	469	504	4,809	28,818	33,626	90	154	244
Wyoming	545	3,763	4,308	2,238	64,117	66,355	1,312	1,233	2,545

Source: IHS Energy; Independent Petroleum Association of America

Table B4

Average Cost per Foot Drilled; Average Cost per Well Drilled; and Total Cost of Drilling (2005-2009)

	Cost of Drilling--Oil			Cost of Drilling--Gas			Cost of Drilling--Dry Hole		
	Cost/ft	Cost/well	Total Cost (Thous$)	Cost/ft	Cost/well	Total Cost (Thous$)	Cost/ft	Cost/well	Total Cost (Thous$)
United States	419	2,009,323	128,775,385	477	3,232,661	413,141,606	424	2,195,226	43,844,218
Federal Offshore	4,288	47,112,743	27,626,444	4,524	44,777,715	40,923,378	4,093	41,910,020	40,705,520
Alabama	630	7,152,018	606,975	374	906,622	1,543,229	438	3,635,221	651,415
Alaska	3,884	24,093,765	14,432,679	2,392	18,902,859	1,416,550	3,279	21,590,133	1,554,075
Arizona	-	-	-	-	-	-	96	413,979	504,799
Arkansas	217	878,072	240,840	220	1,471,043	5,376,979	225	1,290,154	313,116
California	559	1,293,827	13,128,701	286	1,825,783	1,078,859	449	2,411,882	917,879
Colorado	348	2,286,894	803,604	560	3,823,343	47,278,190	308	1,389,780	638,637
Florida	607	1,844,078	9,220	-	-	-	402	443,879	2,219
Illinois	258	642,572	733,081	617	568,628	99,399	229	556,511	369,711
Indiana	261	486,032	156,981	776	1,688,308	334,921	283	516,811	139,335
Kansas	**128**	**392,655**	**2,564,956**	**196**	**404,222**	**1,857,680**	**78**	**302,586**	**1,126,242**
Kentucky	244	379,661	356,691	177	714,606	2,227,990	279	421,669	568,339
Louisiana	816	4,483,667	6,192,323	663	7,184,973	34,183,741	824	6,594,087	9,624,997
Maryland	-	-	-	-	-	-	-	-	-
Michigan	583	2,400,493	513,491	693	1,260,323	1,918,863	427	1,389,546	325,554
Mississippi	564	4,310,296	1,626,952	684	6,335,002	3,238,746	564	4,860,291	1,418,552
Montana	530	5,008,041	5,576,520	356	609,663	1,139,712	519	2,123,228	593,690
Nebraska	304	1,475,997	161,844	327	902,035	237,813	300	1,460,512	288,419
Nevada	60	299,380	1,497	-	-	-	246	1,404,423	18,835
New Mexico	322	2,003,778	5,978,242	314	1,968,100	8,143,401	444	2,498,058	910,709
New York	223	355,536	188,509	236	900,916	614,126	432	2,713,979	265,732
North Dakota	571	6,950,072	17,994,897	980	6,224,508	274,114	471	4,035,444	610,704
Ohio	147	519,163	544,357	152	582,295	1,350,538	276	1,021,445	211,060
Oklahoma	272	1,419,833	6,720,967	407	3,318,881	31,681,369	279	1,455,099	2,380,510
Oregon	-	-	-	230	694,330	7,847	85	188,845	944
Pennsylvania	213	383,788	1,789,771	213	973,165	10,692,170	330	921,055	125,888
South Dakota	530	3,637,975	313,524	490	790,788	29,584	376	1,347,888	33,998
Tennessee	256	396,305	50,536	159	637,024	295,765	273	448,928	109,616
Texas	322	1,894,661	42,024,011	500	4,969,537	175,377,913	388	2,441,203	16,000,010
Utah	300	1,934,648	2,709,893	712	6,113,567	16,417,083	604	2,991,069	524,663
Virginia	-	-	-	197	582,900	1,601,315	-	-	-
West Virginia	168	584,580	66,486	179	892,748	5,644,956	258	771,322	63,934
Wyoming	515	2,638,014	2,137,931	802	4,120,516	52,491,971	706	3,677,468	1,621,014

Source: IHS Energy; Independent Petroleum Association of America

Table B5

Distribution of Drilling and Production Activity among Select "Major" Oil Companies and Independent Companies

Company	Well Count	Share of Wells	Cummulative Oil Production (Barrels)	Cummulative Gas Production (Thousand Cubic Feet)	Share of Oil Production	Share of Gas Production
Shell	919	0.22%	n.a.	n.a.	n.a.	n.a.
BP	289	0.07%	2,503,752	3,427,431,088	0.04%	8.69%
Oxy	2,783	0.67%	443,363,558	4,584,982,258	6.92%	11.62%
Anadarko	2,812	0.67%	13,635,658	2,551,023,293	0.21%	6.47%
Texaco*	1,089	0.26%	1,818,221	65,339,912	0.03%	0.17%
Chevron*	69	0.02%	40,078	103,561,440	0.00%	0.26%
Phillips*	1,840	0.44%	n.a.	n.a.	n.a.	n.a.
Conoco*	110	0.03%	n.a.	n.a.	n.a.	n.a.
Conoco-Phillips*	25	0.01%	n.a.	n.a.	n.a.	n.a.
Exxon-Mobil*	2,369	0.57%	605,067	3,953,598,384	0.01%	10.02%
Independent Producers	404,920	97.05%	5,944,144,189	24,757,128,867	92.79%	62.77%
Kansas Total (as of March 2012)	417,225		6,406,110,523	39,443,065,242		

Note: Well count includes all wells throughout Kansas history in which the listed company was recorded as the "original operator."

* Exxon-Mobil consolidates the pre-merger data because production data for Mobil was unavailable.

Before the merger, Exxon drilled 465 wells and Mobil drilled 1,904. Data for other merged companies are left unconsolidated to provide a sense of history.

Source: Kansas Geological Survey

Table B6

State-by-State Oil Production

	Production (Million Barrels)				Rank				Share of Total (Percent)			
	1981	**1991**	**2001**	**2011**	**1981**	**1991**	**2001**	**2011**	**1981**	**1991**	**2001**	**2011**
Alabama	20.7	18.6	9.3	8.3	17	15	15	15	0.6	0.7	0.4	0.4
Alaska*	615.8	710.9	431.0	219.3	2	1	1	3	19.1	25.3	19.3	10.5
Arizona	0.4	0.1	0.1	0.0	29	30	30	30	0.0	0.0	0.0	0.0
Arkansas	18.4	10.3	7.6	5.9	18	17	16	16	0.6	0.4	0.3	0.3
California**	424.0	374.3	308.7	225.5	3	3	3	2	13.2	13.3	13.9	10.8
Colorado	30.3	31.4	16.5	33.4	14	10	11	10	0.9	1.1	0.7	1.6
Florida	34.8	4.7	4.4	2.0	10	21	19	22	1.1	0.2	0.2	0.1
Illinois	24.1	19.1	10.1	9.3	16	14	14	14	0.7	0.7	0.5	0.4
Indiana	4.7	3.0	2.0	2.0	22	23	22	23	0.1	0.1	0.1	0.1
Kansas	**65.8**	**56.9**	**33.9**	**41.9**	**8**	**8**	**8**	**9**	**2.0**	**2.0**	**1.5**	**2.0**
Kentucky	6.5	5.5	3.0	2.4	21	20	20	20	0.2	0.2	0.1	0.1
Louisiana*	225.8	171.4	117.4	71.8	4	4	4	6	7.0	6.1	5.3	3.4
Michigan	32.7	17.5	7.4	5.1	12	16	17	18	1.0	0.6	0.3	0.2
Mississippi	34.2	27.1	19.5	23.6	11	11	10	12	1.1	1.0	0.9	1.1
Missouri	0.2	0.1	0.1	0.1	30	29	29	29	0.0	0.0	0.0	0.0
Montana	30.8	19.6	15.9	23.6	13	13	12	13	1.0	0.7	0.7	1.1
Nebraska	6.7	5.8	2.9	2.2	20	19	21	21	0.2	0.2	0.1	0.1
Nevada	0.7	3.4	0.6	0.4	28	22	26	26	0.0	0.1	0.0	0.0
New Mexico	71.6	70.4	68.0	70.6	7	7	6	7	2.2	2.5	3.1	3.4
New York	0.8	0.4	0.2	0.4	27	28	28	27	0.0	0.0	0.0	0.0
North Dakota	45.4	35.9	31.7	152.8	9	9	9	4	1.4	1.3	1.4	7.3
Ohio	13.6	9.2	6.1	5.2	19	18	18	17	0.4	0.3	0.3	0.2
Oklahoma	154.1	108.1	68.5	74.5	5	5	5	5	4.8	3.8	3.1	3.6
Pennsylvania	3.7	2.5	1.6	3.7	23	24	23	19	0.1	0.1	0.1	0.2
South Dakota	1.0	1.7	1.3	1.6	25	26	24	25	0.0	0.1	0.1	0.1
Tennessee	0.9	0.5	0.4	0.3	26	27	27	28	0.0	0.0	0.0	0.0
Texas*	934.0	685.1	425.2	521.5	1	2	2	1	29.0	24.4	19.1	24.9
Utah	25.9	24.5	15.3	25.8	15	12	13	11	0.8	0.9	0.7	1.2
Virginia	0.0	0.0	0.0	0.0	31	31	31	31	0.0	0.0	0.0	0.0
West Virginia	3.5	2.0	1.2	1.9	24	25	25	24	0.1	0.1	0.1	0.1
Wyoming	130.6	99.9	57.4	53.3	6	6	7	8	4.0	3.6	2.6	2.5
Total***	3,224.0	2,811.5	2,227.7	2,096.1								

* Includes offshore production
** Includes state and federal offshore production
*** Includes federal Gulf of Mexico offshore production
Source: Energy Information Administration

Table B7

State-by-State Natural Gas Marketed Production

	Production (Million Cubic Feet)				Rank				Share of Total (Percent)			
	1981	1991	2001	2010	1981	1991	2001	2010	1981	1991	2001	2010
Alabama*	79,244	170,847	356,810	222,932	17	12	10	14	0.40	0.92	1.73	1.00
Alaska*	242,564	437,822	471,440	374,226	8	7	8	10	1.22	2.36	2.29	1.67
Arizona	187	1,225	307	183	29	26	29	30	0.00	0.01	0.00	0.00
Arkansas	92,986	164,702	166,804	926,638	15	13	14	7	0.47	0.89	0.81	4.14
California*	380,359	378,384	377,824	286,841	7	8	9	12	1.91	2.04	1.84	1.28
Colorado	195,706	285,961	817,206	1,578,379	9	9	6	5	0.98	1.54	3.97	7.05
Florida	32,470	4,884	5,710	12,409	21	23	23	23	0.16	0.03	0.03	0.06
Illinois	1,295	466	185	1,203	26	29	30	29	0.01	0.00	0.00	0.01
Indiana	330	232	1,064	6,802	28	30	28	24	0.00	0.00	0.01	0.03
Kansas	**640,114**	**628,459**	**480,145**	**324,720**	**5**	**6**	**7**	**11**	**3.21**	**3.39**	**2.33**	**1.45**
Kentuck	61,312	78,904	81,723	135,330	18	18	18	17	0.31	0.43	0.40	0.60
Louisiana*	6,780,184	5,034,361	1,502,086	2,210,099	2	2	4	3	33.98	27.17	7.30	9.87
Maryland	56	29	32	43	30	32	31	31	0.00	0.00	0.00	0.00
Michigan	152,593	195,749	275,036	151,886	12	11	12	15	0.76	1.06	1.34	0.68
Mississippi	181,238	108,031	107,541	73,721	10	17	16	21	0.91	0.58	0.52	0.33
Missouri	0	15	0	0	32	33	33	33	0.00	0.00	0.00	0.00
Montana	56,565	51,999	81,397	87,539	19	20	19	18	0.28	0.28	0.40	0.39
Nebraska	2,519	784	1,208	2,231	24	28	25	26	0.01	0.00	0.01	0.01
Nevada	0	53	7	4	32	31	32	32	0.00	0.00	0.00	0.00
New Mexico	1,132,066	1,038,284	1,689,125	1,292,185	4	4	2	6	5.67	5.60	8.21	5.77
New York	16,074	22,777	27,787	35,813	22	21	22	22	0.08	0.12	0.14	0.16
North Dakota	42,573	53,479	54,732	81,837	20	19	21	19	0.21	0.29	0.27	0.37
Ohio	141,134	147,651	100,107	78,122	13	15	17	20	0.71	0.80	0.49	0.35
Oklahoma	2,019,199	2,153,852	1,615,384	1,827,328	3	3	3	4	10.12	11.62	7.85	8.16
Oregon	5	2,741	1,110	1,407	31	24	26	28	0.00	0.01	0.01	0.01
Pennsylvania	122,454	152,500	130,853	572,902	14	14	15	8	0.61	0.82	0.64	2.56
South Dakota	1,155	882	1,100	1,862	27	27	27	27	0.01	0.00	0.01	0.01
Tennessee	1,719	1,856	2,000	5,144	25	25	24	25	0.01	0.01	0.01	0.02
Texas*	6,910,021	6,280,654	5,282,723	6,715,294	1	1	1	1	34.63	33.89	25.68	29.98
Utah	91,191	144,817	283,913	432,045	16	16	11	9	0.46	0.78	1.38	1.93
Virginia	8,903	14,906	71,543	147,255	23	22	20	16	0.04	0.08	0.35	0.66
West Virginia	161,251	198,605	191,889	265,174	11	10	13	13	0.81	1.07	0.93	1.18
Wyoming	408,356	776,528	1,363,879	2,305,525	6	5	5	2	2.05	4.19	6.63	10.29
Total**	19,955,823	18,532,439	20,570,293	22,402,141								

* Includes state and federal offshore production

** Includes federal Gulf of Mexico offshore production

Source: Energy Information Administration (2011 data unavailable)

Table B8

County-by-County Oil Production (Barrels)

	1950	1960	1970	1980	1990	2000	2010
Allen	29,940	1,012,122	570,796	664,014	512,567	220,231	216,161
Anderson	12,480	433,170	243,408	292,526	430,464	200,118	186,616
Atchison	0	0	0	0	0	0	0
Barber	1,139,892	1,399,886	806,203	964,249	910,886	473,796	1,822,698
Barton	19,424,231	10,245,807	5,628,888	3,752,180	2,861,812	1,600,501	2,193,822
Bourbon	24,342	28,338	123,561	84,610	149,396	40,208	57,374
Brown	5,579	0	4,043	5,953	2,601	0	0
Butler	6,862,459	7,799,582	3,782,978	2,701,731	2,156,498	1,277,899	1,124,699
Chase	37,594	103,734	64,015	38,944	24,111	39,912	30,190
Chautauqua	812,156	866,298	537,780	736,635	545,902	238,409	240,953
Cherokee	0	0	0	0	0	0	0
Cheyenne	0	13,919	0	88,628	61,063	75,936	91,045
Clark	0	196,649	100,066	791,520	425,012	125,679	431,389
Clay	0	10,340	0	0	0	2,500	3,789
Cloud	0	0	0	0	0	0	0
Coffey	107,394	100,672	131,708	375,093	185,116	137,456	222,062
Comanche	0	23,117	126,069	374,555	387,667	326,812	284,821
Cowley	1,908,243	3,672,337	2,231,547	2,113,902	1,174,762	470,553	444,809
Crawford	59,592	40,751	53,479	34,142	34,449	18,253	28,434
Decatur	0	376,531	662,830	464,187	269,100	130,423	288,124
Dickinson	162,132	62,005	36,940	25,369	30,165	14,501	8,889
Doniphan	0	0	0	0	0	0	0
Douglas	4,000	42,981	28,383	59,140	80,773	36,632	53,030
Edwards	15,009	777,673	235,867	841,415	468,072	203,564	172,008
Elk	182,408	226,278	170,399	229,381	196,343	76,333	63,739
Ellis	11,077,013	11,231,495	7,268,850	4,845,947	4,092,086	2,761,998	3,290,648
Ellsworth	4,149,448	1,654,791	1,291,662	737,699	543,132	325,931	276,772
Finney	215,621	361,396	1,316,296	1,190,724	1,626,570	2,427,038	1,672,361
Ford	0	8,444	27,440	14,720	114,394	75,802	362,909
Franklin	278,804	333,974	112,437	249,786	230,430	97,066	110,533
Geary	0	0	1,752	1,341	2,065	1,376	4,033
Gove	0	10,253	196,606	729,550	999,354	451,447	997,889
Graham	2,131,272	6,116,015	3,968,135	2,080,176	1,957,195	922,742	1,552,681
Grant	0	10,181	134,218	151,085	831,228	304,161	496,259
Gray	0	0	0	259,129	132,156	101,539	92,717
Greeley	0	0	0	89,628	353,707	184,831	199,000
Greenwood	5,375,676	4,758,538	2,158,024	1,177,233	935,594	596,150	465,196
Hamilton	0	13,225	3,380	1,626	4,810	334	0
Harper	7,445	1,212,124	887,487	611,442	455,303	306,196	361,448
Harvey	184,531	677,006	888,848	368,218	201,792	134,502	121,756
Haskell	0	2,427,089	1,247,076	639,789	1,316,196	2,397,757	2,006,044
Hodgeman	13,572	406,519	1,271,815	790,407	638,181	398,401	429,451
Jackson	0	0	15,398	0	6,226	0	1,438
Jefferson	50,532	0	0	0	66,613	21,547	19,423
Jewell	0	0	0	0	0	0	0
Johnson	0	5,235	21,975	18,851	234,277	168,286	158,529
Kearny	28,886	76,337	139,807	311,702	502,515	337,118	273,276
Kingman	147,904	3,174,208	2,701,878	1,214,277	742,989	466,910	628,111
Kiowa	8,275	827,953	735,796	743,807	585,580	334,064	268,550
Labette	6,922	109,598	24,059	55,109	36,140	10,867	8,253
Lane	0	0	38,672	768,254	922,170	546,922	931,892
Leavenworth	10,722	0	1,324	1,824	206,869	81,564	62,793
Lincoln	0	0	0	0	0	0	0
Linn	56,739	67,303	35,242	33,683	213,127	71,304	86,638
Logan	0	3,902	18,527	235,368	232,678	254,805	701,702
Lyon	353,959	157,160	175,609	99,197	66,243	19,656	9,470
McPherson	3,477,164	3,502,798	1,740,988	1,198,459	799,671	455,463	420,551
Marion	595,126	3,297,420	614,816	408,950	296,158	154,741	144,803
Marshall	0	0	0	0	0	0	0
Meade	0	1,018,572	643,190	377,565	493,364	194,388	428,716
Miami	492,171	406,792	119,914	315,101	268,341	137,335	126,839
Mitchell	0	0	0	0	0	0	0
Montgomery	785,932	494,293	300,615	487,564	422,449	99,025	133,352
Morris	26,328	425,022	277,407	188,485	147,818	102,751	62,269
Morton	186	1,340,515	2,506,478	1,516,121	1,650,650	512,880	567,385
Nemaha	13,193	10,046	6,662	6,596	193,074	58,470	48,880
Neosho	615,792	488,212	269,568	297,415	155,244	48,025	28,773
Ness	276,327	594,957	2,487,620	2,215,749	2,264,434	1,473,415	1,921,879

Table B8 *(continued)*

County-by-County Oil Production (Barrels)

	1950	1960	1970	1980	1990	2000	2010
Norton	48,295	882,145	546,909	331,496	192,930	100,883	202,837
Osage	0	0	0	15,261	918	642	1,911
Osborne	0	67,016	39,307	156,605	141,133	142,062	148,282
Ottawa	0	0	0	0	0	0	0
Pawnee	454,552	1,301,585	990,910	515,169	386,314	142,944	189,037
Phillips	2,225,857	1,913,264	1,923,650	1,090,842	771,794	456,639	306,251
Pottawatomie	0	0	0	0	1,512	3,174	958
Pratt	2,074,004	1,842,829	1,393,901	687,915	1,094,989	397,346	331,182
Rawlins	0	545,415	667,076	458,013	439,254	175,117	184,901
Reno	2,014,875	777,917	1,032,993	813,340	707,811	555,692	425,931
Republic	0	0	0	0	0	0	0
Rice	8,656,838	4,474,824	4,482,784	1,585,949	1,368,586	780,538	801,180
Riley	0	212,235	101,751	51,606	66,488	26,629	18,011
Rooks	5,759,190	5,634,607	4,216,198	2,672,803	3,168,872	1,632,813	2,008,081
Rush	473,307	301,081	1,110,960	416,226	491,004	221,014	392,920
Russell	13,561,393	8,336,647	6,825,538	4,105,021	3,374,653	1,989,818	1,993,685
Saline	361,030	648,244	347,801	177,669	129,319	71,693	65,720
Scott	50,737	49,423	165,870	108,696	174,034	361,349	662,699
Sedgwick	1,317,395	2,281,774	1,127,662	491,875	302,505	156,542	129,088
Seward	14,176	55,668	955,023	904,219	1,477,078	739,965	380,333
Shawnee	0	0	0	0	0	0	0
Sheridan	421,193	447,956	674,469	276,550	313,703	135,095	341,786
Sherman	0	0	12,859	20,478	8,179	4,431	5,658
Smith	0	0	0	0	0	0	0
Stafford	5,296,899	5,737,031	3,572,135	2,115,411	2,185,220	1,168,549	1,292,724
Stanton	0	31,107	18,732	59,063	476,453	361,505	327,164
Stevens	0	9,170	1,075,804	142,233	616,348	659,761	678,837
Sumner	1,314,572	3,070,483	1,689,124	1,138,696	874,981	509,851	416,571
Thomas	0	1,944	11,896	149,669	364,418	184,905	212,966
Trego	89,902	1,584,441	1,571,495	994,802	900,124	463,143	758,758
Wabaunsee	356,215	280,239	311,280	189,346	111,786	60,412	39,963
Wallace	0	0	0	2,580	266,953	251,161	88,401
Washington	0	0	0	0	0	0	0
Wichita	0	0	2,086	31,980	30,435	64,278	45,894
Wilson	71,005	197,080	173,446	285,161	208,177	112,425	120,440
Woodson	624,366	803,162	863,104	811,803	691,906	493,232	457,433
Wyandotte	0	0	0	0	90	0	0
State Total	107,339,000	113,344,548	85,093,294	59,871,228	57,185,549	35,174,434	40,467,479

Note: The sum of county totals do not add to state total for 1950 and 1960.
Source: Kansas Geological Survey

Table B9

County-by-County Share of Oil Production (State Totals in Barrels)

	1950	1960	1970	1980	1990	2000	2010
Allen	0.03%	0.89%	0.67%	1.11%	0.90%	0.63%	0.53%
Anderson	0.01%	0.38%	0.29%	0.49%	0.75%	0.57%	0.46%
Atchison	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Barber	1.07%	1.23%	0.95%	1.61%	1.59%	1.35%	4.50%
Barton	18.26%	8.98%	6.61%	6.27%	5.00%	4.55%	5.42%
Bourbon	0.02%	0.02%	0.15%	0.14%	0.26%	0.11%	0.14%
Brown	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%	0.00%
Butler	6.45%	6.83%	4.45%	4.51%	3.77%	3.63%	2.78%
Chase	0.04%	0.09%	0.08%	0.07%	0.04%	0.11%	0.07%
Chautauqua	0.76%	0.76%	0.63%	1.23%	0.95%	0.68%	0.60%
Cherokee	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cheyenne	0.00%	0.01%	0.00%	0.15%	0.11%	0.22%	0.22%
Clark	0.00%	0.17%	0.12%	1.32%	0.74%	0.36%	1.07%
Clay	0.00%	0.01%	0.00%	0.00%	0.00%	0.01%	0.01%
Cloud	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coffey	0.10%	0.09%	0.15%	0.63%	0.32%	0.39%	0.55%
Comanche	0.00%	0.02%	0.15%	0.63%	0.68%	0.93%	0.70%
Cowley	1.79%	3.22%	2.62%	3.53%	2.05%	1.34%	1.10%
Crawford	0.06%	0.04%	0.06%	0.06%	0.06%	0.05%	0.07%
Decatur	0.00%	0.33%	0.78%	0.78%	0.47%	0.37%	0.71%
Dickinson	0.15%	0.05%	0.04%	0.04%	0.05%	0.04%	0.02%
Doniphan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.04%	0.03%	0.10%	0.14%	0.10%	0.13%
Edwards	0.01%	0.68%	0.28%	1.41%	0.82%	0.58%	0.43%
Elk	0.17%	0.20%	0.20%	0.38%	0.34%	0.22%	0.16%
Ellis	10.42%	9.84%	8.54%	8.09%	7.16%	7.85%	8.13%
Ellsworth	3.90%	1.45%	1.52%	1.23%	0.95%	0.93%	0.68%
Finney	0.20%	0.32%	1.55%	1.99%	2.84%	6.90%	4.13%
Ford	0.00%	0.01%	0.03%	0.02%	0.20%	0.22%	0.90%
Franklin	0.26%	0.29%	0.13%	0.42%	0.40%	0.28%	0.27%
Geary	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
Gove	0.00%	0.01%	0.23%	1.22%	1.75%	1.28%	2.47%
Graham	2.00%	5.36%	4.66%	3.47%	3.42%	2.62%	3.84%
Grant	0.00%	0.01%	0.16%	0.25%	1.45%	0.86%	1.23%
Gray	0.00%	0.00%	0.00%	0.43%	0.23%	0.29%	0.23%
Greeley	0.00%	0.00%	0.00%	0.15%	0.62%	0.53%	0.49%
Greenwood	5.05%	4.17%	2.54%	1.97%	1.64%	1.70%	1.15%
Hamilton	0.00%	0.01%	0.00%	0.00%	0.01%	0.00%	0.00%
Harper	0.01%	1.06%	1.04%	1.02%	0.80%	0.87%	0.89%
Harvey	0.17%	0.59%	1.04%	0.62%	0.35%	0.38%	0.30%
Haskell	0.00%	2.13%	1.47%	1.07%	2.30%	6.82%	4.96%
Hodgeman	0.01%	0.36%	1.49%	1.32%	1.12%	1.13%	1.06%
Jackson	0.00%	0.00%	0.02%	0.00%	0.01%	0.00%	0.00%
Jefferson	0.05%	0.00%	0.00%	0.00%	0.12%	0.06%	0.05%
Jewell	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Johnson	0.00%	0.00%	0.03%	0.03%	0.41%	0.48%	0.39%
Kearny	0.03%	0.07%	0.16%	0.52%	0.88%	0.96%	0.68%
Kingman	0.14%	2.78%	3.18%	2.03%	1.30%	1.33%	1.55%
Kiowa	0.01%	0.73%	0.86%	1.24%	1.02%	0.95%	0.66%
Labette	0.01%	0.10%	0.03%	0.09%	0.06%	0.03%	0.02%
Lane	0.00%	0.00%	0.05%	1.28%	1.61%	1.56%	2.30%
Leavenworth	0.01%	0.00%	0.00%	0.00%	0.36%	0.23%	0.16%
Lincoln	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Linn	0.05%	0.06%	0.04%	0.06%	0.37%	0.20%	0.21%
Logan	0.00%	0.00%	0.02%	0.39%	0.41%	0.72%	1.73%
Lyon	0.33%	0.14%	0.21%	0.17%	0.12%	0.06%	0.02%
McPherson	3.27%	3.07%	2.05%	2.00%	1.40%	1.30%	1.04%
Marion	0.56%	2.89%	0.72%	0.68%	0.52%	0.44%	0.36%
Marshall	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Meade	0.00%	0.89%	0.76%	0.63%	0.86%	0.55%	1.06%
Miami	0.46%	0.36%	0.14%	0.53%	0.47%	0.39%	0.31%
Mitchell	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Montgomery	0.74%	0.43%	0.35%	0.81%	0.74%	0.28%	0.33%
Morris	0.02%	0.37%	0.33%	0.31%	0.26%	0.29%	0.15%
Morton	0.00%	1.17%	2.95%	2.53%	2.89%	1.46%	1.40%
Nemaha	0.01%	0.01%	0.01%	0.01%	0.34%	0.17%	0.12%
Neosho	0.58%	0.43%	0.32%	0.50%	0.27%	0.14%	0.07%
Ness	0.26%	0.52%	2.92%	3.70%	3.96%	4.19%	4.75%

Table B9 *(continued)*

County-by-County Share of Oil Production (State Totals in Barrels)

	1950	1960	1970	1980	1990	2000	2010
Norton	0.05%	0.77%	0.64%	0.55%	0.34%	0.29%	0.50%
Osage	0.00%	0.00%	0.00%	0.03%	0.00%	0.00%	0.00%
Osborne	0.00%	0.06%	0.05%	0.26%	0.25%	0.40%	0.37%
Ottawa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pawnee	0.43%	1.14%	1.16%	0.86%	0.68%	0.41%	0.47%
Phillips	2.09%	1.68%	2.26%	1.82%	1.35%	1.30%	0.76%
Pottawatomie	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%
Pratt	1.95%	1.61%	1.64%	1.15%	1.91%	1.13%	0.82%
Rawlins	0.00%	0.48%	0.78%	0.76%	0.77%	0.50%	0.46%
Reno	1.89%	0.68%	1.21%	1.36%	1.24%	1.58%	1.05%
Republic	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rice	8.14%	3.92%	5.27%	2.65%	2.39%	2.22%	1.98%
Riley	0.00%	0.19%	0.12%	0.09%	0.12%	0.08%	0.04%
Rooks	5.42%	4.94%	4.95%	4.46%	5.54%	4.64%	4.96%
Rush	0.45%	0.26%	1.31%	0.70%	0.86%	0.63%	0.97%
Russell	12.75%	7.30%	8.02%	6.86%	5.90%	5.66%	4.93%
Saline	0.34%	0.57%	0.41%	0.30%	0.23%	0.20%	0.16%
Scott	0.05%	0.04%	0.19%	0.18%	0.30%	1.03%	1.64%
Sedgwick	1.24%	2.00%	1.33%	0.82%	0.53%	0.45%	0.32%
Seward	0.01%	0.05%	1.12%	1.51%	2.58%	2.10%	0.94%
Shawnee	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sheridan	0.40%	0.39%	0.79%	0.46%	0.55%	0.38%	0.84%
Sherman	0.00%	0.00%	0.02%	0.03%	0.01%	0.01%	0.01%
Smith	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Stafford	4.98%	5.03%	4.20%	3.53%	3.82%	3.32%	3.19%
Stanton	0.00%	0.03%	0.02%	0.10%	0.83%	1.03%	0.81%
Stevens	0.00%	0.01%	1.26%	0.24%	1.08%	1.88%	1.68%
Sumner	1.24%	2.69%	1.99%	1.90%	1.53%	1.45%	1.03%
Thomas	0.00%	0.00%	0.01%	0.25%	0.64%	0.53%	0.53%
Trego	0.08%	1.39%	1.85%	1.66%	1.57%	1.32%	1.87%
Wabaunsee	0.33%	0.25%	0.37%	0.32%	0.20%	0.17%	0.10%
Wallace	0.00%	0.00%	0.00%	0.00%	0.47%	0.71%	0.22%
Washington	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wichita	0.00%	0.00%	0.00%	0.05%	0.05%	0.18%	0.11%
Wilson	0.07%	0.17%	0.20%	0.48%	0.36%	0.32%	0.30%
Woodson	0.59%	0.70%	1.01%	1.36%	1.21%	1.40%	1.13%
Wyandotte	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
State Total	107,339,000	113,344,548	85,093,294	59,871,228	57,185,549	35,174,434	40,467,479

Source: Kansas Geological Survey

Table B10

County-by-County Gas Production (1,000 Cubic Feet)

	1953*	1960	1970	1980	1990	2000	2010
Allen	357,136	84,667	56,169	23,185	59,668	193,163	479,405
Anderson	0	0	0	7,773	19,953	0	0
Atchison	0	0	0	0	509,711	0	21,239
Barber	6,644,619	53,315,227	30,787,783	15,924,038	14,387,053	11,522,597	19,988,407
Barton	2,530,856	720,233	1,293,969	357,434	563,111	425,351	346,469
Bourbon	0	0	0	0	3,831	4,832	23,380
Brown	0	0	0	0	0	0	0
Butler	0	0	0	0	900	0	0
Chase	69,530	34,540	0	51,455	288,847	288,281	187,927
Chautauqua	134,660	102,454	2,300	239,784	589,357	695,686	583,593
Cherokee	0	0	0	0	0	0	0
Cheyenne	0	0	0	250,619	252,608	391,159	4,297,846
Clark	697,936	6,811,276	7,622,545	7,267,621	4,547,587	3,343,851	3,250,392
Clay	0	0	0	0	0	0	0
Cloud	0	0	0	0	0	0	0
Coffey	11,324	721	0	9,556	2,167	0	48,591
Comanche	0	0	10,269,579	11,433,163	7,936,788	9,896,846	5,462,113
Cowley	1,147,183	1,413,270	504,861	1,844,459	799,301	59,801	155,710
Crawford	45,124	28,651	0	5,217	0	0	25,041
Decatur	0	0	0	0	0	0	0
Dickinson	0	0	0	0	0	0	0
Doniphan	0	0	0	0	0	0	0
Douglas	0	0	0	0	3,337	0	0
Edwards	205,319	1,780,355	5,883,402	6,827,946	3,518,282	2,337,765	1,771,409
Elk	323,433	151,308	94,841	296,577	442,471	163,870	16,781
Ellis	0	0	0	0	0	3,935	0
Ellsworth	17,312	39,332	12,637	909,447	126,950	87,411	356,041
Finney	30,784,079	53,961,070	55,119,195	42,564,954	35,991,543	41,635,762	20,780,789
Ford	10,861	389,851	40,682	1,634,863	1,602,950	463,088	1,841,060
Franklin	0	0	0	129,909	76,733	5,320	7,837
Geary	0	0	0	0	0	0	0
Gove	0	0	0	0	0	0	0
Graham	0	0	0	0	0	0	0
Grant	84,403,364	91,748,893	166,553,679	103,571,719	107,170,799	77,263,890	34,728,185
Gray	0	0	0	0	99,741	97,513	292,578
Greeley	0	0	3,537	4,449,341	5,392,775	4,969,652	2,579,266
Greenwood	0	0	0	0	27,962	1,476	0
Hamilton	5,367,827	4,548,756	19,157,520	12,234,013	10,287,735	13,109,060	6,634,281
Harper	106,507	4,860,913	5,626,767	5,959,346	5,341,887	3,955,949	5,000,614
Harvey	432,415	339,089	394,861	1,872,721	519,500	265,328	246,127
Haskell	31,315,837	35,945,374	56,006,875	37,849,909	37,398,294	44,418,824	24,052,614
Hodgeman	0	0	0	0	56,754	37,098	0
Jackson	0	0	0	0	0	0	0
Jefferson	36,384	0	0	0	159,886	0	0
Jewell	0	0	0	0	0	0	0
Johnson	25,728	76,816	0	30,331	267,122	217,046	46,096
Kearny	71,955,888	69,931,846	127,193,423	88,603,826	58,305,831	65,609,222	30,875,353
Kingman	1,368,757	18,982,088	29,303,547	19,733,353	12,553,998	7,359,218	7,507,643
Kiowa	4,094	3,384,213	22,121,167	15,077,139	11,530,130	5,601,834	3,133,430
Labette	27,871	71,220	0	0	235,196	101,765	4,237,576
Lane	0	0	0	0	0	0	0
Leavenworth	18,545	4,225	0	0	1,585,820	124,877	85,619
Lincoln	0	0	0	0	0	0	0
Linn	10,635	0	0	0	45,215	14,834	0
Logan	0	0	0	0	0	0	0
Lyon	0	0	0	13,465	0	0	0
McPherson	0	260,320	577,449	1,449,044	495,928	189,537	123,168
Marion	108,986	988,700	1,169,913	1,642,677	1,061,074	593,867	448,539
Marshall	0	0	0	0	0	0	0
Meade	2,987,016	14,312,613	15,621,769	10,207,092	8,843,614	6,169,935	4,944,467
Miami	67,126	0	0	223	2,412	83,959	211,694
Mitchell	0	0	0	0	0	0	0
Montgomery	597,832	338,631	0	493,711	1,040,844	1,184,101	12,284,485
Morris	48,371	428,895	0	1,072,105	0	0	0
Morton	24,357,419	76,950,127	87,922,772	57,602,753	49,217,313	43,168,233	23,704,723
Nemaha	0	0	0	0	0	0	0
Neosho	129,315	117,744	668	345	69,513	151,271	12,940,892
Ness	0	0	0	0	0	0	0

Table B10 *(continued)*

County-by-County Gas Production (1,000 Cubic Feet)

	1953*	**1960**	**1970**	**1980**	**1990**	**2000**	**2010**
Norton	0	0	0	0	0	0	0
Osage	0	0	0	0	0	0	0
Osborne	0	0	0	0	0	0	0
Ottawa	0	0	0	0	0	0	0
Pawnee	3,146,047	2,869,283	3,438,583	3,049,770	2,093,986	1,235,647	677,891
Phillips	0	0	0	0	0	0	0
Pottawatomie	0	0	0	0	0	0	0
Pratt	2,323,599	1,364,422	1,037,314	6,757,066	3,345,701	1,620,755	2,887,566
Rawlins	0	0	0	0	0	0	
Reno	448,918	3,963,203	1,892,149	1,368,771	872,434	1,362,340	781,789
Republic	0	0	0	0	0	0	0
Rice	377,030	458,170	683,006	1,321,201	1,220,114	560,177	647,512
Riley	0	0	0	0	0	0	
Rooks	0	0	0	0	0	0	
Rush	1,353,835	1,681,004	2,204,811	793,657	762,977	300,572	271,613
Russell	0	279,705	15,547	177,665	33,248	0	0
Saline	0	0	0	0	0	0	0
Scott	0	0	147,200	224,713	360,474	317,998	375,415
Sedgwick	558,751	16,375	0	383,471	66,911	19,871	11,293
Seward	26,997,298	33,009,597	39,723,417	27,536,072	34,734,682	31,836,473	17,177,937
Shawnee	0	0	0	0	0	0	0
Sheridan	0	0	0	0	0	0	0
Sherman	0	0	0	0	338,194	289,978	1,042,573
Smith	0	0	0	0	0	0	0
Stafford	1,161,615	1,149,863	1,372,098	1,220,554	1,320,616	1,060,411	562,713
Stanton	16,018,254	21,848,436	39,210,192	30,144,656	15,346,607	24,972,105	12,736,668
Stevens	101,239,764	122,005,132	165,782,609	166,614,937	147,874,199	122,221,338	48,801,747
Sumner	0	339,126	2,162,059	1,901,058	246,461	711,635	710,031
Thomas	0	0	0	0	0	0	0
Trego	0	0	0	0	0	0	0
Wabaunsee	0	0	0	0	0	0	0
Wallace	0	0	0	0	981	140,639	76,041
Washington	0	0	0	0	0	0	0
Wichita	0	0	0	0	152,413	104,365	74,211
Wilson	191,642	153,456	5,179	200,714	413,715	635,502	12,483,535
Woodson	11,824	6,774	1,375	1,079	123,082	43,181	109,700
Wyandotte	5,470	0	0	5,645	0	0	
State Total	420,588,383	632,609,850	901,017,449	693,342,142	592,739,286	533,658,257	333,149,615

* The production from the Hugoton gas field was not split among counties before 1953. The sum of county totals do not add to state total for 1953 and 1960.
Source: Kansas Geological Survey

Table B11

County-by-County Share of Natural Gas Production (State Totals in 1,000 Cubic Feet)

	1953*	1960	1970	1980	1990	2000	2010
Allen	0.08%	0.01%	0.01%	0.00%	0.01%	0.04%	0.14%
Anderson	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Atchison	0.00%	0.00%	0.00%	0.00%	0.09%	0.00%	0.01%
Barber	1.58%	8.45%	3.42%	2.30%	2.43%	2.16%	6.00%
Barton	0.60%	0.11%	0.14%	0.05%	0.10%	0.08%	0.10%
Bourbon	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
Brown	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Butler	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Chase	0.02%	0.01%	0.00%	0.01%	0.05%	0.05%	0.06%
Chautauqua	0.03%	0.02%	0.00%	0.03%	0.10%	0.13%	0.18%
Cherokee	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cheyenne	0.00%	0.00%	0.00%	0.04%	0.04%	0.07%	1.29%
Clark	0.17%	1.08%	0.85%	1.05%	0.77%	0.63%	0.98%
Clay	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Cloud	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Coffey	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
Comanche	0.00%	0.00%	1.14%	1.65%	1.34%	1.85%	1.64%
Cowley	0.27%	0.22%	0.06%	0.27%	0.13%	0.01%	0.05%
Crawford	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%
Decatur	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Dickinson	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Doniphan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Douglas	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Edwards	0.05%	0.28%	0.65%	0.98%	0.59%	0.44%	0.53%
Elk	0.08%	0.02%	0.01%	0.04%	0.07%	0.03%	0.01%
Ellis	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ellsworth	0.00%	0.01%	0.00%	0.13%	0.02%	0.02%	0.11%
Finney	7.33%	8.55%	6.12%	6.14%	6.07%	7.80%	6.24%
Ford	0.00%	0.06%	0.00%	0.24%	0.27%	0.09%	0.55%
Franklin	0.00%	0.00%	0.00%	0.02%	0.01%	0.00%	0.00%
Geary	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Gove	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Graham	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Grant	20.09%	14.53%	18.49%	14.94%	18.08%	14.48%	10.42%
Gray	0.00%	0.00%	0.00%	0.00%	0.02%	0.02%	0.09%
Greeley	0.00%	0.00%	0.00%	0.64%	0.91%	0.93%	0.77%
Greenwood	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Hamilton	1.28%	0.72%	2.13%	1.76%	1.74%	2.46%	1.99%
Harper	0.03%	0.77%	0.62%	0.86%	0.90%	0.74%	1.50%
Harvey	0.10%	0.05%	0.04%	0.27%	0.09%	0.05%	0.07%
Haskell	7.45%	5.69%	6.22%	5.46%	6.31%	8.32%	7.22%
Hodgeman	0.00%	0.00%	0.00%	0.00%	0.01%	0.01%	0.00%
Jackson	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Jefferson	0.01%	0.00%	0.00%	0.00%	0.03%	0.00%	0.00%
Jewell	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Johnson	0.01%	0.01%	0.00%	0.00%	0.05%	0.04%	0.01%
Kearny	17.12%	11.08%	14.12%	12.78%	9.84%	12.29%	9.27%
Kingman	0.33%	3.01%	3.25%	2.85%	2.12%	1.38%	2.25%
Kiowa	0.00%	0.54%	2.46%	2.17%	1.95%	1.05%	0.94%
Labette	0.01%	0.01%	0.00%	0.00%	0.04%	0.02%	1.27%
Lane	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Leavenworth	0.00%	0.00%	0.00%	0.00%	0.27%	0.02%	0.03%
Lincoln	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Linn	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%	0.00%
Logan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Lyon	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
McPherson	0.00%	0.04%	0.06%	0.21%	0.08%	0.04%	0.04%
Marion	0.03%	0.16%	0.13%	0.24%	0.18%	0.11%	0.13%
Marshall	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Meade	0.71%	2.27%	1.73%	1.47%	1.49%	1.16%	1.48%
Miami	0.02%	0.00%	0.00%	0.00%	0.00%	0.02%	0.06%
Mitchell	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Montgomery	0.14%	0.05%	0.00%	0.07%	0.18%	0.22%	3.69%
Morris	0.01%	0.07%	0.00%	0.15%	0.00%	0.00%	0.00%
Morton	5.80%	12.19%	9.76%	8.31%	8.30%	8.09%	7.12%
Nemaha	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Neosho	0.03%	0.02%	0.00%	0.00%	0.01%	0.03%	3.88%
Ness	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%

Table B11 *(continued)*

County-by-County Share of Natural Gas Production (State Totals in 1,000 Cubic Feet)

	1953*	1960	1970	1980	1990	2000	2010
Norton	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Osage	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Osborne	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Ottawa	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pawnee	0.75%	0.45%	0.38%	0.44%	0.35%	0.23%	0.20%
Phillips	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pottawatomie	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pratt	0.55%	0.22%	0.12%	0.97%	0.56%	0.30%	0.87%
Rawlins	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Reno	0.11%	0.63%	0.21%	0.20%	0.15%	0.26%	0.23%
Republic	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rice	0.09%	0.07%	0.08%	0.19%	0.21%	0.10%	0.19%
Riley	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rooks	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Rush	0.32%	0.27%	0.24%	0.11%	0.13%	0.06%	0.08%
Russell	0.00%	0.04%	0.00%	0.03%	0.01%	0.00%	0.00%
Saline	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Scott	0.00%	0.00%	0.02%	0.03%	0.06%	0.06%	0.11%
Sedgwick	0.13%	0.00%	0.00%	0.06%	0.01%	0.00%	0.00%
Seward	6.43%	5.23%	4.41%	3.97%	5.86%	5.97%	5.16%
Shawnee	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sheridan	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Sherman	0.00%	0.00%	0.00%	0.00%	0.06%	0.05%	0.31%
Smith	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Stafford	0.28%	0.18%	0.15%	0.18%	0.22%	0.20%	0.17%
Stanton	3.81%	3.46%	4.35%	4.35%	2.59%	4.68%	3.82%
Stevens	24.09%	19.33%	18.40%	24.03%	24.95%	22.90%	14.65%
Sumner	0.00%	0.05%	0.24%	0.27%	0.04%	0.13%	0.21%
Thomas	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Trego	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wabaunsee	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wallace	0.00%	0.00%	0.00%	0.00%	0.00%	0.03%	0.02%
Washington	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Wichita	0.00%	0.00%	0.00%	0.00%	0.03%	0.02%	0.02%
Wilson	0.05%	0.02%	0.00%	0.03%	0.07%	0.12%	3.75%
Woodson	0.00%	0.00%	0.00%	0.00%	0.02%	0.01%	0.03%
Wyandotte	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
State Total	420,588,383	632,609,850	901,017,449	693,342,142	592,739,286	533,658,257	333,149,615

* The production from the Hugoton gas field was not split among counties before 1953.
Source: Kansas Geological Survey

Table B12

Estimated Economic Impact of Upstream and Downstream Oil and Gas Industry (Average Annual Economic Contribution from 1998 to 2010; Thousands of 2010 Dollars)

Upstream Sector	Job Count: Estab. with Employees**	Job Count: Estab. without Employees**	Payroll:* Estab. with Employees	Receipts: Estab. without Employees	Estimated Indirect Jobs	Estimated Indirect Payroll	Estimated Induced Jobs	Estimated Induced Payroll
Oil and gas extraction	2,811	6,143	$194,767	$486,933	4,830	$235,377	7,278	$210,569
Drilling oil and gas wells	1,322	0	70,905	0	728	38,375	802	24,357
Support activities for oil and gas operations	2,925	302	152,266	22,528	2,042	100,146	1,928	61,280
Oil and gas pipeline construction	1,108	52	74,097	2,659	379	27,523	483	23,347
Pipeline transportation of crude oil	173	0	18,261	0	202	10,168	175	6,317
Pipeline transportation of natural gas	701	0	74,965	0	816	41,740	709	25,932
Geophysical surveying and mapping	212	39	11,292	1,630	97	2,689	156	3,505
Downstream Sector								
Natural gas distribution	1,807	0	144,191	0	833	40,718	1,515	41,248
Petroleum refineries	1,519	0	139,400	0	5,774	452,803	10,544	425,299
Liquefied petroleum gas, bottled gas, dealers	521	52	21,012	7,599	36	2,019	36	1,717
Refined petroleum product pipeline transportation	466	0	42,268	0	542	23,534	471	14,621
Naural-gas powered electricity generation	272	0	27,439	0	83	6,461	250	13,676
Asphalt paving mixture and block mfg.	200	16	10,989	604	142	7,815	647	17,775
Asphalt shingle and coating materials mfg.	241	5	14,727	933	215	13,270	1,198	39,189
Petroleum lubricating oil and grease mfg.	187	13	13,943	978	226	13,219	1,132	37,436
Nitrogenous fertilizer manufacturing	183	0	14,783	0	309	22,033	234	9,883
Heating oil dealers	176	52	6,855	7,599	14	999	14	850
Petroleum merchant wholesalers	1,587	34	105,773	6,286	611	29,104	913	31,297
Gasoline stations	11,123	125	230,669	23,224	1,736	68,116	2,320	71,649
General freight trucking	9,248	3,395	476,997	338,655	4,639	255,613	5,554	233,728
Specialized freight trucking	4,604	362	206,930	30,199	1,822	76,013	2,182	69,505
Rail transportation	403	0	49,789	0	277	16,985	345	14,807
Industrial gas mfg.	237	0	17,689	0	346	27,828	368	14,159

* Includes estimates of benefits.
** Note: Job counts have been adjusted when necessary to estimate only those counts supported by the oil and gas value chain.
Estab. = Establishments (places of business with a physical address).
Source: Census Bureau; Bureau of Labor Statistics; IMPLAN; Center for Applied Economics, KU School of Business

Table B13

Estimated Share of Select Tax Supported by the Oil and Gas Industry Value Chain (Average Annual Economic Contribution from 1998 to 2010; Thousands of 2010 Dollars)

	O&G Property + Severance	Motor Fuels	Unemp Comp Tax	Personal Income Tax	Residential Property	Sales Tax	Insurance Premiums	Mortgage Registration	Vehicle Related Taxes/ Fees	Alcohol and Tobacco	Total	Share of State-wide Avg. Total
Oil and gas extraction	298,538	0	2,655	32,485	22,374	49,892	1,798	715	7,574	3,558	419,589	4.5%
Drilling oil and gas wells	0	0	566	3,621	3,139	5,827	251	100	1,031	419	14,953	0.2%
Support activities for oil and gas operations	0	0	1,273	8,402	7,525	13,935	607	243	2,527	988	35,499	0.4%
Oil and gas pipeline construction	0	0	364	3,660	2,132	5,156	172	68	718	367	12,638	0.1%
Pipeline transportation of crude oil	0	0	97	1,018	553	1,462	46	19	194	104	3,494	0.0%
Pipeline transportation of natural gas	0	0	387	4,211	2,168	6,064	183	76	784	421	14,294	0.2%
Geophysical Surveying and Mapping	0	0	87	342	548	764	43	17	179	55	2,035	0.0%
Natural gas distribution	0	0	737	6,013	4,213	9,173	344	141	1,468	641	22,730.2	0.2%
Petroleum refineries	0	0	3,092	34,272	17,818	48,326	1,474	598	6,283	3,372	115,234.7	1.2%
Liquefied petroleum gas, bottled gas, dealers	0	0	99	740	633	1,277	52	22	228	89	3,140.1	0.0%
Refined petroleum product pipeline transportation	0	0	255	2,229	1,443	3,359	119	50	518	230	8,204.6	0.1%
Naural-gas powered electricity generation	0	0	106	1,878	608	2,377	50	20	214	164	5,417.6	0.1%
Asphalt paving mixture and block mfg.	0	0	148	995	955	1,716	81	33	360	114	4,402.8	0.0%
Asphalt shingle and coating materials mfg.	0	0	280	2,041	1,580	3,237	134	57	584	221	8,133.0	0.1%
Petroleum lubricating oil and grease mfg.	0	0	304	1,946	1,601	3,021	132	55	546	216	7,821.5	0.1%
Nitrogenous fertilizer manufacturing	0	0	119	1,538	732	2,025	60	24	257	142	4,895.9	0.1%
Heating oil dealers	0	0	38	562	254	678	21	9	91	48	1,699.8	0.0%
Petroleum merchant wholesalers	0	0	544	4,530	3,183	7,003	262	106	1,112	494	17,233.3	0.2%
Gasoline stations	0	447,605	2,612	5,640	15,208	15,700	1,259	516	5,405	1,078	495,024.1	5.3%
General freight trucking	0	0	3,400	48,292	23,217	73,735	1,895	769	8,069	5,143	164,519.0	1.8%
Specialized freight trucking	0	0	1,503	11,969	9,101	21,451	744	302	3,168	1,494	49,732.1	0.5%
Rail transportation	0	0	992	11,898	5,807	16,676	480	196	2,075	1,130	39,255.2	0.4%
Industrial gas mfg.	0	0	162	2,011	935	2,751	78	32	335	188	6,492.0	0.1%

Note: Estimates do not include corporate income taxes or business-level property taxes. These levies could be substantial but there is no credible way to estimate them.

Source: Kansas Tax Facts (various years); Kansas Department of Revenue; Center for Applied Economics, KU School of Business

Table B14

Property Taxes Paid by Oil and Gas Properties (Average Inflation-Adjusted Dollars and Shares, 1998-2010)

County	Average Property Taxes Paid (Millions)	Share of O&G Property Taxes Paid Statewide (Percent)	O&G Share of Total Property Tax Paid (Percent)
Kansas	$189.55	n.a.	5.7%
Allen	0.26	0.1	2.1
Anderson	0.16	0.1	1.6
Atchison	0.00	0.0	0.0
Barber	4.11	2.0	36.7
Barton	3.52	1.7	10.5
Bourbon	0.04	0.0	0.3
Brown	0.00	0.0	0.0
Butler	1.79	0.9	2.5
Chase	0.12	0.1	2.2
Chautauqua	0.42	0.2	10.0
Cherokee	0.00	0.0	0.0
Cheyenne	0.57	0.3	13.1
Clark	1.65	0.8	23.2
Clay	0.00	0.0	0.0
Cloud	0.00	0.0	0.0
Coffey	0.09	0.0	0.2
Comanche	2.77	1.5	49.8
Cowley	0.84	0.4	2.5
Crawford	0.02	0.0	0.1
Decatur	0.45	0.2	8.7
Dickinson	0.01	0.0	0.1
Doniphan	0.00	0.0	0.0
Douglas	0.03	0.0	0.0
Edwards	0.78	0.4	12.3
Elk	0.12	0.1	3.2
Ellis	4.93	2.4	14.6
Ellsworth	0.51	0.3	5.7
Finney	14.20	7.8	26.0
Ford	0.49	0.2	1.2
Franklin	0.08	0.0	0.3
Geary	0.01	0.0	0.0
Gove	0.90	0.4	16.6
Graham	2.69	1.2	37.3
Grant	19.33	10.8	65.6
Gray	0.22	0.1	2.5
Greeley	1.28	0.7	25.0
Greenwood	0.69	0.3	7.9
Hamilton	3.95	2.2	42.8
Harper	1.92	1.0	18.3
Harvey	0.29	0.1	1.0
Haskell	12.88	7.0	73.1
Hodgeman	0.92	0.4	16.6
Jackson	0.00	0.0	0.0
Jefferson	0.03	0.0	0.1
Jewell	0.00	0.0	0.0
Johnson	0.13	0.1	0.0
Kearny	16.86	9.5	75.2
Kingman	3.18	1.6	23.5
Kiowa	1.76	1.0	21.5
Labette	0.25	0.1	1.2
Lane	1.62	0.8	27.8
Leavenworth	0.10	0.0	0.2
Lincoln	0.00	0.0	0.0
Linn	0.05	0.0	0.3
Logan	0.61	0.3	11.0
Lyon	0.02	0.0	0.1
Marion	0.38	0.2	2.7
Marshall	0.00	0.0	0.0
McPherson	0.57	0.3	1.6
Meade	1.87	1.0	15.9
Miami	$0.13	0.1%	0.3%
Mitchell	0.00	0.0	0.0
Montgomery	1.16	0.5	2.5
Morris	0.15	0.1	2.1
Morton	10.59	5.9	65.8
Nemaha	0.11	0.1	1.1
Neosho	1.13	0.5	6.4
Ness	3.14	1.5	39.8
Norton	0.24	0.1	4.1
Osage	0.00	0.0	0.0
Osborne	0.19	0.1	3.5
Ottawa	0.00	0.0	0.0
Pawnee	0.50	0.3	5.4
Phillips	0.64	0.3	8.6
Pottawatomie	0.00	0.0	0.0
Pratt	1.40	0.7	7.1
Rawlins	0.39	0.2	8.5
Reno	1.54	0.8	2.1
Republic	0.00	0.0	0.0
Rice	1.36	0.7	9.1
Riley	0.01	0.0	0.0
Rooks	3.43	1.6	34.4
Rush	0.54	0.3	9.5
Russell	3.28	1.6	24.9
Saline	0.08	0.0	0.1
Scott	0.97	0.4	9.2
Sedgwick	0.24	0.1	0.1
Seward	10.85	5.8	34.0
Shawnee	0.00	0.0	0.0
Sheridan	0.44	0.2	9.1
Sherman	0.08	0.0	1.0
Smith	0.00	0.0	0.0
Stafford	2.26	1.1	22.3
Stanton	7.87	4.4	70.1
Stevens	21.74	12.1	78.1
Sumner	1.17	0.6	4.3
Thomas	0.35	0.2	3.0
Trego	1.15	0.5	18.1
Wabaunsee	0.08	0.0	1.0
Wallace	0.39	0.2	11.1
Washington	0.00	0.0	0.0
Wichita	0.12	0.1	2.3
Wilson	1.03	0.4	9.9
Woodson	0.36	0.2	8.4
Wyandotte	0.00	0.0	0.0

Source: Kansas Department of Revenue; Center for Applied Economics, KU School of Business

DIRECTORY OF EXHIBITS, CHARTS AND MAPS

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