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Hydraulic Fracturing:

Environmental Costs vs. Economic Benefits

Finance Honors Thesis

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Importance of Refined Oil

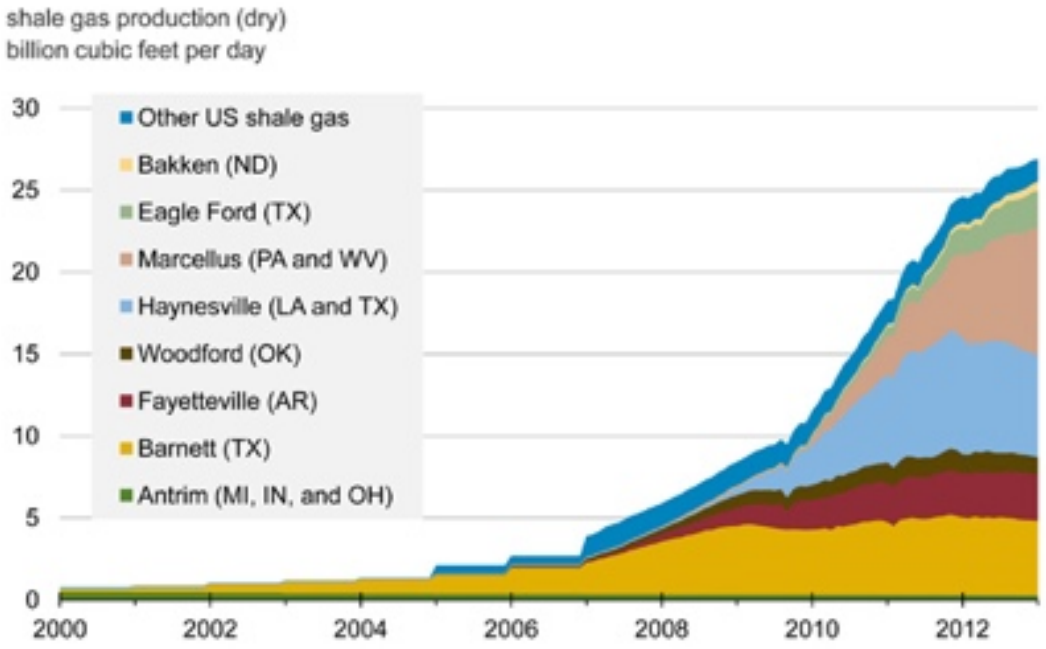
Crude oil is a naturally occurring petroleum liquid that is made up of hydrocarbon deposits and other organic materials (“Crude Oil”). It is relied upon by the oil and natural gas industry because the world’s population uses refined oil in many ways. Before oil is refined, however, it goes through an intricate process to make it into the products we use. I have bene fortunate enough to get to work at an oil and gas manufacturing company and see the process of refining up close and visit multiple refineries to know what all goes into the practice. Refining is a complex series of processes, discussed below, that manufactures finished petroleum products out of barrels and barrels of crude oil. Refining begins as a distillation process by heating and separating crude oil, but more sophisticated processes and equipment are used in order to produce the mix of products that the market demands, including not only gasoline but jet fuel, asphalt, kerosene, and other materials. The more sophisticated processes minimize the production of heavier products (for example, residual fuel oil) because they hold lower value to the company. Because of the low value of the heavy products, refiners produce more mid-weighted products (jet fuel, kerosene, home heating oil and diesel fuel) and even more lighter products (liquid petroleum gases, naphtha, and gasoline), which hold the most value ("What Is Crude Oil, and What Is It Used For?").

History of Fracking

As the crude oil resources in the world have quickly diminished because of high market demand for refined products, companies have searched for ways to look for new sources of oil, such as shale reservoirs and other “tight oil” reserves. The increase in shale gas production over the past few decades is exceptional, as show below. Oil is trapped in open spaces in porous

rocks called porosity. This oil that is acquired through the fracking process is referred to as "tight oil", and can be refined through the process discussed in the next section to make the fuels and other products that we use daily.

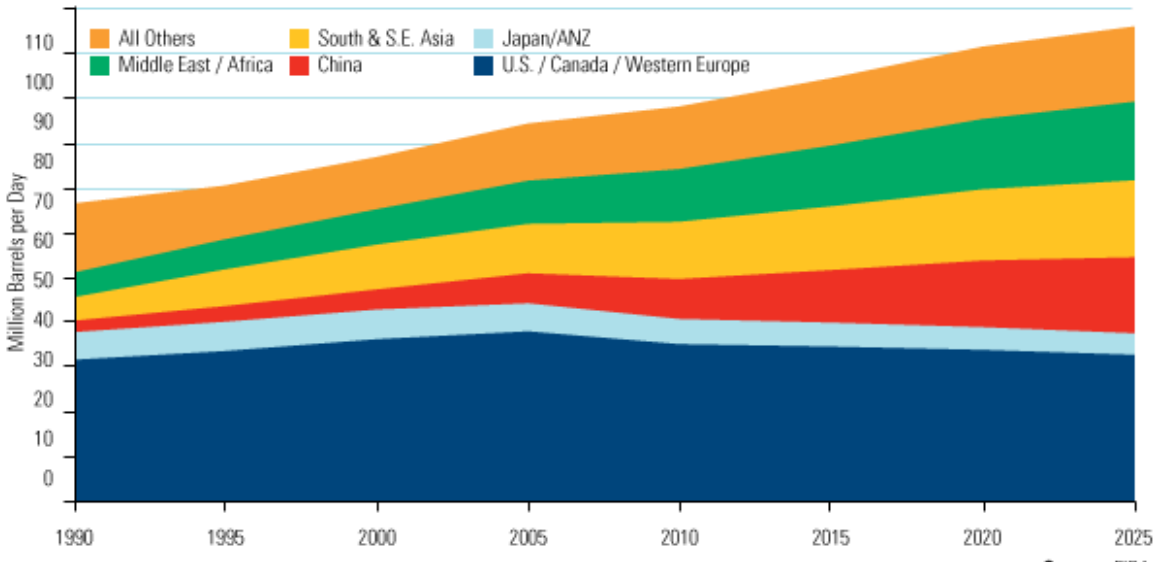
Exhibit 1: Shale Gas Production 2000-2012



Source: LCI Energy Insight

Fracking first began because as a population, we needed more refined oil. The practice of fracking is not new, and actually dates back to the mid-19th century. However, the media and other sources have made it a more well-known issue in recent years. Oil usage has gone up constantly and the future looks to continue this pattern, as shown in Exhibit 2 below.

Exhibit: World Oil Demand 1990-2025



Source: PIRA

Shale oil and tight oil require more stimulation to release the oil once the well has been drilled than free-flowing oil that has typically been drilled through vertical drilling. Instead of this historical vertical drilling process, the oil trapped in the porosity is getting out through hydraulic drilling, or fracking. In conventional oil reservoirs the reservoir permeability, or the state of the rocks that allows liquid to flow through them, is sufficient that hydraulic fracturing is not be needed to achieve the process of getting oil out of the ground. However, in unconventional oil (for example, shale oil), the permeability is very low, meaning that few liquids are able to pass through the rock. Therefore, additional pathways must be created to enable the flow of hydrocarbons. To create the pathways, fluids are pumped under pressure from surface into the reservoir, many hundreds to thousands of meters below ground. As will be discussed in greater detail later, these fluids are what actually cause the fracking process to become a danger to the environment. It is not the equipment that the companies are using, but

the fluids that can create problems if not disposed of and used in the proper ways. This process is complicated and intricate and has taken years of research to determine how it can be done (Understanding Tight Oil).

Process of Fracking

The energy industry has explored for and developed conventional oil reserves for many years through vertically drilling to get crude oil from the rock formations it is found in. Historically, vertical drilling includes many steps. This process has gotten even more complicated with the use of horizontal drilling (often referred to as fracking) – or going beyond the conventional methods to get more oil from the rocks by drilling horizontally through them as well as vertically into the ground. To begin with, companies prepare the drilling site they plan to use. Preparing a drilling site includes ensuring the site can be accessed and that it is going to be safe for an oil rig to be located on. This step is taken by upstream companies that work to pump crude oil out of the ground. Next, a company has to drill a borehole. A borehole is drilled straight into the ground. This is where the name vertical drilling comes from, as the drill bit, the tool used to drill the hole, is drilled directly into the ground. This process is complicated because it requires placement of the hole in the perfect spot. This spot is determined based on where the aquifer of freshwater is underneath the earth's surface. A special mud is then used to cool the drill bit, to carry the rock cuttings back to surface to be removed, and to provide stability to the walls of the borehole (a deep, narrow hole used to get the actual crude oil out of the ground). Once the hole extends past the deepest freshwater aquifer (typically about 1000 feet into the ground), the drill pipe is removed and replaced with a steel pipe, called a surface casing. In the next step of the process, cement is pumped down the newly made surface casing

and then back up between the casing and the borehole wall, where it sets. This cement provides a bond which prevents any fluids moving between the casing and the hole to make sure that when crude oil is pumped out of the ground, it is not contaminated with anything. Tests are then performed by the company to make sure that the bond is definitely impermeable before any drilling takes place.

The following steps are what separate historical vertical drilling with horizontal drilling. In all of the previous steps, no fracking has taken place. However, the steps performed after this are considered to be horizontal drilling. A perforating gun is lowered to the rock layer. This perforating gun is fired, causing small holes through the casing and the cement and into the targeted rock to be formed. “Stimulation fluid”, which is a mixture of over 90% water and sand, plus chemical additives, is pumped under controlled conditions into deep, underground reservoir formations. The chemicals are used to keep bacteria from forming and to carry sand. These chemicals are typically non-hazardous and are needed to help improve the efficiency of the hydraulic fracturing. This stimulation fluid is pumped at extremely high pressures throughout the perforations made by the perforating gun. This process creates fractures in the shale rock which contains the oil and natural gas. The sand is left in the fractures in the rock in order to keep them open when the pump pressure is relieved. This allows previously trapped oil or natural gas to flow to the well bore. Once the hydraulic fracturing process is completed, production can begin, oil and gas can flow from the well bore and the fracturing fluid can be recovered ("Fracking and Earthquakes").

Environmental Effects of Fracking

Mud and fluid byproducts are created from the fluids that are pumped into the ground while horizontally drilling. These byproducts are the central concerns of the environmental effects of fracking. While many think that fracking itself is the problem, it is actually waste created from hydraulic fracturing that causes, if anything at all causes, the spike in earthquakes that Oklahoma has experienced over the last ten years. This fluid comes from disposal wells, which look like normal oil and gas wells typically. These wells are used to bury waste fluid underground. The EPA says it is perfectly safe to store these waste fluids underground, because it is safely away from drinking water sources. This is a good thing for oil and gas companies, because treating this water would be extremely expensive for the companies. Scientists believe that the fault lines that are held in place by all the rocks around and above them. When fluid is injected in the ground as a result of fracking, it can add pressure to the fault lines, which can cause fault lines to slip, which can cause an earthquake ("Exploring the Link between Earthquakes and Oil and Gas Disposal Wells").

Environmentalists argue that air pollution, water contamination and earthquakes have all been consequences of the fluids created by the increased fracking practice over the last few decades. A case study by Finkel in Pennsylvania found that of the more than 8600 abandoned wells in the state of Pennsylvania in 2009 alone, 259 were plugged because of leaking gas, oil, and acid drainage into the groundwater, surface water, and air. However, drilling companies are not legally required to list the chemical compounds used in fracking, and therefore it is difficult to assess the full scope of the contents of fracking fluids for specific companies and in specific locations. Cleanup to abandoned drilling sites is important and must include restoration

of damaged or contaminated streams and soil, improper handling of wastewater disposal, and improper disposal of radioactive material and hazardous waste. Anti-fracking groups argue that companies are not safely cleaning up abandoned sites and this is adding to water and air contamination. In August 2010, the Environmental Protection Agency (EPA) sent letters to drilling companies requesting detailed information about the chemicals contained in fluids used in fracking. This information is essential to better understand the health and environmental consequences of fracking (Finkel). The companies complied, and this information has helped to increase regulation in regards to the practice. However, it is difficult to keep this information constantly flowing in to the EPA since they are not required to disclose their hydraulic fracturing processes and therefore the information is not being kept track by anyone.

Besides water and air contamination, fracking has raised concerns regarding the way it may damage underground water supplies. It is difficult for states to know what regulations need to be set in regards to underground drilling, particularly the disposal of the polluted water. Upstream companies are expected to submit water management plans to the state agencies that oversee environmental protection, but often there is little state oversight as with any bureaucracy; companies are expected to self-report violations. No state has an effective and efficient underground water monitoring system in place, and no comprehensive data exists on spills, again making it hard to say that fracking is the direct cause of water contamination.

Soil contamination also has not been addressed fully. “Drilling sludge” (a mixture that includes drilling mud and rock cuttings containing hydrocarbons, radioactive material, and heavy metals) is brought to the surface during the drilling phase. Flow back waste fluids, a byproduct of fracking, must be disposed of safely because the fluids can potentially

contaminate air and soil. Radioactive hazardous waste needs to be taken to special disposal sites. However, dumping is widely suspected, further jeopardizing both soil and watersheds. Again, greater laws and regulations must be put into place if a correlation between dumping and soil contamination can be stated as a definite.

Another great environmental concern of fracking, and the one with perhaps the furthest reaching political unrest, is the theory that fracking causes earthquakes. The micro seismic events that occur during the actual fracking process are generally less than minus two in magnitude. A study of hydraulic fracturing-related seismic activity conducted in England showed that the combination of geological factors necessary to create a higher-than-normal seismic event was “extremely rare” and such events would be limited “to around magnitude 3 on the Richter scale as a ‘worst-case scenario.” A magnitude 3 earthquake, like the one this study is referring to, is described by the United States Geological Survey as causing “vibrations similar to the passing of a truck.” In addition to this study, an Oklahoma Geological Survey study on seismicity near hydraulic fracturing activities concluded that it was “impossible to say with a high degree of certainty whether or not these earthquakes were triggered by natural means or by the nearby hydraulic-fracturing operation.” The study did note the events under examination were “small earthquakes with only one local resident having reported feeling them. The earthquakes range in magnitude from 1.0 to 2.8” (“Fracking and Earthquakes”).

Political actions are often taken because of the fear that fracking might cause these earthquakes, despite little scientific proof. Just earlier in April, Governor Mary Fallin signed a House Bill 3158 that gives the Oklahoma Corporation Commission the power to “take whatever action is necessary, without notice or hearing” in regards to them having the ability to respond

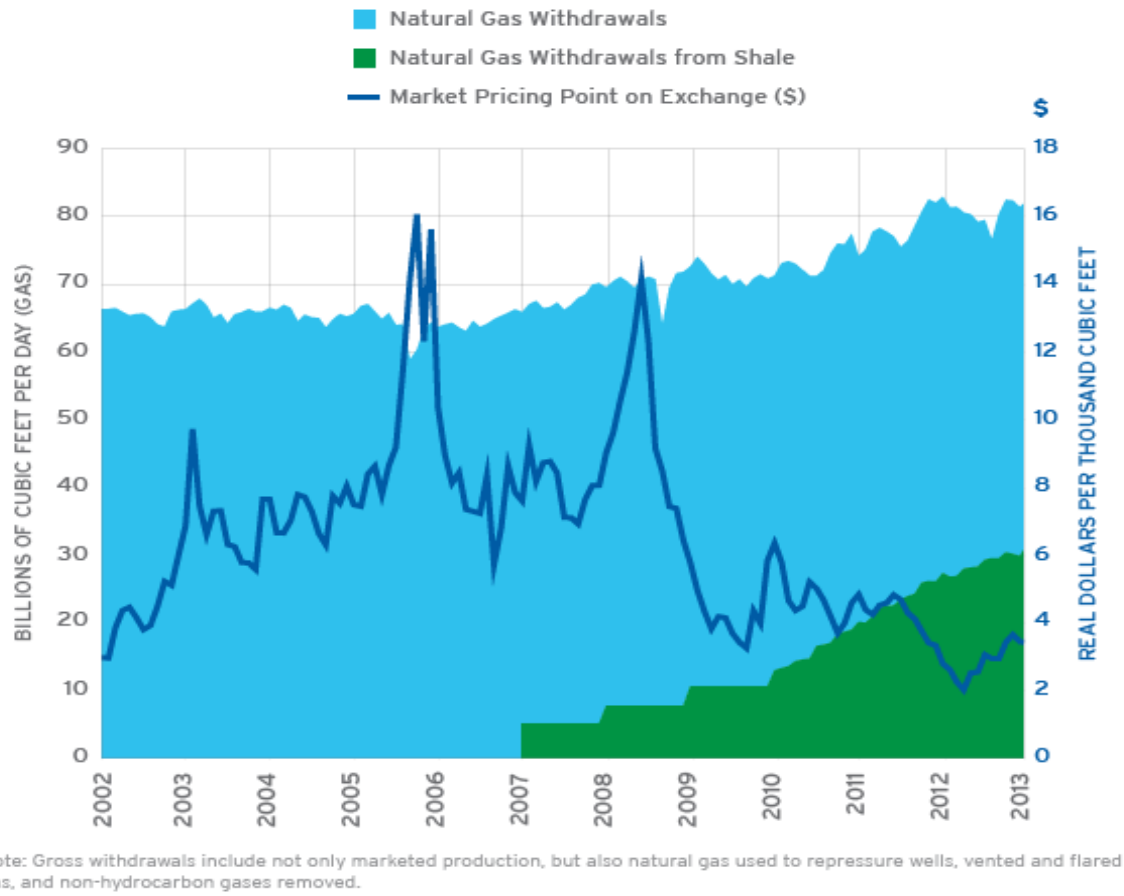
to emergencies however they deem fit. This gives them the legal power to perform an action they were already taking, to take action against oil and gas operations that are “linked to earthquakes” (Wertz).

Economic Benefits of Fracking

These new innovations in drilling and fracking have not only created environmental concerns and therefore created negative publicity, but they have also done incredible good things for mankind, like the advanced that President Obama mentioned in the quote at the beginning of the paper. Fracking has enabled tremendous amounts of natural gas to be extracted from underground shale formations that were long thought to be dry, and therefore worthless to the energy industry. However, many, including President Obama, now believe these formations might be creating an economic boom that the world needs.

There are economic benefits of fracking for the individual consumer. The first fact that leads to this conclusion is that as fracking grows, gas prices drop. The U.S. fracking revolution has caused natural gas prices to drop 47 percent compared to what the price would have been prior to the fracking revolution in 2013 as shown by Exhibit 3.

Exhibit 3: Fracking and Natural Gas Prices



Source: US Energy Information Association

Household owners are seeing economic gains. Gas bills have dropped $13 billion per year in the United States from 2007 to 2013 as a result of increased fracking, which adds up to $200 per year for gas-consuming households. Moreover, all types of energy consumers, including commercial, industrial, and electric power consumers, saw economic gains totaling $74 billion per year from increased fracking (Dews).

Since so much of the world uses energy, numerous regions are experiencing economic benefits in the times of an energy boom and economic detriments in times of an energy

downturn. Specifically, to Oklahoma, an economic downturn has happened in recent months due to the sharp decline in oil prices. Oil prices dropped sharply in the second half of 2014, causing energy companies to make significant cuts in their 2015 capital spending budgets and, in the worst cases, lay off workers. Through April 2015, Oklahoma oil and gas jobs already have declined more than 10 percent from their late-2014 peak. Previous episodes of large declines in the price of oil when Oklahoma's energy sector was large have been accompanied by declines in overall state employment and several years of weak job growth. Roughly one-quarter of the jobs in Oklahoma are either directly or indirectly tied to the energy industry. These facts alone show the importance that the energy industry plays in both Oklahoma's employment and overall economy.

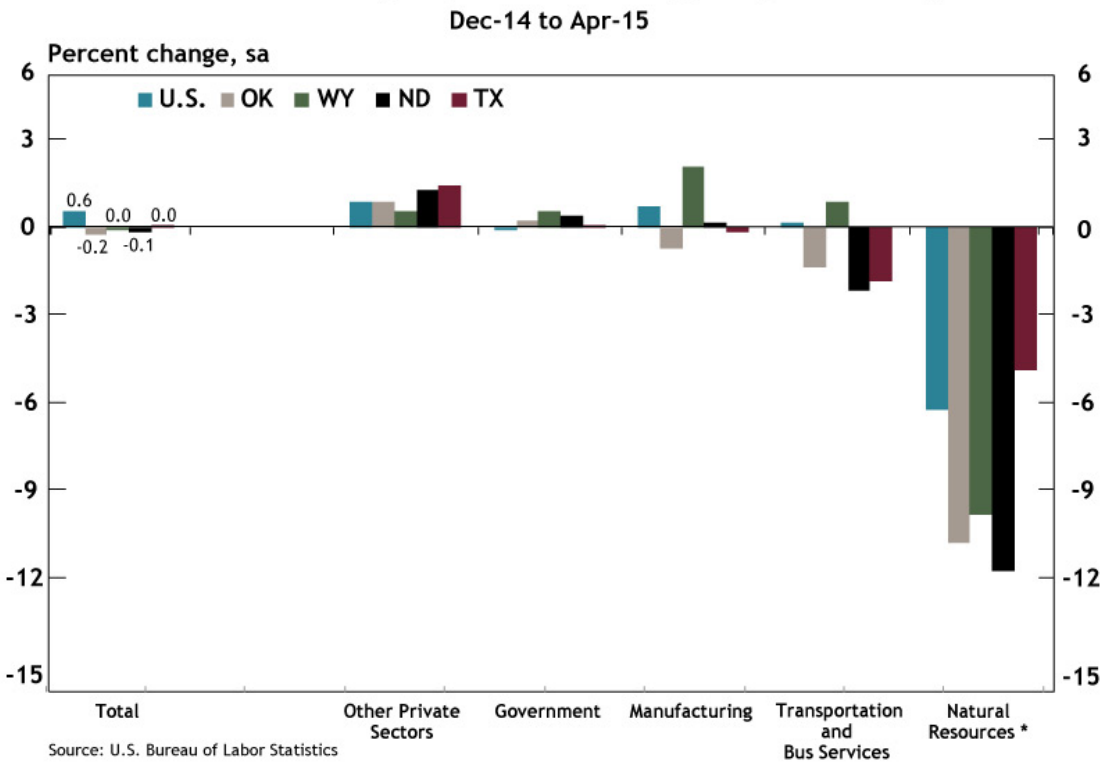
In Oklahoma and surrounding states, a downturn in the energy industry has lasting effects on not only those companies that work in the natural gas industry, but also on other companies in other industries. In three cases when oil and gas comprised a large share of state economic activity—1982, 1985 and 2008—and oil prices dropped, total Oklahoma employment fell by at least 2 percent in the following year and remained below its peak for three years or more. In each case, employment fell not only in the oil and gas industry, but in other sectors of the economy as well. The dependency that Oklahoma has on the oil and gas industry is large, and because of that, many sectors are affected when the energy industry is in a down cycle. There are several reasons why this occurs and why the broader state economy is affected by the oil and gas industry performance. The oil and gas sector purchases many goods and services from other industries, often from other Oklahoma companies; many of these are local companies that depend on oil and gas companies buying their products or using their services

for profit. As energy activity falls, so does demand for these goods and services, which can result in cutbacks among producers and loss for the companies that provide input. Just to site one example, a variety of manufactured goods are used in drilling and completing wells, from pipe to machinery to fracking fluids. Oil and gas firms also use services provided by truck and rail transportation, legal and accounting firms and others. In addition, as workers in the oil and gas sector lose jobs, have pay reduced, or even just fear a loss of employment or income, they may reduce their spending, hurting local economies and industries like retail trade, housing and hospitality. This negative effect is typically larger for oil and gas than other sectors because wages for oil and gas jobs generally are much higher. Income taxes and sales taxes are also both affected at the state and local levels when oil and gas workers lose jobs or have their pay reduced. Declines in these revenue streams can lead to cuts in government services and employment.

The sharp decline in energy activity in Oklahoma appears to indeed be affecting other industries and overall state economic growth. In 2015, Oklahoma manufacturing employment was down 1.4 percent through April, while transportation and business services jobs were off 0.7 percent. Together with the sharp decline in energy jobs, these losses have pulled total Oklahoma employment down by 0.2 percent from December to April. In addition, tax revenues in the state have declined. Severance tax receipts have dropped, and the total state tax receipts in May were 6 percent less than year-ago levels. These negative effects in the Oklahoma economy are largely in contrast to the effect of weaker oil and gas activity on the national economy, but similar to the effect in other energy states. While energy jobs are down in virtually all states in 2015, overall national employment has continued to grow solidly. Total

employment in North Dakota, Wyoming and Texas, however, is flat or down slightly since December (shown below).

Exhibit 4: Employment Change by Industry



Source: US Bureau of Labor Statistics

Within Oklahoma, the consequences of the effect have varied dependent on the part of the state. The largest decline in energy jobs has been in non-metro areas, where oil and gas also comprise a larger share of the economy. This is likely due to a smaller effect on headquarters jobs in cities than jobs associated with rigs, which are typical to smaller, more rural communities. According to Bruce Benbrook, a banker in Woodward, OK, Woodward sales tax declined 25% in 2015 alone. “This has been felt by the entire city of Woodward,” Benbrook states. Oklahoma employment outside the two major metro areas of Oklahoma City and Tulsa

is down 1.4 percent since December, with sharp declines not only in the energy sector but also in manufacturing, transportation and several services sectors.

The two large metro areas have generally been less affected and therefore done better economically than the smaller areas of the state. The Tulsa metro area has seen flat employment in 2015, as declines in energy, manufacturing and transportation jobs have been offset by increases in other sectors. Employment in the Oklahoma City metro area has grown similarly to the nation through April despite sharp job losses in oil and gas employment, as other industries continue to grow.

State employment data can go only through April 2015 right now, until the tax season for 2016 is complete, and state tax data generally lag by several months. However, insights into whether negative spillovers continued in May and are likely to persist can be seen through other sources and are predicted for the future right now. These sources include recent Federal Reserve business surveys, higher-frequency state labor market and energy data, and the outlook for oil prices. These sources suggest the sector's declining employment is likely to continue, but at a slower rate. Oil and gas firms have been and plan to continue cutting hours, bonuses and, in some cases, wages of remaining workers. These factors may dampen local consumer spending in energy-dependent areas.

Research Results

Despite the environmental detriments of fracking, for the sake of Oklahoma's economy overall, fracking must continue in the state and surrounding areas. While greater supervision and regulation may be needed, our state is reliant on the practice of fracking. Not only does fracking create more revenue for oil and gas companies, which Oklahoma is largely dependent

on, but individual consumers are benefitted with lower gas prices when fracking is involved as well. Furthermore, the environmental consequences of fracking are extremely difficult to detect and therefore it does not make logical sense for companies to stop fracking based on theories that have yet to be proven.

Discussion and Defense

After the thesis presentation, professors and students agreed with my thesis conclusion that fracking must continue in the state of Oklahoma. Many of the students were going to work for an oil and gas company and had been exposed to the refining process, the process of fracking, and/or were familiar with the products made because of refining.

Conclusion

Oil and gas activity in Oklahoma began a decline in late 2014, with job cuts in the high-paying sector persisting through spring 2015 and picking back up again recently. Similar to past episodes of sizable declines in oil prices when the Oklahoma energy sector is large, this downturn appears to have spilled over into other industries, including manufacturing, transportation and business services. The result has been an overall slight decline in Oklahoma jobs and tax revenues in 2015. Higher-frequency data suggest the pace of the downturn may be lessening slightly. However, the extent to which difficulties persist depends largely on the future path of oil prices, which in turn depends on many domestic and international factors. Because Oklahoma is dependent on the energy industry and the energy industry companies are dependent on the process of fracking in this day and age, fracking must continue- despite environmental consequences suspicions- in order for the Oklahoma economy to survive.

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