Peak Oil, Price Volatility and State Revenue

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1. Introduction

"High reliance on O&G revenues creates two challenges for the state: managing revenue volatility and protecting long-run sustainability." Thomas Clifford, Secretary, New Mexico Department of Finance and Administration, August 2013.

Oil producing states, such as New Mexico, rely heavily on severance taxes and other production tax revenues. Only a few years ago, discussion and analysis of the future of such revenue centered on the peak oil hypothesis which suggested inevitable long term decline in oil production and oil-related tax revenue. Given rapid increases in US oil production, concerns about peak oil are no longer at the center of the discussion. The historical record suggests that oil price volatility will remain a central feature of the industry despite the reduced concerns over peak oil. This paper addresses both peak oil and oil price volatility using REMI model simulations. The focus of this paper is on the employment and output effects of these two phenomena on New Mexico. Energy tax revenues under alternative scenarios will also be presented.

2. Oil and gas production and the New Mexico economy

The New Mexico economy has not yet recovered from the effects of the Great Recession (December 2007 to June 2009). Five years after the national recovery began, New Mexico's non-farm payroll employment remains 31,000 jobs below (as of August 2014) its December 2007 level (Bureau of Labor Statistics, SAE database, October 14, 2014). Unlike the national economy, which surpassed its Dec 2007 employment level in May 2014, there is little prospect for a quick recovery in New Mexico. For decades, the state has been heavily dependent on federal government expenditures at its national laboratories, military bases, and research universities. In the current environment, federal expenditures are unlikely to be an engine of growth. In contrast, the oil and gas industry (mainly oil) is one of the few bright spots in the New Mexico economy.

In 2013, New Mexico ranked 6th in the production of crude oil and 7th in the production of natural gas (Energy Information Administration, State Energy Profiles, http://www.eia.gov/state/?sid=NM ,October 16, 2014). Oil production has been increasing rapidly in New Mexico in the last five years. Natural gas production has been declining due to relatively low prices. Nevertheless, in 2013, the value oil and gas production in New Mexico exceeded $15 billion. In 2013, directly and indirectly, the oil and gas industry accounted for more than 30 percent of state revenue and directly accounted for 22,107 jobs (Table 2.1) or 2.8 percent of total employment. Oil and gas industry employment is also high wage employment in New Mexico.

Table 2.1

New Mexico oil and gas employment

		Employment	
NAICS	**Category**	**2003**	**2013**
211111	Crude Petroleum and Natural Gas Extraction	2,934	4,636
211112	Natural gas liquid extraction	140	560
213111	Drilling oil and gas wells	1,903	2,380
213112	Support Activities for oil and gas operations	5,489	12,805
221210	Natural Gas Distribution	397	816
3241	Petroleum and coal products manufacturing	726	772
325110	Petrochemical manufacturing	ND	
486110	Pipeline transportation of crude oil*	46	35
486210	Pipeline transportation of natural gas	822	103
486910	Pipeline transportation of refined petroleum products	ND	
333132	Oil and gas field machinery and equipment	ND	
424720	petroleum merchant wholesalers	1,065	898
	Total oil and gas employment	12,457	22,107
	Total Covered Employment	745,935	791,804

Source: Bureau of Labor Statistics, Quarterly Census of Employment and Wages, 2013
Pipeline transportation of crude oil for 2013 calculated as a residual.
ND = Not Disclosed
*Petroleum refineries included in petroleum and coal products manufacturing.

While the oil and gas industry contributes substantially to state revenue, the spread effects (forward and backward linkages if you prefer) to the rest of the economy are limited. Oil production is concentrated in Eddy and Lea Counties, which are enjoying a boom period unlike anything seen in many decades. San Juan County is the state's largest natural gas producer, but natural gas production, has been declining.

But even a quick look at employment growth, unemployment rates, or per capita income in the state's 33 counties will confirm that the state as a whole has not experienced the same boom conditions as the oil producing counties. New Mexico has experienced oil and gas booms in the past and a brief look at the history of oil and gas production in New Mexico indicates that a continued oil boom is far from assured.

2.1 Oil Production

New Mexico has produced oil since the early 1900s. Production data are available from 1924 when the state produced 98,000 barrels. Production increased rapidly in the 1920s and 1930s. In 1940, New Mexico oil production reached 39.1 million barrels. New Mexico oil production peaked in 1969 at 129.3 million barrels. A decade later, New Mexico oil production had decreased by nearly 40% (79.6 million barrels in 1979). For the most part, New Mexico production continued to decline in the 1980s, 1990s, and early 2000s. In 2008 New Mexico production was only 60.1 million barrels (Figure 2.1.1).

Within the state there was a general consensus that the decrease in production was an irreversible long-term trend. This was the same trend analysts were noting for the nation as a whole. Peak oil was upon us and the only question was how long it would be before we 'ran out of oil.'

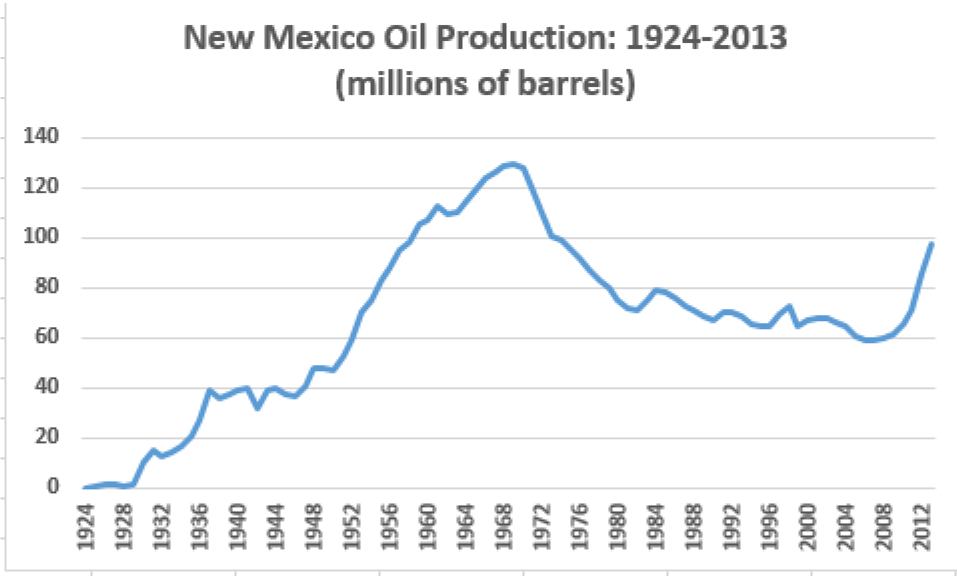
The oil industry can make fools of even the most sophisticated analysts. By 2013 New Mexico oil production reached 100 million barrels –nearly a 60 percent increase since 2009. In 2014 New Mexico oil production is on a pace to be 114 or 115 million barrels –a figure not reached in forty years. Despite a fall in crude oil prices in recent months, New Mexico's oil production could reach its previous peak in the next few years.

Nearly all (95%) of the increase in oil production in New Mexico in recent years has occurred in Eddy and Lea Counties. The boom in oil production is the result of relatively high and stable prices, and several advances in oil exploration and extraction technology. The best known of the technological advances are hydraulic fracturing and horizontal drilling but there are many other technological changes contributing to increased production. These include advances in seismic testing, digital mapping, more efficient drill bits, and dozens of others. The technological changes are not of course limited to New Mexico. The combination of new technology and relatively high prices has resulted in a dramatic increase in oil production in many areas in the US and in other nations. We are experiencing what many observers have called a hydrocarbon revolution.

Whether or not the increase in oil production in New Mexico (and elsewhere) can be sustained for many years is an unanswered question. In the New Mexico portion of the Permian basin (Eddy and Lea Counties), proved reserves seem to increase each year despite increases in production. There are large untapped oil reserves in the San Juan Basin (Mancos Shale) that may be brought into production in the next few years. Some estimates suggest that the Mancos Shale may have as much as 6 billion barrels of oil, enough to extend current New Mexico production levels for about 60 years. The current obstacle to increased production in San Juan County is transporting oil out of the region.

Some observers are less optimistic and point to rapid decay rates (the rate at which production from a new well declines). Industry insiders told one of the authors that this fear is exaggerated. They expect decay rates of up to 50 percent in the first few months of production and then fairly stable production for many years. Oil price volatility is another threat to long-run increases in oil production in New Mexico.

Figure 2.1.1



Sources: (1) 1924-1958 (Petroleum Facts and Figures Centennial Edition 1959, p, 40-41 Crude Oil Production, by states); (2) 1959 (Petroleum Facts and Figures 1961 Edition, p, 34 Crude Oil Production, by states); (3) 1981-2013 (Energy Information Administration, New Mexico Field production of crude oil, 2014). The figure for 2013 was estimated by the authors from monthly data through November 2013.

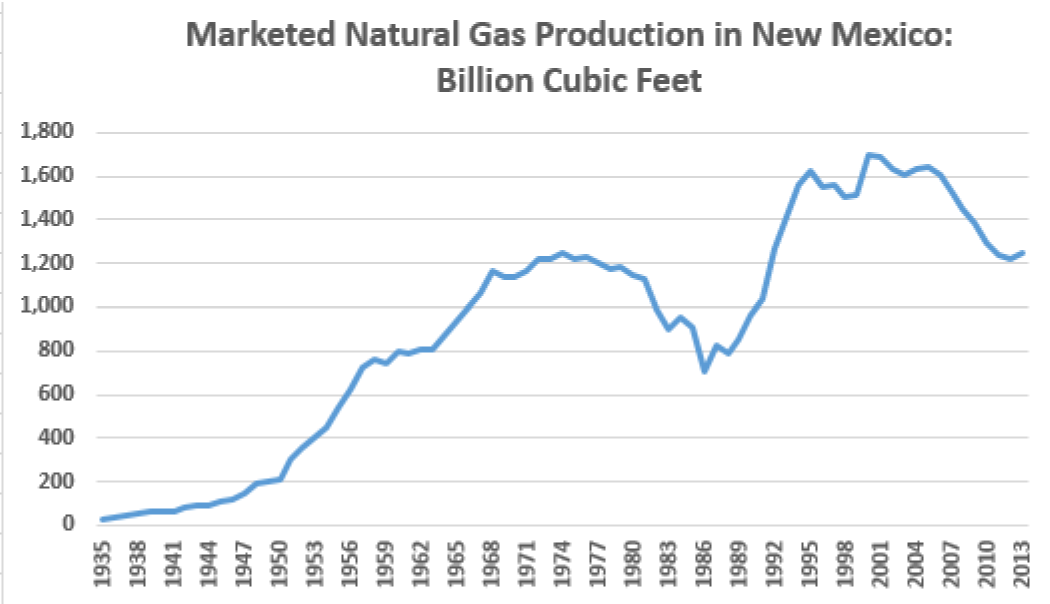
2.2 Natural Gas

The natural gas industry is closely associated with the oil industry and combined the two industries are often called "oil and gas". This relationship is exemplified by the name of an industry association: The New Mexico Oil and Gas Association. While it is the case that many wells produce both commodities, the two industries differ in many respects. Both oil and gas are hydrocarbons but they are not perfect substitutes and they respond to different market forces. Indeed, there are several types of natural gas. Most frequently, the term natural gas is a reference to dry natural gas as opposed to natural gas liquids. In New Mexico, most of the oil production is from Eddy and Lea Counties but these two counties also produce some natural gas. San Juan County produces a lot of natural gas but very little oil.

Dry natural gas production in New Mexico is shown in Figure 2.2.1 from 1935 to 2013. New Mexico produced 27.93 billion cubic feet of natural gas in 1935. Production in New Mexico climbed steadily from 1935 to 1958, reaching 761.44 billion cubic feet by 1958. There were small declines in 1959 and 1961, with production climbed between 1962 and 1968 with production rising above 1 trillion cubic feet annually. 1969-1970 showed small declines as well, but then there was steady growth in NM production between 1971 and 1974. By 1974 production was 1.244 trillion cubic feet, but then began a long decline. By 1980 production had fallen to 1.14 trillion cubic feet, and by 1988 production had fallen to below a trillion cubic feet per year at only 702.6 billion cubic feet. Production then began to rise in New Mexico, and by 1991 production had again risen to above 1 trillion cubic feet annually. Production levels generally increased in New Mexico between 1991 and 2007, with production ranging between 1.03 trillion and 1.695 trillion cubic feet. Natural gas production in New Mexico declined substantially after

2006 and in 2013 was 1.2 trillion cubic feet. This downward trend in natural gas production in recent years is in sharp contrast to the large increases in oil production in the state.

Figure 2.2.1



Sources: (1) 1935-1968 (Petroleum Facts and Figures 1971 Edition, p, 102-107 Gross and Marketed Production of Natural Gas, by States); (2) 1969-2013 Energy Information Administration http://www.eia.gov/dnav/ng/hist/n9050nm2M.htm . 2013 estimated from January to November data.

3. Peak Oil

In 1956 M. King Hubbert presented a paper to the Annual Conference of the American Petroleum Institute. In that paper he suggested that there existed a peak to oil production. Since it has taken 500 million years to accumulate fossil fuels, continued production of this 'fixed resource' would at some time in the future reach a peak and then decline. The position of the production peak depends on the rate of production and the assumed reserves. At the time, he calculated World reserves to be approximately 1,250 billion barrels. Given production rates and reserves he estimated that oil production would peak around the year 2000. (See Figure 3.1).

He suggested that the peak oil concept could be applied to a particular oil field, a region (such as a state), a nation, or to the world. He was also careful not to suggest that the peaks for any of these geographical areas would occur at the same time.

Figure 3.1

Hubbert's Peak:

From M. King Hubbert's "Nuclear Energy and Fossil Fuel"—a paper delivered to the American Petroleum Institute's 1956 annual conference.

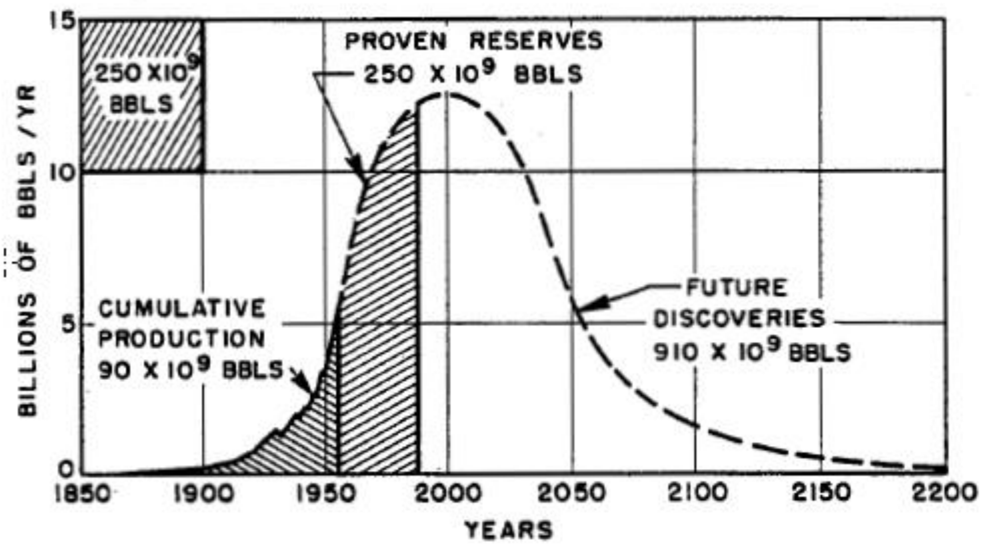


Figure 20 – Ultimate world crude-oil production based upon initial reserves of 1250 billion barrels.

Figure 3.2 shows crude oil production for the United States and New Mexico from 1960 to 2013. This figure indicates that peak production occurred in the United States in 1970 and peak production in New Mexico in 1969. The figure does not show a continuous decline of production since 1970 and 1969 that would be consistent with the exhaustion of the resource. The last few years show an increase in production.

Figures 3.3 and 3.4 provide an answer to the paradox. For New Mexico proven reserves were 710 million barrels in 2002. Between 2002 and 2012, New Mexico produced 721 million barrels. If the 2002 reserve figure (710 million barrels) had been correct, the state would have 'run out of oil altogether by 2012 –with implied reserves = - 11 million barrels. Yet, despite large increases in production, New Mexico reserves were reported to have increased to 965 million barrels in 2012. Roughly the same story can be told for US production and reserves. Despite production increases, reserves increase at the same time.

While Hubbert's Peak may occur at some point, for the foreseeable future the quantity of oil produced is not dependent on the physical supply of oil in the ground but technology, prices, and the willingness to produce it. As Hubbert pointed out, multiple peaks are possible.

Figure 3.2

US and New Mexico Field Production of Crude Oil: 1960 to 2013
Millions of BBLS per Year

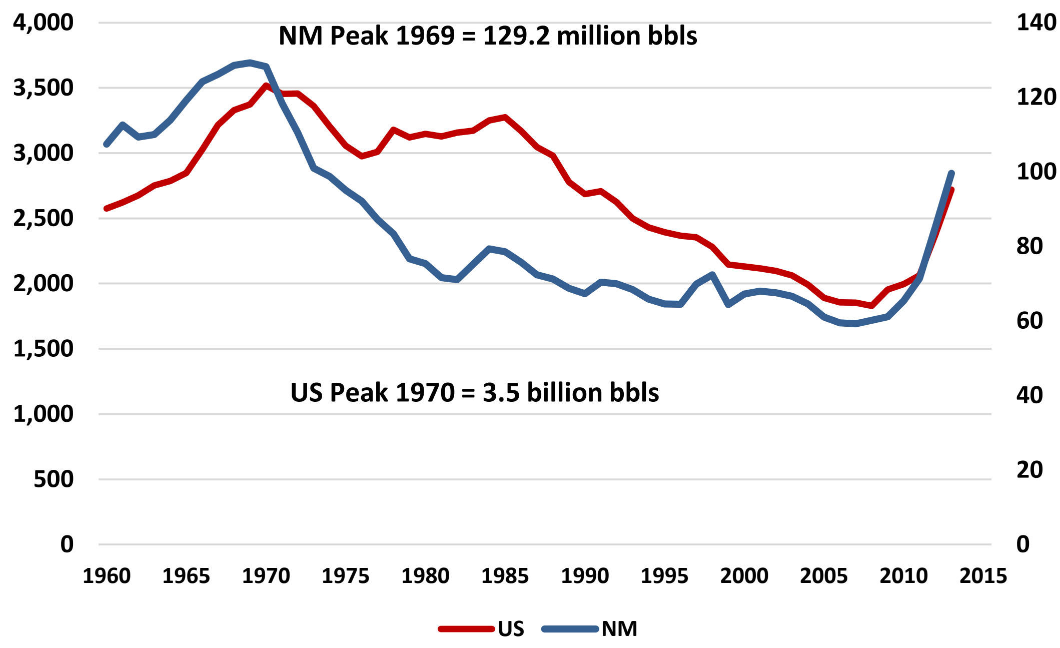
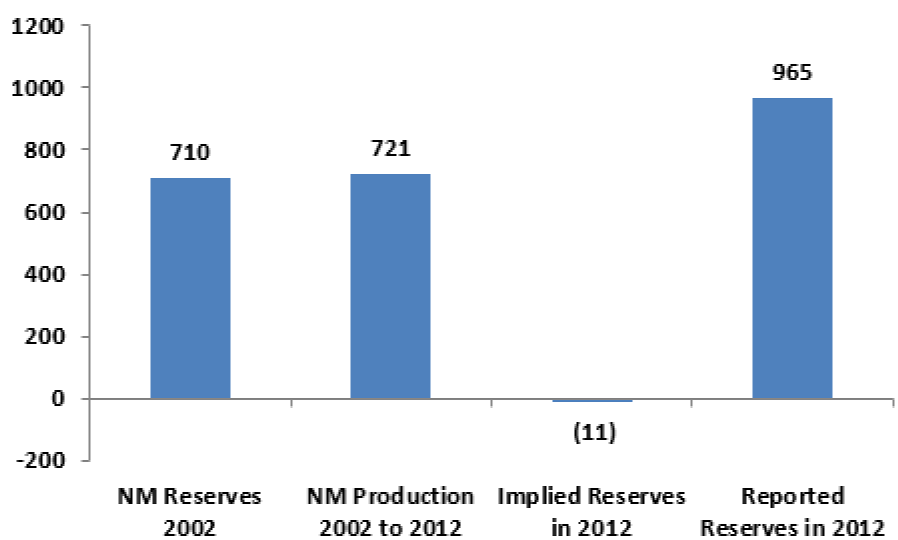


Table 3.3

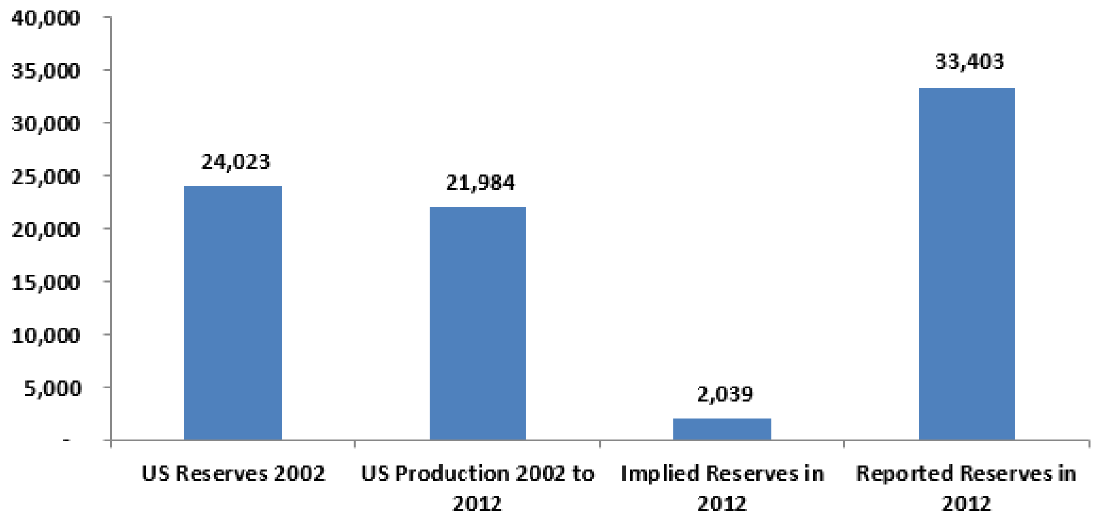
New Mexico oil production and proven reserves: 2002 to 2012
(millions of barrels)



Source: Energy Information Administration, Proven Reserves of Crude Oil

Figure 3.4

United States oil production and proven reserves: 2002 to 2012 (millions of barrels)



Source: Energy Information Administration, Proven Reserves of Crude Oil

4. Gas and Oil Taxes

The State of New Mexico directly imposes several taxes on extractive industries operating in the state see Table 4.1). In addition, the economic activity of the industries indirectly generate Personal Income Taxes (PIT) on the income received by employees, Corporate Income Taxes (CIT) received by owners of the businesses, and Gross Receipt (GRT) and Compensating taxes on the spending of these individuals and businesses.

Direct taxes include the severance tax, the emergency school tax, the resource excise tax, oil conservation tax and a processors tax. Most of these taxes are imposed on the value of production less specified exemptions and deductions. In addition extractive industries are subject to the property tax.

Extractive industries leasing federal or state lands also make royalty payments to the appropriate agency. Those agencies then return a portion of those royalties to the originating state's general fund.

Extractive businesses operating on State Trust Lands pay royalties to the State Land Office. Monies are put in the Land Grant Permanent Fund and the interest is transferred to the general fund to support public schools, state universities, specialized schools and hospitals.

Table 4.1

Description of Distribution and Source of Oil and Gas Tax Revenues in New Mexico

Revenue Source	Description	Distribution
Oil and Gas Emergency School Tax	Severance tax on oil, gas , helium, carbon dioxide, and other hydrocarbons	General Fund
Conservation Tax	Severance tax based on value	General Fund
Natural Gas Processors Tax	Severance tax base on Value	General Fund
Resource Excise Tax	Paid in lieu of GRT	General Fund
Federal Mineral Leasing	Money passed through to state from oil and gas extraction on Federal Land	General Fund
Land Grant Permanent Fund	Royalties from mining and other activity on state trust land set aside at Statehood.	State Investment Council invests funds. Distributed to 21 trust land beneficiaries (public schools and hospitals) receive payments from the land use.
Severance Tax Permanent Fund	Funded by taxes on extraction of oil and gas and small amounts of other minerals.	Revenue is used to retire debt for government projects. Half of the available revenue can be used for debt service on one-time spending for projects. 45% can be spent on public school infrastructure.
Direct Taxes on Oil and Gas	Property Taxes	Chaves, Colfax, Eddy, Harding, Lea, McKinley, Quay, Rio Arriba, Roosevelt, Sandoval, San Juan, and Union Counties

The extractive tax rates are shown in Table 4.2.

Table 4.2

Statutory Tax Rates	
Tax	Rate
Severance Tax	3.75% of Gross Value
Conservation Tax	.24% of Taxable Value
Emergency School Tax	3.15% of Taxable Value
Processors Tax	.75% of Taxable Value
Property Tax	County Dependent
Federal Royalty Rate	4.2% of Value
Severance Tax: NM State Statutes 7-26-5 Conservation Tax: NM State Statutes 7-30-4 Emergency School Tax: NM State Statutes 7-31-4 Processors Tax: NM State Statutes 7-25-5 Property Tax: NM State Statutes 7-36-27	

The importance of oil and gas taxes to the state cannot be overstated. In a 2009 technical report titled "The Economic Impact of Oil and Gas Extraction in New Mexico," Jim Peach reported the amounts of direct extractive tax revenue from oil and gas for fiscal years 2006-2008 (see table 4.3). Contributions to the general fund ranged from $972 million to $1,141 million. Contributions to the Severance Tax Fund ranged from $170.9 million to $191 million. And contributions from State Land Office royalties ranged from $1,596.5 million to $1,826.8 million.

Table 4.3

Oil and Gas Contributions to the New Mexico General Fund 2006-2008 (Millions of Dollars)

State General Fund	FY 2006	FY 2007	FY 2008	FY2009*	CY 2008**
Oil & Gas Emergency School Tax	483.2	431.8	557.7	370	463.9
O&G Conservation Tax	22.6	19.5	27.1	18.4	22.8
Natural Gas Processors Tax	26.8	35.6	30.6	40.2	35.4
Federal Minerals leasing	556.5	501	564.2	507	535.6
State Land Office	52.7	50.4	46.1	36.4	41.3
Total General Fund	**1,141.80**	**1,038.30**	**1,225.70**	**972**	**1,098.90**
Severance Tax Permanent Fund	171.8	170.9	177.2	191.3	184.3
State Land Office Royalties	405.3	390.5	459.9	433.2	446.6
Total State Revenues	**1,718.90**	**1,599.70**	**1,862.80**	**1,596.50**	**1,729.70**

** Estimated from New Mexico Consensus Revenue Forecasts, August 14, 2009*

*** Average of Fiscal Years 2008 and 2009.*

Source: New Mexico State Board of Finance, General Revenue Estimates, Fiscal Years 2006 through 2008.

In addition to the direct extractive taxes, oil and gas activity generates gross receipts taxes, personal income taxes and capital income taxes. These three tax sources generate nearly 80% of all non-mineral

tax revenues. These indirect revenues were calculated using an effective tax rate based on labor income. In 2008, these taxes were estimated to be $191 million or about 3.3% of FY 2009 revenue.
Table 4.4 extends Table 4.3 through the year 2014. The amount of the taxes listed in the table now amount to about 19% of total general fund revenues.

Table 4.4

Oil and Gas Contributions to the New Mexico General Fund 2010-2014 (Millions of Dollars)

State General Fund	FY2010	FY2011	FY2012	FY2013	FY014
Oil & Gas Emergency School Tax	324.5	376.1	390.7	382.3	481.0
O&G Conservation Tax	16.4	19.4	20.4	20.7	26.2
Natural Gas Processors Tax	40.4	18.2	23.0	24.0	16.3
Federal Minerals leasing	355.3	411.8	502.4	465.0	569.8
State Land Office	67.7	65.6	92.5	44.6	47.5
Total Contributions to General Fund	**804.3**	**891.1**	**1029.0**	**936.6**	**1140.8**
Federal Minerals leasing	187.1	184.6	183.4	176.2	170.5
State Land Office Royalties	437.1	446.2	459.8	438.3	449.0
Total Contributions to State Revenues	**1428.5**	**1521.9**	**1672.2**	**1551.1**	**1760.3**
State General Fund Revenues	5277.6	5470.6	5764.6	5651.2	6007.7
Percent of GF Oil and Gas Contributions to General Fund Revenues	15.2	16.3	17.9	16.6	19.0

Source: New Mexico State Board of Finance, General Revenue Estimates, Fiscal Years 2010 through 2014 and calculations by authors.

In January 2014, the New Mexico Tax Research Institute published a study by Laird Graeser titled "Fiscal Impacts of Oil and Natural Gas Production in New Mexico – Preliminary Report". The purpose of this study was to estimate the impact of oil and gas production on the general fund. This preliminary report provided estimates for FY 2013. Table 4.4 lists the results of that study. Using both direct extractive taxes and the indirect taxes, it was estimated that the oil and gas industries were responsible for 31.5% of the general fund.

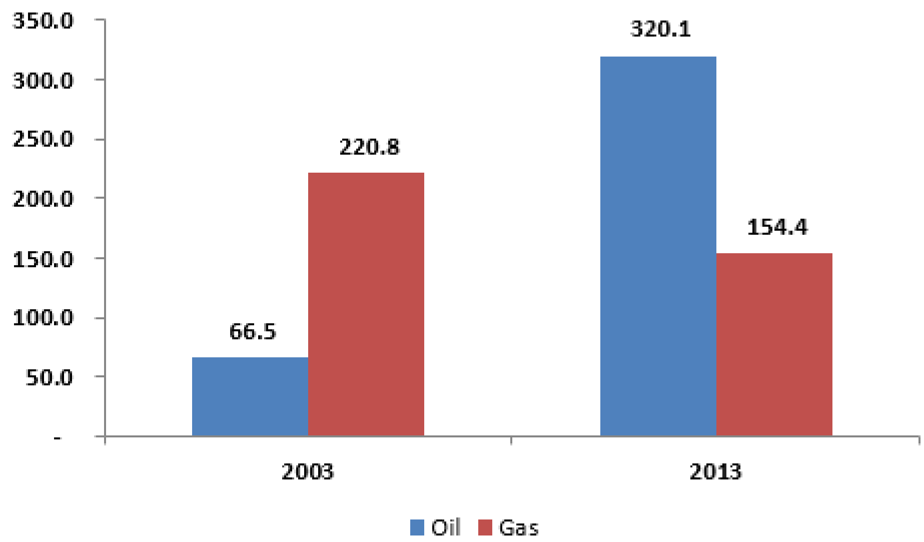
Table 4.4 Contributions of the Oil and Gas industries to the General Fund - 2013

FY 2013 General Fund			
Category	**Amount ($ millions)**	**OGAS Attributed Amounts ($ millions)**	**Approx. % OGAS**
Gross Receipts Tax	$1,912.7	$127.5	6.7%
Compensating Tax	$50.7	$14.8	29.2%
Selective Sales Taxes	$405.2	>0	0.0%
Net Personal Income	$1,225.7	$120.3	9.8%
Corporate Income Tax	$263.0	$54.0	20.5%
Oil & Gas School Tax	$385.0	$385.0	100.0%
7% Oil Conservation	$21.2	$20.2	95.2%
Resources excise	$15.1	$0.0	0.0%
Natural Gas Processors	$24.2	$24.2	100.0%
Perm. Fund Income	$440.9	$425.9	96.6%
Sev Tax Income Fund	$176.2	$151.5	86.0%
Federal Mineral Leasing	$459.6	$407.6	88.7%
Land Office Income	$44.6	$30.3	68.0%
All other categories	$166.2	$0.0	0.0%
Recurring General Fund/Total	$5,590.2	$1,761.2	31.5%

The vast majority of extractive tax revenues come from oil and gas taxes production. Until the early-2000's, natural gas produced over seventy-five percent of the revenues to the state from the two sources. Given the fall in prices for natural gas and rapid increases in oil prices and production, oil is now the more important revenue source. For example, Figure 4.1 displays severance tax revenue in 2003 and 2014 for both oil and gas. In 2003, oil accounted for only 23.1% of severance tax revenue ($66.5 million). By 2013, oil accounted for 67.5 percent of severance tax revenue.

Figure 4.1

Oil and Gas Severance tax revenue 2003 and 2013
(Millions of Dollars)



Source: New Mexico On-gard system, and author calculations.

5. Oil Price Volatility

Oil price volatility is an important issue nationally and takes on particular significance in oil producing states. At the national level, oil price shocks may create macro-economic disturbances. Kliesen (2008, p. 506) argues that all or nearly all post WWII recessions in the US were preceded by an increase in oil prices. Others recognize that price volatility in other energy sectors is also disruptive (Kilian 2008). There is no consensus definition of an energy price shock (Hamilton 2003) or agreement among economists on how energy price shocks affect the macro-economy (Barsky and Kilian 2004, Bernanke 2004, Federer 1996, Jones et al. 2004). A frequently heard explanation is that high energy prices are equivalent to a tax on consumer income and result in a decrease in consumption of other goods and services. It is also possible that oil price increases result in a downturn in investment when businesses recognize the oil-price related decrease in consumer expenditures. A little imagination or a perusal of the literature provides many other possible transmission mechanisms from energy to macroeconomic activity.

In the oil producing states price volatility is also an important issue. While the production of primary energy commodities is widely dispersed in the U.S., energy production is highly concentrated in only a dozen or so states. When energy prices increase rapidly, economic activity in the energy states may increase substantially at the same time other states are suffering from a decrease in economic activity (Snead 2009). Although energy price increases receive the most attention, energy price decreases can result in less drilling activity, oil production and state revenue. Oil production is, however, much less sensitive to price swings than drilling activity.

With few exceptions, oil prices have been highly variable since the 1930s. Table 5.1 presents the mean, standard deviation, and coefficient of variation of annual West Texas Intermediate prices by decade since the 1930s. Prices are expressed in 2009 dollars. Nominal prices of WTI were converted to 2009 dollars using the implicit price deflator for GDP (www.bea.gov). As indicated in Table 5.1 both the 1950s and 1960s were periods of relative price stability. In those decades, the coefficient of variation (standard deviation divided by the mean times 100) was less than 4 while other decades exhibit considerably more variation. The last time period shown (2010-2013) is not a complete decade but it is a time period that has had less oil price variability than at any time since the 1950s and 1960s. This last time period corresponds to the dramatic increases in oil production described above. For all practical purposes, WTI prices have been high (in the $90-$110 range) and relatively stable for five years.

Table 5.1

Selected Statistics Real WTI Prices (2009 dollars)

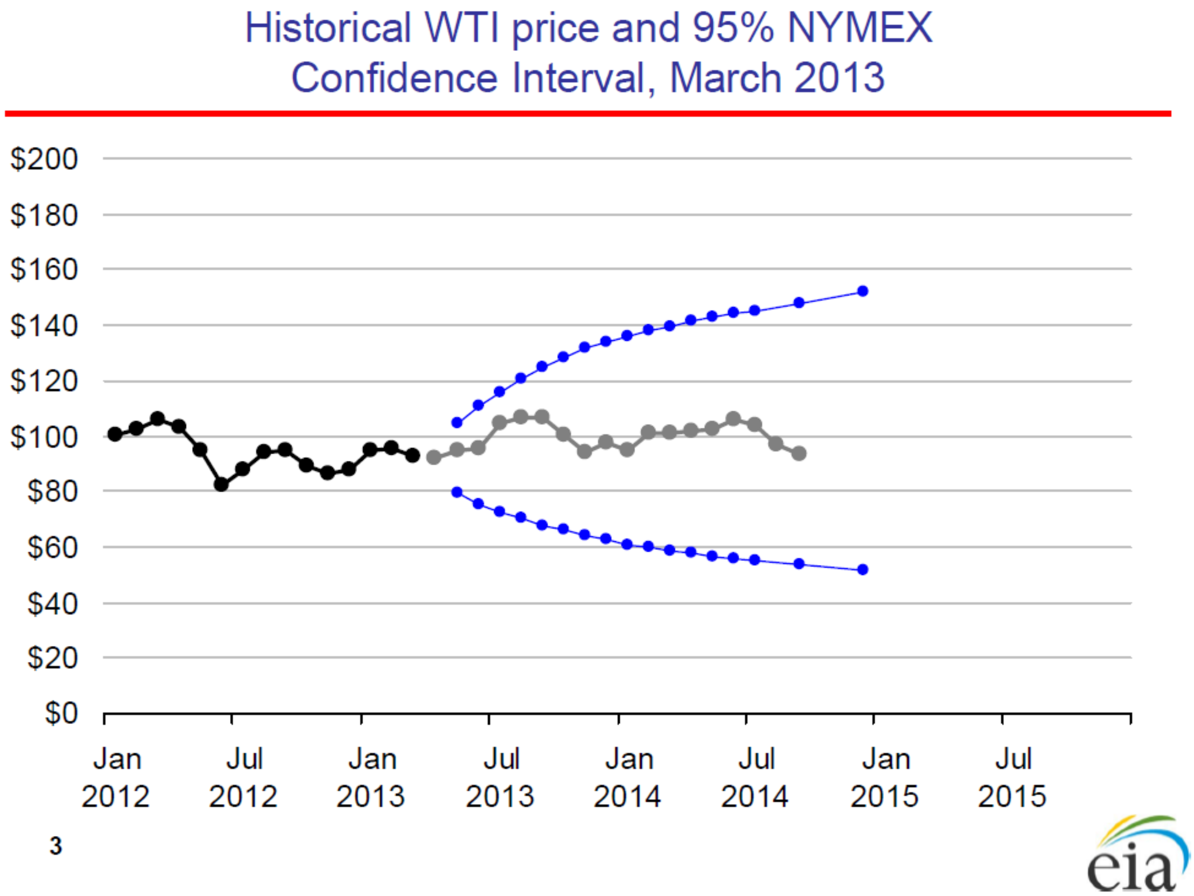
	Mean	Standard Deviation	Coefficient of Variation
1930 to 1939	8.83	2.15	24.35
1940 to 1949	11.28	3.06	27.11
1950 to 1959	16.27	0.53	3.28
1960 to 1969	14.39	0.52	3.62
1970 to 1979	29.94	14.33	47.85
1980 to 1989	49.76	19.98	40.14
1990 to 1999	26.81	4.76	17.77
2000 to 2009	54.92	21.59	39.32
2010 to 2013	80.69	5.45	6.38

Source: Author calculations.

There is no guarantee, of course, that high and stable oil prices are a permanent feature of oil markets. The historical record indicates otherwise. Appendix I contains charts of the annual percent change in oil prices by decade from the 1930s to the early 2010s. These charts indicate considerable variability in oil prices over short time periods except during the 1950s and 1960s (as already mentioned).

The Energy Information Administration (EIA) produces forecasts of oil prices as part of the "Short Term Energy Outlook" program. As a by-product of this effort, EIA produces 'confidence intervals' of oil prices based on data from futures prices. These "confidence intervals" are not produced in the same fashion that you were taught in statistics classes nor do they have the same meaning. Figure 5.1 is an example of the EIA confidence intervals which are generally done for a period of 18 months into the future. In some sense, the EIA is 95% confident that WTI prices will be between $50 and $160 by January, 2015. This is a somewhat narrower interval than EIA often publishes. The authors are more reluctant than many analysts to provide forecasts, but we will conduct various simulation experiments under alternative assumptions about oil and gas prices.

Figure 5.1



6. Natural Gas price volatility:

For those states that produce natural gas, volatility in natural gas prices is also important. Table 6.1 presents the mean, standard variation and coefficient of variation for U.S. wellhead prices for natural gas by decade since the 1930s. Prices are expressed in real 2009 dollars. Nominal prices were converted to 2009 dollars using the implicit price deflator for GDP (www.bea.gov).

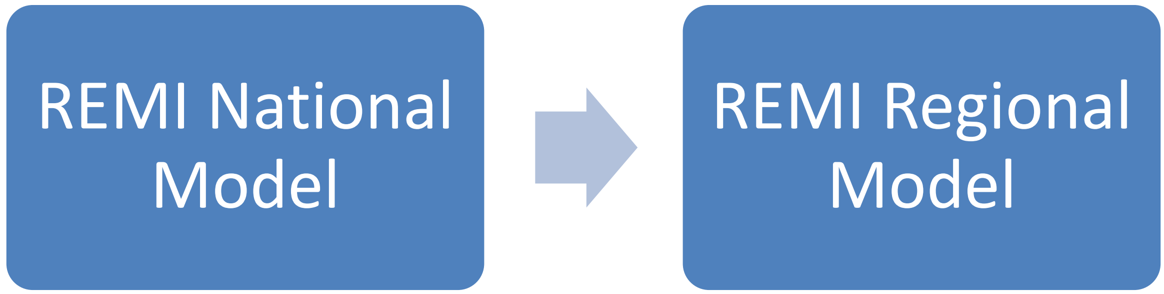
The only decade in which price variability was fairly stable was in the 1960s. All other decades reflected much more variability. The highest variability occurred in the 1970s.

Table 6.1

Selected Statistics Natural Gas Real Wellhead Prices (2009 Dollars)			
Decade	Mean	Standard Deviation	Coefficient of Variation
1930 to 1939	0.74	0.09	11.75
1940 to 1949	0.51	0.06	10.72
1950 to 1959	0.62	0.09	13.83
1960 to 1969	0.83	0.04	4.59
1970 to 1979	1.49	0.80	51.06
1980 to 1989	3.79	0.90	22.48
1990 to 1999	2.77	0.66	22.58
2000 to 2009	5.73	1.62	26.89
2010 to 2012	3.59	0.97	22.02
Source: Author Calculations			

7. The REMI Model

The characteristics of the REMI models are well known (Rickman and Schewer 1995; Treyz, Rickman, and Shao 1991). Briefly, the REMI models are long-run, dynamic models. The simulation period currently runs to 2050 and historical data on most variables are available from 1990. The models are based on annual data. The REMI national model interacts directly with one or more regional models as shown in the following diagram.



The regional models can contain any combination of counties or county equivalents. The regional model used in this analysis is for the State of New Mexico (issued October 2009).

A key driver of the models (national and state) is an input-output (Leontief model) derived from the national I-O model produced by the Bureau of Economic Analysis. The models used here are based on 169 sectors while the national I-O model contains more than 450 sectors.

The REMI models contain more than a static I-O model. The models also incorporate Computable General Equilibrium (CGE) techniques, single year of age cohort-component population projection models, and equations based on the New Economic Geography (Krugman 1998).

REMI models offer a variety of options to model energy changes. These include changes in relative fuel costs, relative delivered prices, modifying costs of production, and changing the fuel mix (fuel weight shares among, changing consumption patterns for gasoline and oil, fuel oil and coal, electricity, and natural gas). There are also several transportation related items that can be changed. Modifying trade flows and intermediate demand in several sectors are also possibilities. New energy industries may be created. Examples include uranium mining and milling (NAICS 212291) and petroleum refineries (NAICS 32411).

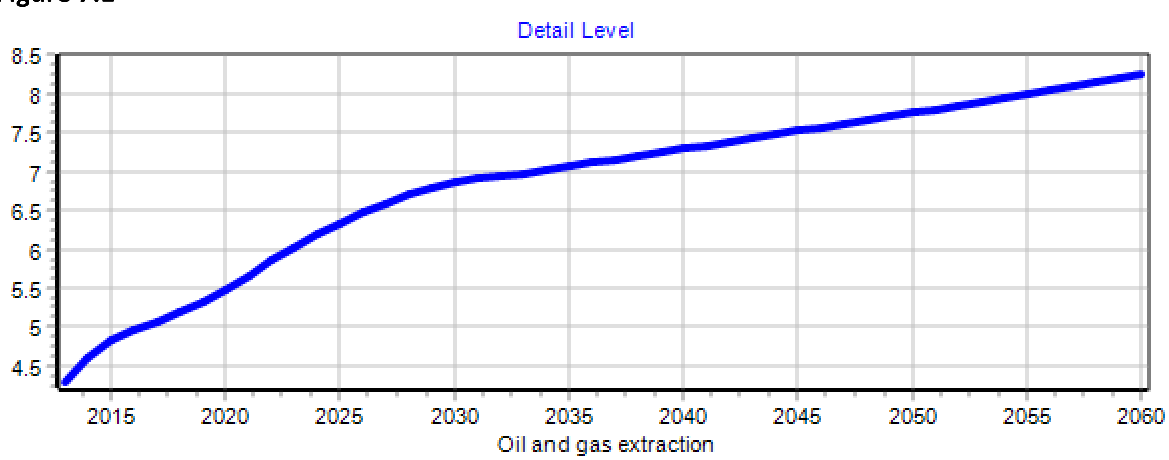
In addition, it is possible in the REMI models to modify employment (output) in several energy sectors including: oil and gas extraction (NAICS211), coal mining (NAICS 2121), electric power generation, transmission and distribution (NAICS 2211), natural gas distribution (NAICS 2212), petroleum and coal products manufacturing (NAICS 324), and pipeline transportation (NAICS 486). Most of these changes can be made to either the national model or the regional model(s).

The experiments described below involve modifying employment in the oil and gas extraction sector in the national control and examining the effect of this modification on economic activity in the New Mexico regional model.

7. Simulations:

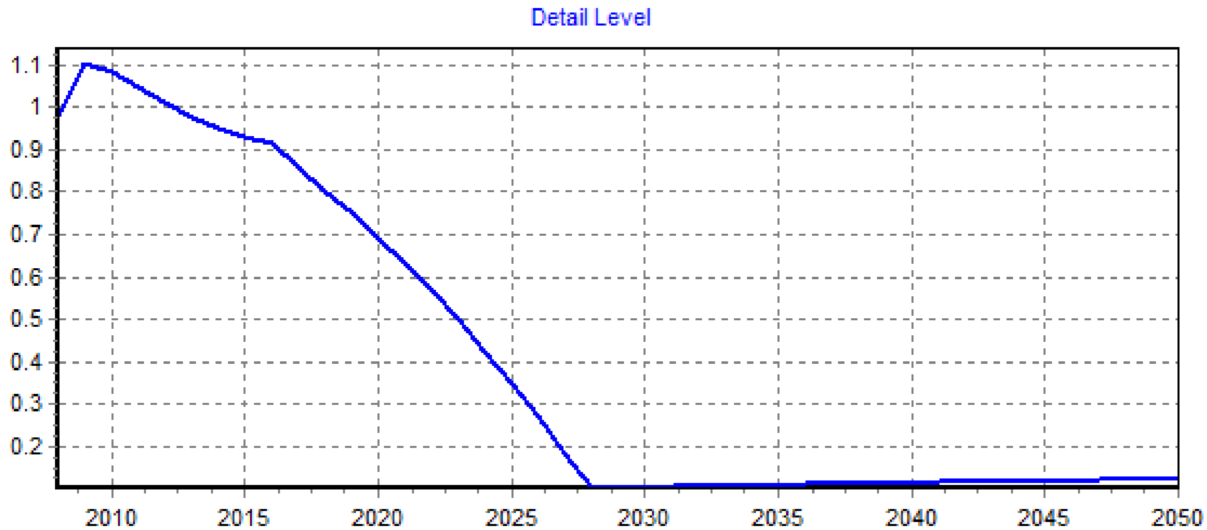
Five simulations are presented below. The first set of simulations addresses peak oil production without addressing price volatility. While we refer to peak oil, in the REMI model, oil and gas output (or value added or employment) extraction is in a single sector (oil and gas extraction). In the current REMI model (version 1.6.3, released August 2014), there is no peak oil assumption. Figure 7.1 displays value added in oil and gas extraction in New Mexico in the REMI baseline.

Figure 7.1



In In sharp contrast, earlier versions of the REMI model exhibited a significant peak in oil and gas extraction. Value added oil and gas extraction from the 2009 REMI PI+ model (Version 1.1) is shown in Figure 7.2.

Figure 7.2



The simulations were run separately for peak oil (three simulations) and oil price volatility (two simulations). The simulations in REMI are for calendar years. New Mexico's fiscal year runs from July 1 to June 30 so comparisons with the forecasts of the Consensus Revenue Forecasting Group are only approximate. The Consensus Revenue Forecasting Group consists of economists from the Department of Finance and Administration, The Department of Taxation and Revenue, and the Legislative Finance Committee. The simulations are not intended as forecasts. Rather, the simulations are intended only to illustrate the variability of key economic variables and energy taxes under alternative assumptions about the future.

7.1 Peak Oil Simulations:

Simulation 1, peak in oil and gas occurs in 2014 but there are no decreases in subsequent years. In this simulation, oil and gas employment is held constant at 2014 levels throughout the simulation. This scenario is in sharp contrast to the REMI baseline which has substantial increases in oil and gas extraction for the foreseeable future. Peak oil Scenario 1 is plausible if either oil prices decline or production decay rates of new wells is higher than expected.

The results of this simulation (see Table 7.1.1) suggest rather modest changes in total employment, real GDP, real Personal Income, and population through 2020. The implied energy tax revenues through 2020 do not show large differences when compared to the Consensus Revenue Forecast of August 2014. By the end of the simulation period (2030), large differences in key variables are apparent. Total employment in New Mexico in 2030 is 2.75 percent lower than the REMI baseline while Real GDP is 3.97 percent lower than the REMI baseline. The consensus forecasting group does not attempt to forecast energy revenue beyond FY19, but such revenue is $822 million less in 2030 than in the REMI baseline.

Table 7.1.1

Peak Oil Simulation 1 Percent change in selected variables compared to REMI model baseline								
	2015	2016	2017	2018	2019	2020	2025	2030
Total Employment	-0.34	-0.55	-0.76	-0.95	-1.16	-1.38	-2.44	-2.75
GDP	-0.55	-0.85	-1.13	-1.40	-1.70	-2.20	-3.54	-3.97
Real Personal Income	-0.26	-0.43	-0.60	-0.76	-0.94	-1.13	-2.05	-2.39
Population	-0.44	-0.11	-0.18	-0.29	-0.40	-0.52	-1.15	-1.99
Estimated Energy Tax Revenue								
Nominal dollars (millions)								
Energy Tax Revenue	$ 1,154	$ 1,159	$ 1,168	$ 1,176	$ 1,185	$ 1,193	$ 1,285	$ 1,461
Source: REMI model simulations assuming peak oil in 2014 with no subsequent decrease.								

In Simulation 2, peak oil and gas also occurs in 2014 but in this scenario a decay rate of 5 percent per year for twenty years is also imposed. In other words, beginning in 2015, employment in oil and gas extraction decrease by 5 percent per year throughout the simulation period. This scenario is also plausible given changes in national and international market conditions, and production decay rates higher than anticipated.

The results of simulation 2 (see Table 7.1.2) suggest larger negative effects on total employment, real GDP, real Personal Income, and population throughout the projection period. The implied energy tax revenues decrease throughout the simulation period. The estimated energy revenues under this scenario in 2020 ($815 million) are $325 million less than the FY19 forecast of the consensus forecasting group. By the end of the simulation period (2030), large differences in all key variables are apparent. Total employment in New Mexico in 2030 is 6.6 percent lower than the REMI baseline while Real GDP is 9.5 percent lower than the REMI baseline. Under this scenario, energy related revenues for the state decrease by 50% by the year 2030.

Table 7.1.2

Peak Oil Simulation 2 Percent change in selected variables compared to REMI model baseline								
	2015	2016	2017	2018	2019	2020	2025	2030
Total Employment	-0.66	-1.23	-1.79	-2.32	-2.85	-3.37	-5.53	-6.60
GDP	-1.08	-1.91	-2.7	-3.45	-4.2	-4.93	-8.41	-9.50
Real Personal Income	-0.51	-0.96	-1.41	-1.86	-2.30	-2.74	-4.65	-5.15
Population	-0.09	-0.23	-0.43	-0.67	-0.94	-1.25	-3.03	-4.63
Estimated Energy Tax Revenue								
Nominal dollars (millions)								
Energy Tax Revenue	$ 1,088	$ 1,028	$ 972	$ 919	$ 867	$ 815	$ 603	$ 510
Source: REMI model simulations assuming peak oil in 2014 with 5 % decay rate								

In simulation 3, oil and gas does not peak until 2019. Between 2014 and 2019, oil and gas extraction grows at the rate observed in the REMI baseline. Beginning in 2020, with New Mexico production at roughly 165 million barrels per year, production ceases to grow and remains flat throughout the projection period. Starting in 2020 and continuing through 2030, key economic variables decrease and do so at increasing rates. Energy related tax revenues decrease from $1,224 million in 2015 to $839 million in 2030. Results are shown in Table 7.1.3.

Table 7.1.3

Peak Oil Simulation 3 Percent change in selected variables compared to REMI model baseline	2015	2016	2017	2018	2019	2020	2025	2030
Total Employment	0.00	0.00	0.00	0.00	0.00	-0.51	-3.54	-5.23
GDP	0.00	0.00	0.00	0.00	0.00	-0.84	-5.12	-7.48
Real Personal Income	0.00	0.00	0.00	0.00	0.00	-0.39	-2.82	-4.35
Population	0.00	0.00	0.00	0.00	0.00	-0.07	-1.27	-2.95
Estimated Energy Tax Revenue								
Nominal dollars (millions)								
Energy Tax Revenue	$ 1,224	$ 1,263	$ 1,306	$ 1,350	$ 1,402	$ 1,331	$ 1,041	$ 839

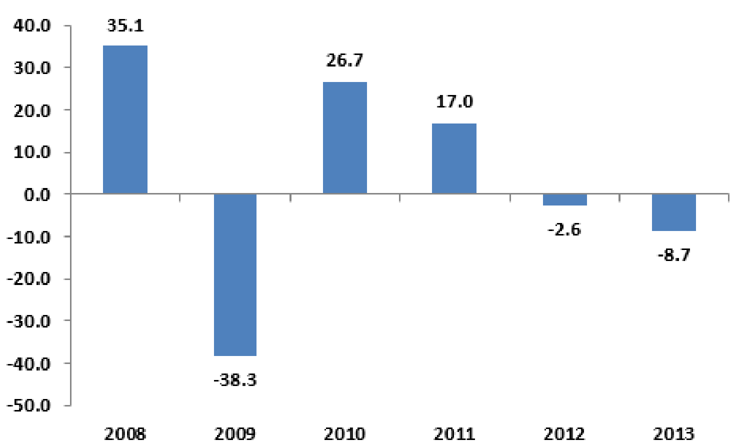
Source: REMI model simulations assuming peak oil in 2019 with 5 % decay rate

7.2 Oil price volatility simulations:

Simulation 1 imposes half of the variability in oil prices over the 2008-2013 period on the next six years (2015-2020). The choice of imposing half the variability in oil prices is arbitrary but can be intuitively justified by considering two facts. First, oil price variability between 2008 and 2013 was very large. In 2009 real WTI prices dropped by 38.3 percent and, then, increased by 26.7 percent in the following year (Chart 7.2.1). Second, historically oil prices vary more than employment. The price variability simulations were carried out only to the year 2020.

Chart 7.2.1

Percent Change in Real WTI Prices: 2008 to 2013



The results of simulation 1 are displayed in Table 7.2.2 below. The effects on key economic variables were modest in all years. In all years, with the exception of 2016, the estimated energy tax revenue is greater than the Consensus forecast. In 2016, 2017 and 2018, however, the estimated energy tax revenues were smaller than in the REMI baseline.

Table 7.2.2

Oil Price Volatility Simulation 1 **Percent change in selected variables compared to REMI model baseline**						
	2015	2016	2017	2018	2019	2020
Total Employment	1.19	-1.02	0.73	0.68	0.09	0.24
GDP	1.95	-1.87	1.32	1.03	0.02	-0.43
Real Personal Income	0.92	-0.76	0.58	0.53	0.10	-0.14
Population	0.15	0.00	0.10	0.17	0.16	0.11
Estimated Energy Tax Revenue						
Nominal dollars (millions)						
Energy Tax Revenue	$1,472	$985	$1,507	$1,482	$1,380	$1,384
Source: REMI model simulations assuming half the Real WTI Price Variability 2008-2013						

In simulation 2, oil price variability over a longer time period was considered. From 1994 to 2013 the mean annual percent change in real WTI prices was 8.6 percent with a standard deviation of 22.7 percent. For each year in the simulation period (2015 to 2020), a random normal variable was generated with the mean and standard deviation just mentioned. These random values were used to generate the percent changes in each year. The method used in simulation 2 reflects a longer view of price variability and uncertainty about when price variability might occur.

The results of simulation 2 are shown in Table 7.2.3. The results show fairly strong negative impacts on the overall economy in 2016, 2017, and 2018. In 2017 total employment decreases by 1.38 percent and real GDP declines by 2.05 percent in comparison to the REMI baseline. In contrast, 2019 showed strong positive impacts with total employment increasing by 1.54 percent and real GDP by 2.71 percent over the REMI baseline. Energy tax revenues were higher than both the REMI baseline and Consensus forecast in 2015 and 2019. There was, however, considerable variability in energy tax revenues over the simulation period. In 2016, for example, energy tax revenues were less than half of the 2019 figure.

Table 7.2.3

Oil Price Volatility Simulation 2 **Percent change in selected variables compared to REMI model baseline**						
	2015	2016	2017	2018	2019	2020
Total Employment	0.73	-1.46	-1.38	-0.85	1.54	-0.36
GDP	1.19	-2.5	-2.05	1.1	2.71	-0.81
Real Personal Income	0.56	-1.11	-1.06	-0.69	1.09	-0.33
Population	0.09	-0.11	-0.27	-0.34	-0.10	-0.15
Estimated Energy Tax Revenue						
Nominal dollars (millions)						
Oil and gas production taxes	$1,375	$913	$1,057	$1,244	$1,840	$1,294
Source: REMI model simulation assuming random normal distribution based on real WTI price variability (standard deviation) from 1994 to 2013						

Table 7.2.4 provides a summary of the effect of each of the five simulations on the estimated amount of energy tax revenues generated over the next five years and years 2025 and 2030. Also included in the

table is the REMI baseline taxes generated, the consensus Forecast for the State of New Mexico and a rule of thumb used by state revenue estimators.

Table 7.2.4

Summary Table: Estimated Energy Tax Revenue
Nominal Dollars: Millions

	2015	2016	2017	2018	2019	2020	2025	2030
Consensus Forecast*	1152.2	1170.2	1161.6	1157.2	1149.3	1141.7		
REMI Baseline	$1,224	$1,263	$1,306	$1,350	$1,402	$1,458	$1,823	$2,238
Peak Oil Scenario 1	$1,154	$1,159	$1,168	$1,176	$1,185	$1,193	$1,285	$1,461
Peak Oil Scenario 2	$1,088	$1,028	$972	$919	$867	$815	$603	$510
Peak Oil Scenario 3	$1,224	$1,263	$1,306	$1,350	$1,402	$1,331	$1,041	$839
Price Volatility Scenario 1	$1,472	$985	$1,507	$1,482	$1,380	$1,384		
Rule of Thumb**	$ 1,583	$ 980	$ 1,133	$ 1,191	$ 1,090	$ 1,156		
Price Volatility Scenario 2	$1,375	$913	$1,057	$1,244	$1,840	$1,294		

* Consensus forecast values are for FY 14 to FY 19 and include non-oil and gas revenue including coal and Carbon Dioxide
Source: See Tables 7.1.1 to 7.2.2
** Rule-of-thumb using same prices implied in Price volatility scenario 1 ($1 change in WTI = $6 million delta in state revenue. Natural gas price change of $0.10 = $8.4 million change in state revenue.

8. Conclusions

Peak oil may or may not occur in the near future. If peak oil does occur soon, it is not likely to do so because of a physical shortage of oil in the ground. A more likely scenario is that peak oil occurs because of market conditions or policy choices. In any case, there is considerable uncertainty concerning the peak itself and the timing of such a peak.

Oil price volatility has been common throughout the history of commercial oil production. Oil price stability has occurred, most recently in the 1950s and 1960s, but the historical record clearly indicates that long periods of price stability are the exception rather than the rule.

Both peak oil production and price instability warrant careful analysis because of potential impacts on economic variables, particularly energy tax revenues in energy producing states. Both phenomenon can and should be taken into consideration in regional models. The model simulations presented in this paper indicate that both peak oil and oil price instability can be modeled in a relatively straight-forward fashion and that the necessary effort is warranted. While revenue forecasters are generally required to provide point estimates, simulation exercises such as those reported here can provide valuable insight into the uncertainty of those estimates.

Further, many regional models, such as the REMI PI+ model used in this analysis, contain explicit assumptions about peak oil and oil price uncertainty. An obvious lesson is that these assumptions should be examined and modified when necessary. The REMI PI+ models contain assumptions about peak oil and price stability, but it is a simple matter to modify these assumptions.

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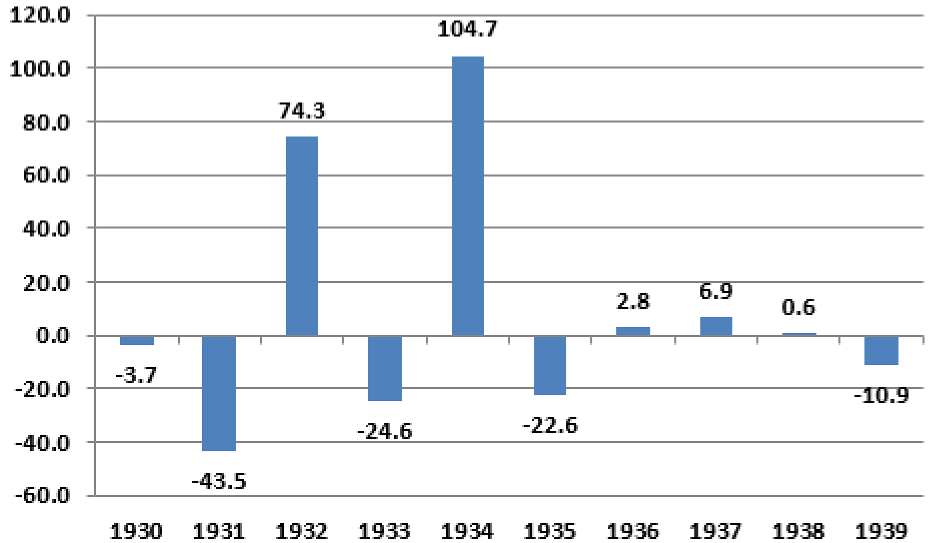
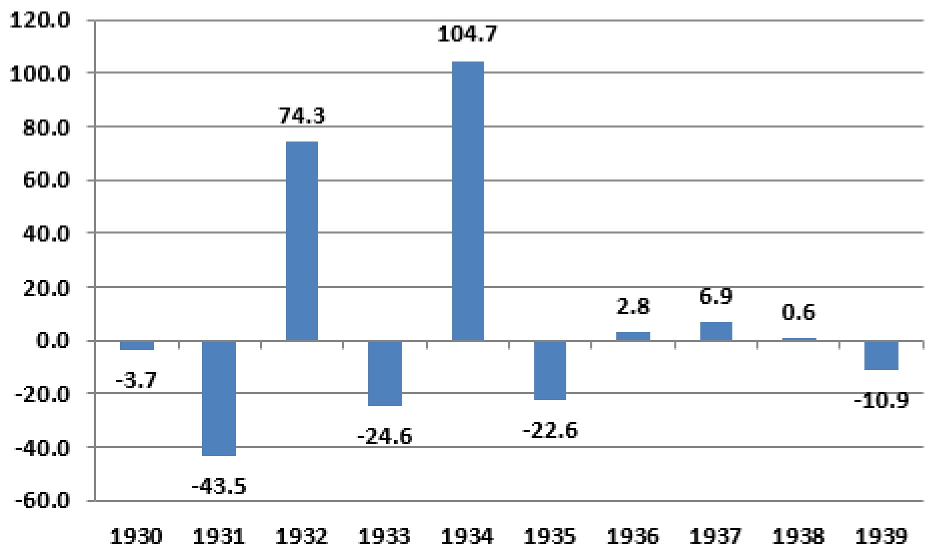
Appendix A

All charts in Appendix A exhibit year to year percent changes in West Texas Intermediate prices ($ per barrel) deflated by the Implicit Price Deflator for GDP. The base year for the GDP deflator is 2009. The deflator was downloaded from www.bea.gov on October 16, 2014.

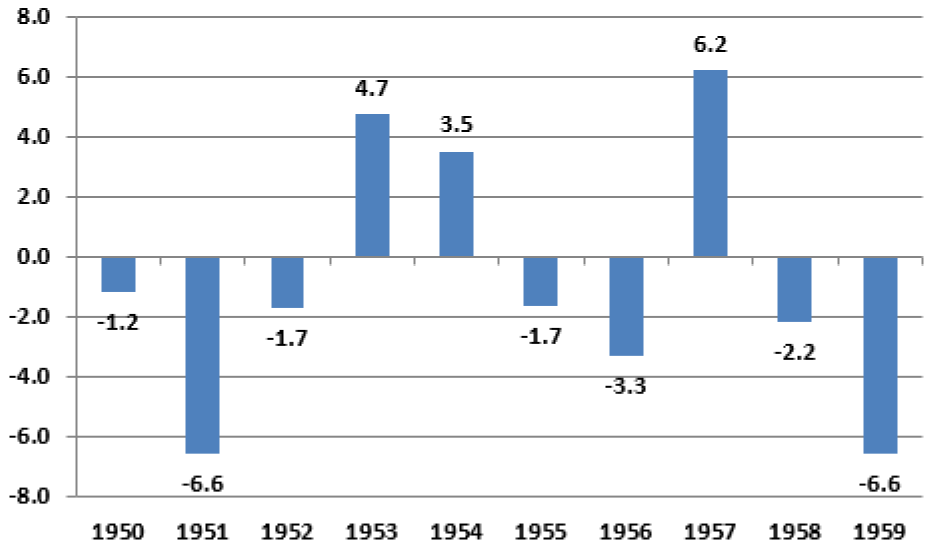
Percent Change in Real WTI Prices 1930s



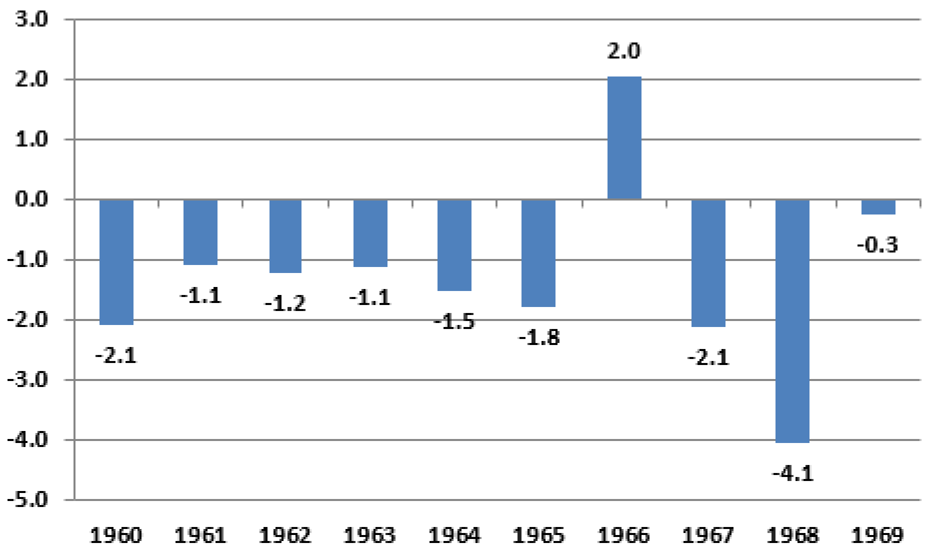
Percent Change in Real WTI Prices 1930s



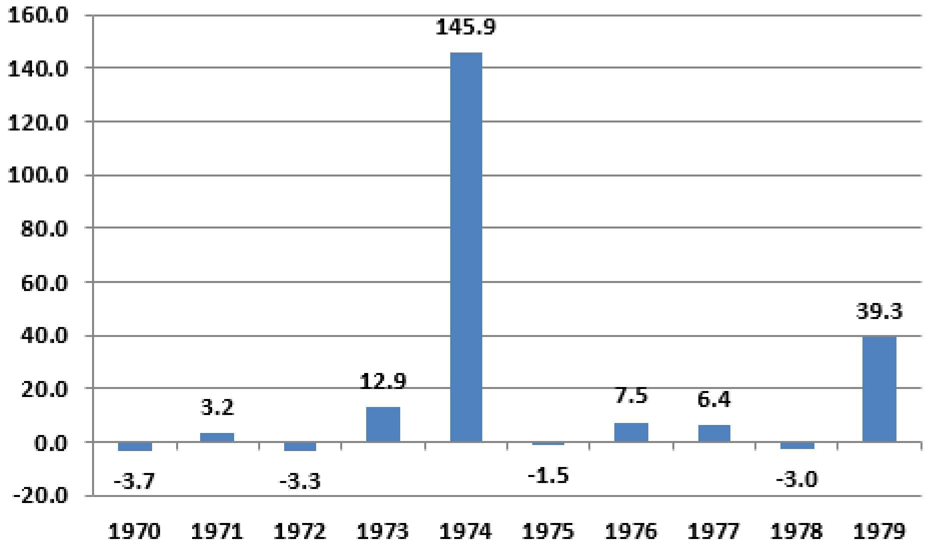
Percent Change in Real WTI Prices 1950s



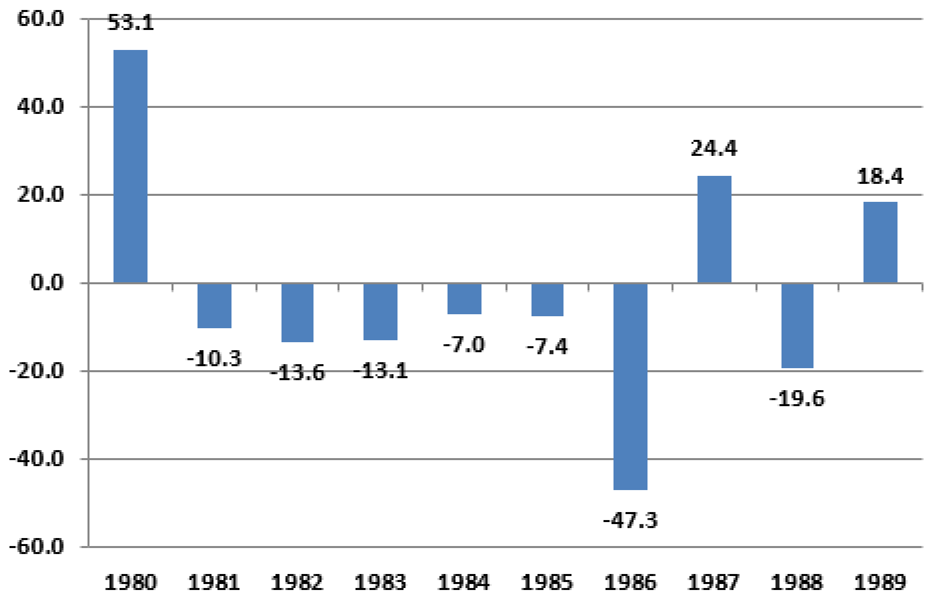
Percent Change in Real WTI Prices 1960s



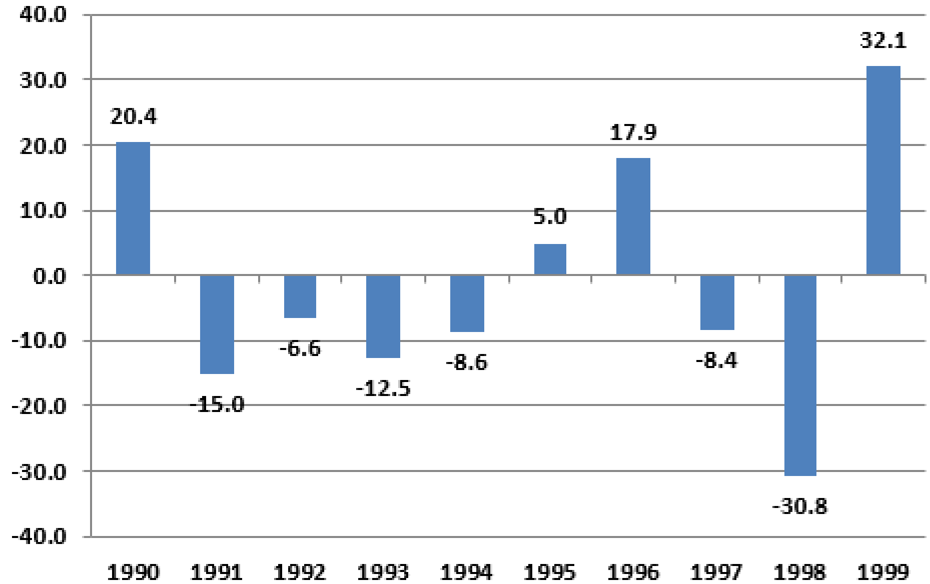
Percent Change in Real WTI Prices 1970s



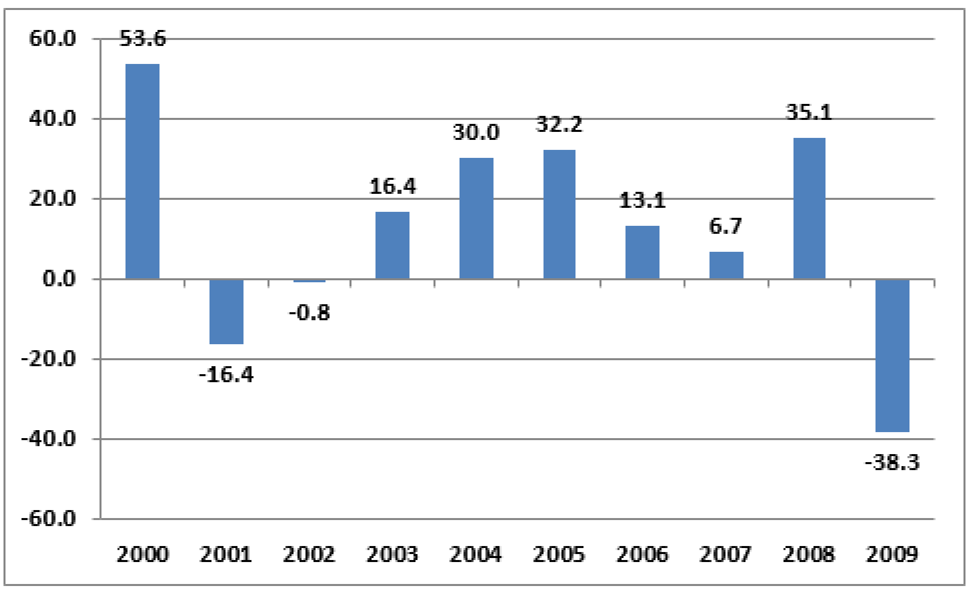
Percent Change in Real WTI Prices 1980s



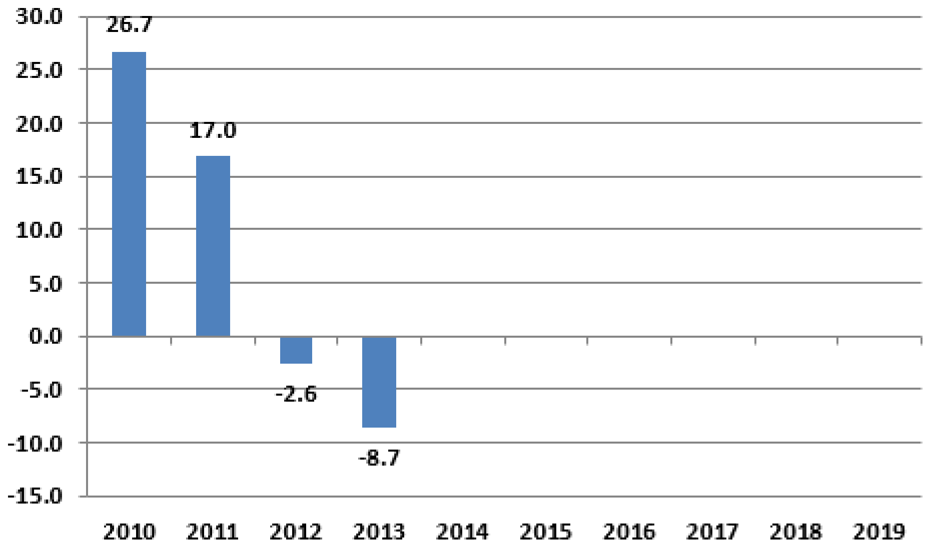
Percent Change in Real WTI Prices 1990s



Percent Change in Real WTI Prices 2000s



Percent Change in Real WTI Prices 2010s



Annual Percent Change in Real WTI prices