Oil Production and the Elasticity of the State Tax Base: Evidence from North Dakota

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Abstract

An important question in local public finance has been the impact of local economic conditions on the tax base. However, there is little causal evidence of the extent to which changes in local economic conditions impact the fiscal position of state and local governments. In this paper, I exploit an exogenous positive shock to local economic conditions caused by a boom in oil production in the state of North Dakota. The state surpassed California and Alaska to become the nation's second-largest producer of oil, behind only Texas, and its share of national oil production increased from nearly 1 percent in 2000 to over 12 percent in 2013. Using an instrumental variable (IV) strategy, I estimate a causal relationship between local economic conditions, as measured by the value of oil produced, and the tax base. My estimates suggest that the oil boom led to an 18 percent increase in the sales tax base and a 16 percent increase in the income tax base for oil counties in North Dakota.

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I. Introduction

Since the year 2000, increases in oil and natural gas production in the United States represented a positive shock to local labor market conditions that increased earnings and employment in impacted areas (Allcott and Keniston, 2014; Vachon, 2014a and 2014b). This boom in production was made possible due to a combination of rising prices and advancements in extraction technologies – the joint use of horizontal drilling and hydraulic fracturing, colloquially known as "fracking". Of any state or region, the boom had an outsized impact on North Dakota. During this period, the state surpassed California and Alaska to become the nation's second-largest producer of oil, behind only Texas, and its share of national oil production increased from nearly 1 percent in 2000 to over 12 percent in 2013.

A central theme of this boom has been a debate over the impact of fracking on local economic conditions in impacted areas. While many studies find that the boom had a positive impact on local labor market conditions, we know little about the impact of increased oil production on tax revenues. An important question in local public finance has been the impact of local economic conditions on the tax base and revenues. This topic is of particular interest given that sales and income tax bases as well as revenues are sensitive to business cycle fluctuations and changes in personal income.

The goal of this analysis is to estimate the impact of this plausibly exogenous increase in oil production on the tax base in North Dakota. I estimate the elasticity of the tax base with respect to the value of oil produced using an instrumental variable (IV) estimation strategy. I implement this strategy using a county-level panel dataset of administrative income and tax base data as well as oil production data for 2000 through 2010. To estimate the causal relationship between local economic conditions and the tax base, I use the value of county oil reserves as an instrument for the value of oil produced. I construct the instrument using oil reserves data and West Texas Intermediate (WTI) crude oil prices. This methodology allows me to exploit spatial variation in oil reserves at the county level and time-series variation in oil prices.

Overall, my IV estimates suggest that there is a substantial, statistically significant, positive relationship between local economic conditions and the sales and income tax bases. I estimate the short-run elasticities of these tax bases with respect to the value of oil produced for North Dakota. I find an elasticity of the sales tax base with respect to oil production of 0.18 and an elasticity of the income tax base with respect to oil production of 0.16. These estimates suggest that the doubling in the value of oil production during the period of interest led to an 18 percent increase in the sales tax base and a 16 percent increase in the income tax base for oil counties. Beyond providing these new estimates, this paper contributes to a growing body of literature that examines the impact of natural resource booms on various labor market outcomes, such as earnings, employment, migration, and social insurance (Acemoglu et al., 2013; Aldy, 2014; Allcott and Keniston, 2014; Black et al., 2002; Black et al., 2005; Carrington, 1996; Cascio and Narayan, 2015; Feyrer et al., 2014; Marchand, 2012; Vachon, 2014a and 2014b; Weber, 2012).

The rest of this paper proceeds as follows. Section II provides an overview of the oil boom; the exposition of this section largely draws upon that in Vachon (2014a). Section III describes changes to North Dakota's state taxes as well as important sources of state tax revenue. Section IV outlines the econometric specification. Section V describes the identification strategy. Section VI presents the estimation and results, and Section VII concludes.

II. Oil Boom Background

The source of oil is organic matter that is preserved and buried in some sedimentary rocks. For an oil deposit to be considered for commercial production, three important geological criteria must be met (Hyne, 2012). First, there must be a subsurface source rock that generated the oil (see Figure 1). The most common source rock is black shale. Shale originated as organic matter-rich mud on ancient seafloors.[1] As it was covered with more and more sediments and buried further below the Earth's surface, the heat from geological pressure turned the organic matter into oil. Second, there must be a separate subsurface reservoir rock that holds the oil. Reservoir rocks are sedimentary rock layers that contain billions of tiny spaces, or pores. Sandstone (composed of compressed grains of sand) and limestone (composed of broken down seashells and corals) are common reservoir rocks. Oil is able to flow through sandstone, limestone, and other reservoir rocks through the pore spaces between the sediments. Third, there must be a geological trap and cap rock to concentrate the oil into commercially extractable quantities. The trap is a geological high point in the formation that prevents the oil from flowing upward; the cap rock is a seal that prevents oil from flowing through it, concentrating the oil in the reservoir rock.

In "conventional" oil extraction, a well is drilled into the reservoir rock. Such methods characterized oil production in the United States, including North Dakota, for much of the previous century.[2] In contrast, the recent oil boom uses "unconventional" oil extraction because it involves drilling into and extracting resources from the shale source rock, which is less porous

[1] The shale oil extracted from the Bakken was formed approximately 350 million years ago during the late Devonian and early Mississippian geologic periods (Hyne, 2012).
[2] While the focus of this paper is on the Bakken formation, the explanations of the geology of fossil fuels and extraction technologies can generally be applied to other regions with shale oil and gas reserves and extraction (i.e. Marcellus and Utica in the Appalachian region, Eagle Ford and Barnett in Texas, and Woodford in Oklahoma, among others).

and permeable than typical reservoir rocks (i.e. sandstone and limestone, among others) (Maugeri, 2012). In particular, shale oil is extracted using the combined application of horizontal drilling and fracking techniques. Horizontal drilling is particularly effective in these formations because more well surface area is exposed to the oil-rich rock as compared to traditional vertical drilling. Hydraulic fracturing is the process of injecting large volumes of fluids into a well to fracture the rock. The fluid used is generally combined with sand before it is injected. The sand particles, known as propping agents, hold open the fractures, allowing oil to flow into the well (Hyne, 2012).

Figure 2 presents the time-series price and production data for North Dakota. Geologists and petroleum experts have been aware of North Dakota's reserves since the middle of the previous century when Amerada Petroleum Corporation drilled the area's first commercial oil well at the Clarence Iversen farm in Tioga, North Dakota in 1951. However, later that year Amerada made another important discovery at the Henry O. Bakken farm, also in Tioga. The Bakken well is important because it was the first in the area drilled into the older (deeper) geologic formation that became known as the Bakken formation. From 1951 through the 1970s, oil production averaged a modest 20 million to 25 million barrels per year. Beginning in 1973 with the OPEC embargo and continuing through the oil crisis of 1979, rising oil prices led to a boom in production in North Dakota in the 1980s. Even with record-high oil prices, annual production peaked at approximately 50 million barrels in 1984, compared to nearly 900 million barrels produced in Texas that year (U.S. Energy Information Administration, 2014).

While oil companies have had access to horizontal drilling and fracking technologies for some time, their combined application was not successful until 2000, when Mitchell Energy extracted natural gas from the Barnett shale in Texas (Maugeri, 2012). In North Dakota's

Bakken, Continental Resources is credited with the first commercially successful combined horizontal drilling and fracking oil well in 2004 (Continental Resources, 2014). North Dakota oil production hit nearly 250 million barrels in 2012 and continues to increase. Production resulting from this most recent boom dwarfs that of the 1980s.

III. North Dakota State Tax Background

There are four main sources of state tax revenues in North Dakota. Table 1 presents the share of state tax revenues by source. From Panel A, these major sources of tax revenues are severance taxes, sales taxes, individual income taxes, and corporate income taxes. Severance and sales taxes each make up approximately 27 percent of revenues, and individual income taxes make up 16 percent of revenues. Corporate income taxes represent a much smaller share of total revenues, at less than 6 percent. Panels B and C show the sources of total revenues for the pre-boom (2000-2004) and boom (2005-2012) periods, respectively. Revenues from sales and income taxes declined as a share of total revenues from the pre-boom period to the boom period.

Figures 3a and 3b present the time-series of total tax revenues and oil production and prices, respectively. These data come from the United States Bureau of the Census' *Annual Survey of State Government Finances* and the North Dakota Department of Mineral Resources, Oil and Gas Division. From the 1950s through the late 1990s, tax revenues increased from less than $500 million in 1952 to approximately $1.5 billion in 2000. Tax revenues and oil production both increase from the 1950s through the late 1960s. However, revenues and production diverge from the 1960s through the 1980s. From 2000 through 2012, there appears to be a generally positive relationship between tax revenues and prices and production. In 2004, coinciding with the introduction of new extraction technologies, tax revenues and oil production increase more rapidly; tax revenues increased from $1.5 billion in 2004 to nearly $4 billion in 2012.

A. Severance Taxes

The most important state tax related to oil production is the severance tax. It has two main components: the oil production tax and the oil extraction tax. First, the oil production tax rate is 5 percent on the gross value of all oil produced, except for oil produced on government or Native American lands.[3] Second, the oil extraction tax rate is 6.5 percent on the gross value of all oil produced.[4] There are two significant differences between these two taxes. First, revenue allocations differ. Revenues from the production tax are allocated between the state's general fund and the state's oil impact fund, while revenues from the extraction tax are allocated between the state's general fund, the state's water resources fund, and education (ND OSTC, 2013). Second, various changes to tax law allow for reductions to the extraction tax rate.

Under special circumstances, oil produced is subject to a reduced extraction tax rate or exempt from taxation. Several changes to the extraction tax allow for reduced rates. The extraction tax is lowered to 4 percent for oil produced from wells meeting the following criteria: the well is a "new well" that started producing oil after April 27, 1987, or secondary and tertiary recovery methods are used in extraction. Secondary and tertiary recovery methods are typically used to stimulate production when the subsurface pressure becomes insufficient to force oil to the surface. In these cases, the tax rate is 6.5 percent when the price per barrel of oil exceeds a "trigger" price for each month in any consecutive five-month period, and the tax rate is 4 percent when the price of oil is below the trigger price for each month in any consecutive five-month

[3] The production tax was introduced in 1953 and imposed a 4.25 percent tax on the value of oil produced; the rate increased to 5 percent in 1957.
[4] The extraction tax was introduced in 1980 at a rate of 6.5 percent.

period. Figure 4a presents a stylized depiction of this mechanism for a trigger price of $45 per barrel. The rates in this figure would apply to wells completed in January 2004, and the figure assumes the trigger is in effect when the well was completed. As such, extraction tax rate remains at 4 percent through June 2014. Because oil prices are above the trigger price of $45 for five consecutive months from February 2004 through June 2004, the extraction tax rate increases to 6.5 percent in July 2004. Prices below $45 from July 2004 to November 2004 put the trigger into effect, and the extraction tax rate is 4 percent through March 2004.

The North Dakota government sets the trigger price each year. From 1991 through 2000, the trigger price was $33 per barrel and not adjusted for inflation. Beginning in 2001, the trigger price was set to $35.50 per barrel and adjusted for inflation using the producer price index for industrial commodities. Table 2 presents nominal and real trigger prices for 2000 through 2010.[5]

In addition to this basic scenario, there are a number of special cases that reduce extraction tax rates. Some oil produced is subject to a 2 percent extraction tax rate. For oil produced from horizontal wells, the lower amount of the first 75 thousand barrels or 4.5 million dollars of gross revenue is taxed at a 2 percent extraction rate during the first eighteen months oil is produced.[6] This rate for horizontal wells takes effect "the first day of the month following a month for which the average price of a barrel of crude oil is less than fifty-five dollars" and is effective until "the first day of the month following a month in which the average price of a barrel of crude oil exceeds seventy dollars" (ND Legislative Branch, 2014). Figure 4b presents a stylized depiction of extraction taxes for horizontal wells in this case. The rates in this figure would apply to wells completed in April 2009, and the figure assumes the 2 percent rate is in effect upon completion of the well. Extraction tax rates remain at 2 percent until April 2010,

[5] For simplicity, real trigger prices presented in Table 2 are adjusted using the consumer price index.
[6] The first 75 thousand barrels produced from a well near the Bakken are taxed at a 2 percent extraction rate.

after a five-month period of prices above $70 at which point extraction tax rates rise to 6.5 percent.

Furthermore, some oil produced is exempt from extraction tax entirely; initial production is exempt from the extraction tax for fifteen months for vertical wells and twenty-four months for horizontal wells. This tax exemption is in effect when the price of oil is below the trigger price for each month in any consecutive five-month period and becomes ineffective when the price per barrel exceeds the trigger price for each month in any consecutive five-month period (ND OSTC, 2013). Overall, the implementation of the extraction tax is quite complex.

Figure 5a illustrates the time-series relationship between severance tax revenues and oil production. This figure shows a positive relationship between oil production and severance tax revenues. There is an increase in severance tax revenues with the boom in production in the 1970s and early 1980s; as production decreases then levels off in the 1980s, severance tax revenues do the same. Then, with the introduction of new extraction technologies and the Bakken oil boom, there is another increase in both severance tax revenues and oil production. During the most recent boom in oil production, severance tax revenues increased from $200 million in 2000 to over $1.6 billion in 2012; oil production increased from 32 million barrels in 2000 to approximately 250 million barrels in 2012.

Figure 5b presents the time-series relationship between severance tax revenues and oil prices. While there is a positive relationship between oil prices and severance tax revenues, revenues appear to be less sensitive to increases in price from the 1950s through the late 1990s as compared to the period between 2000 and 2012. Despite large price fluctuations and the introduction of the 6.5 percent extraction tax, the increase in severance tax revenues in the 1970s and 1980s is relatively modest. Oil prices increase from $19 in 1973 to nearly $100 in 1980, whereas severance tax revenues increase from $76 million to $400 million over the same period. From 2000 through 2012, severance tax revenues are more sensitive to large increases in price. During this period, prices increase from approximately $38 in 2000 to almost $90 in 2012; severance tax revenues increase from $200 million to $1.6 billion. Figure 5c illustrates revenues for the production and extraction taxes separately from 1989 through 2012. This data come from ND OSTC . As the figure shows, there is a highly positive correlation between production and extraction tax revenues. There is some divergence between 1994 and 2010, with production tax revenues slightly larger than extraction tax revenues during this period.

Figures 5d and 5e show the time-series relationships between the share of severance tax revenues and oil production and prices, respectively. From Figure 5c, the increase in production in the 1970s and 1980s, in combination with the introduction of the extraction tax in 1980 and the slight decline in total revenues, led to a large increase in the share of total revenues from severance taxes. The share of revenues from severance taxes increased from 1.7 percent in 1973 to 35 percent in 1982. Following the decrease in production during the 1980s, the share of revenue from severance taxes remained between 10 and 15 percent until after 2004. Between 2004 and 2012, the share of revenues from severance taxes increased from 14 percent to over 40 percent. Figure 5d presents the relationship between the share of revenues from severance taxes and the price of oil. The share of revenues is sensitive to changes in price over the entire series.

B. Sales Taxes

From Table 1, sales taxes make up more than one quarter of all tax revenues in North Dakota. North Dakota defines the sales tax base as the sum of taxable sales and taxable purchases, where taxable sales represent retail sales and taxable purchases represent the purchase of intermediate goods by businesses. The North Dakota state sales tax rate is currently 5 percent. In addition, cities and counties within the state have the choice of whether to implement a local option sales tax.

North Dakota first implemented a state sales tax in 1935. This initial legislation called for a 2 percent tax on “sales to consumers of personal property; sales or service of gas, steam, electricity, water and communication; sales of tickets to places of amusement; and subscription sales of magazines” (ND OSTC, 2013). In the time since the sales tax was enacted, the base has been increased to include hotel accommodations, tobacco products, and alcoholic beverages, among other things. Alcohol is taxed at a higher rate of 7 percent, while farm machinery and equipment are taxed at a lower rate of 3 percent. At the same time, the state legislature exempted certain goods and services from the sales tax. Groceries, with the exception of candy and soda, are exempt from sales taxes. In addition, various exemptions apply to the purchase of medical equipment, farm equipment and chemicals, and computing equipment for new and growing businesses, among others. The sales tax rate has remained at 5 percent since it was lowered from a high of 5.5 percent in 1989. Table 3 outlines the legislative changes to the sales tax base from 2000 to 2010, the primary period of interest for this study. These changes include additional exemptions for farm machinery, computer equipment for businesses, certain medical sales and purchases, and the sales of natural gas, among others.

Figures 6a and 6b present the time-series of sales tax revenues and oil production and prices, respectively. Sales tax revenues increase from less than $100 million in 1952 to approximately $420 million in 1976 and remain between $330 million and $430 million until the late 1990s. The decrease in revenues between 1976 and 1983 coincides with an increase in the sales tax rate from 3 to 4 percent that was in effect from 1977 through 1983. There is no clear relationship between sales tax revenues and increases in oil production or prices in the 1970s and 1980s despite large fluctuations in both production and prices during this period. From 2000 through 2012, there appears to be a positive relationship between tax revenues and production and prices, although sales tax revenues do not appear responsive to the large, temporary reduction in prices from 2008 to 2009. In 2004, coinciding with the introduction of new extraction technologies, sales tax revenues and oil production increase more rapidly; tax revenues increased from $424 million in 2004 to nearly $1.1 billion in 2012.

Figures 6c and 6d present the time-series of the share of revenues from sales taxes and oil production and prices, respectively. The figures show no clear relationship between sales tax revenue shares and oil production and prices. However, the overall downward trend in sales taxes as a share of total revenues since the 1970s may be explained by the general increase in the share of severance taxes over this time period. Sales taxes as a share of revenue decreased from 39 percent in 1973 to 27 percent in 2012.

C. *Income Taxes*

Income taxes represent the third largest source of tax revenue in North Dakota. The state requires that individuals with a federal income tax filing requirement file a North Dakota state income tax return. North Dakota uses federal taxable income, minus various deductions, as its income tax base. Federal taxable income is equal to AGI minus personal exemptions and (either standard or itemized) deductions. North Dakota taxable income is equal to federal taxable income minus deductions; the major deductions include certain lump-sum pension distributions and up to 30 percent of capital gains and dividends.

Three major changes to the North Dakota income tax rate schedule between 2000 and 2010 are outlined in Table 4. Until tax year 2000, income tax payments in North Dakota were equal to federal income tax liability times a flat tax rate of 14 percent.[7] As shown in Table 4, the flat tax was replaced with a new rate schedule for the 2001 tax year. For single filers, the new schedule imposed a 2.1 percent tax on the first $27,050 dollars earned, and the top marginal tax rate of 5.55 percent applied to earnings over $297,350. For the 2009 tax year, this was replaced with a new rate schedule that reduced marginal tax rates overall. The 2009 schedule imposed a 1.84 percent on the first $33,950 dollars earned, and the top marginal tax rate of 4.86 percent applied to earnings over $372,950.[8]

Figures 7a and 7b present the time-series of income tax revenues and oil production and prices, respectively. There does not appear to be a clear relationship between income tax revenues and oil production or prices. During the initial increase in production and prices in the 1970s and 1980s, income tax revenues fell from $260 million in 1975 to $77 million in 1983 as oil production and prices are rising then increased to $210 million in 1988 as prices and production fell. In contrast, income tax revenues have increased since 1990 as oil production and prices have increased as well.

Figures 7c and 7d show the time-series of the share of revenues from income taxes and oil production and prices, respectively. The figures generally illustrate a negative relationship between the share of revenues from income taxes and oil production and prices. During the initial increase in production and prices in the 1970s and 1980s, the share of revenues from

[7] The flat tax was initially introduced in 1981 with a rate of 7.5 percent; the rate increased to 10.5 percent in 1983 and 14 percent in 1987 (ND OSTC, 2010 and 2014).

[8] Prior to the 2009 tax year, individuals could choose between two income tax return forms, ND-1 (short form) and ND-2 (long form). Each relied on different deductions, credits, and rates. Long form ND-2 was repealed, and, since 2009, all individuals required to file must use ND-1. Because over 98 percent of filers benefitted from filing ND-1 versus ND-2 during that time, this section focuses on form ND-1.

income taxes fell from 25 percent 1975 to less than 7 percent in 1983 as oil production and prices are rising then increased to 17 percent million in 1988 as prices and production fell. With the most recent increases in oil production and prices, the share of revenues from income taxes fell from 18 percent in 2007 to just over 10 percent in 2012.

IV. Econometric Specifications

The goal of the current paper is to estimate the impact of local economic conditions, as measured by oil production, on the tax base. This paper is related to a strain of the public finance literature that examines the impact of economic conditions, as measured by changes in income, on tax bases and revenues. Table 5 summarizes some of the major contributions to this literature. For each paper, I show the data sources used in the estimation, the time period studied, the geographic area, the outcomes of interest (tax base or tax revenues), explanatory variables, the tax instrument studied, and the estimates for the income elasticity of the tax base or tax revenues. Beginning with Groves and Kahn's (1952) seminal paper, the standard model used to estimate the income elasticity of the tax base (revenues) is presented as:

$$ln(T_{st}) = \rho + \gamma ln(Y_{st}) + \delta \boldsymbol{X}_{st} + \varepsilon_{st}, \quad (1)$$

where $ln(T_{st})$ is the natural logarithm of the tax base (revenues), $\boldsymbol{X}_{st}$ is a vector of control variables, and ε_{st} is the error term for state s in year t. The explanatory variable, $ln(Y_{st})$, is the natural logarithm of income. Because of the log-log specification of (1), the focal parameter, γ, is interpreted as the income elasticity of the tax base.

Groves and Kahn (1952) examined tax revenue data from various states between 1930 and 1950. The authors found estimates of the income elasticity of sales tax revenues ranging from 0.99 in Ohio to 1.11 in California, Illinois, and Oklahoma. Wilford (1965) examined revenues in Texas between 1947 and 1960. He found that the per capita income elasticity of various tax revenues were larger than the aggregate income elasticity.

As Dye (2004) explains in his review of the literature, “two important criteria used to evaluate state taxes or tax systems are the long–run or trend rate of growth in revenue and the short–run cyclical variability or stability of revenue over the business cycle” (p. 135). The approach by Groves and Kahn (1952) and Wilford (1965), among others, does not consider that short- and long-term elasticity estimates might differ and should be measured separately.

Williams et al. (1973) were the first to point out that long-run and short-run elasticities must be measured separately. Specifically, estimates of γ from (1) represent the long-run elasticity. Williams et al. (1973) estimated long-run elasticities using (1). To estimate short-run elasticities, they first-differenced (1), regressing the first-difference in the natural logarithm of the tax base on the first-difference in the natural logarithm of income, where the first-difference of the natural logarithm represents the growth rate. For sales tax revenues, they found a long-run elasticity of 1.4 and a short-run elasticity of 0.8. Following Williams et al. (1973), Fox and Campbell (1984), for example, allowed the income elasticity to vary over the cycle by including a business cycle indicator variable to the standard specification. Using data from Tennessee, they estimated short-run sales tax revenue elasticities for each year from 1975 to 1982. They found elasticity estimates ranging from 0.16 in 1976 to 0.92 in 1979.

Sobel and Holcombe (1996) and Holcombe and Sobel (1997) provided an econometric framework to support Williams et al. (1973). They pointed out that tax revenues and incomes are non-stationary (both taxes and income trend upward over time). They test for non-stationarity using the Augmented Dickey-Fuller test. Non-stationarity poses two econometric challenges in estimating the income elasticity of the tax base. First, non-stationarity in the tax base and income will bias short-run estimates of γ. Following Williams et al. (1973), they used the first-differenced form of the natural logarithm of the tax base and earnings and show that the differenced forms of these variables are stationary. Second, non-stationarity will bias long-run estimates of γ as well as the standard errors in (1). They found that serial correlation in the error term will bias the coefficient and that the direction of that bias will depend on the cyclicality of business cycles (how many peaks v. troughs). Following Stock and Watson (1993), they employed dynamic ordinary least squares (DOLS) to provide long-run estimates of γ. DOLS is a procedure that adds leads and lags of the independent variable to correct for coefficient bias. In addition, to consistently estimate the standard errors, they used the Newey-West (1987) correction. DOLS and the error correction produce qualitatively and quantitatively similar estimates of the long-run elasticities as compared to the standard models.

Using a national dataset for 1951-1990, Sobel and Holcombe (1996) found a short-term income elasticity of the tax base of 1.08 and a long-term elasticity of 0.69. Bruce et al. (2006) followed Sobel and Holcombe (1996) using DOLS to estimate long-run elasticities. They build upon short-run models, estimating separate elasticities that depend on location in the business cycle. They estimate separate elasticities for each state. For the sales tax, they find a long-run elasticity of 0.8; they find short-run elasticities that range from -2 to over 3.

To estimate a causal relationship between local economic conditions and the sales tax base, I rely on county-level variation in oil production in North Dakota between 2000 and 2010. I present the relationship between the value of oil produced and the sales tax base as:

(2) $$\Delta ln(B_{it}) = \phi + \beta \Delta ln(P_{it}) + u_{it},$$

where B_{it} represents the tax base for county i in year t, and u_{it} is the error term. The main explanatory variable is P_{it}, the value of oil produced. The focal parameter, β, represents the short-run elasticity of the sales tax base with respect to the value of oil produced.[9]

Following Sobel and Holcombe (1996) and Bruce et al. (2006), I test for non-stationarity in $\Delta ln(B_{it})$ and $\Delta ln(P_{it})$. The Augmented Dickey-Fuller test used by the previous authors is not suitable for panel data. As such, I employ the Im-Pesaran-Shin (IPS) (2003) unit root (i.e. non-stationarity) test for panel data and reject the null hypothesis that all panels contain a unit root at the 1 percent level.

I construct a county-level panel dataset of administrative oil production data as well as administrative sales and income tax base data for 2000 through 2010. I calculate the value of oil produced at the county level using oil production data from United States Department of Agriculture's Economic Research Service (USDA ERS) as well as WTI crude oil prices from the United States Department of Energy's Energy Information Administration (EIA). Data from the North Dakota Office of the State Tax Commissioner (ND OSTC) contain the value of county-level taxable sales and purchases, which together make up the sales tax base. Taxable sales represent retail sales while taxable purchases represent the purchase of intermediate goods by businesses. Data from the Internal Revenue Service (IRS) Statistics of Income (SOI) contain Adjusted Gross Income (AGI). I use adjusted gross income (AGI) from federal income tax returns aggregated to the county level as a measure of the income tax base. This data come from the Internal Revenue Service (IRS) Statistics of Income (SOI). AGI is commonly used in the

[9] I am not able to estimate long-run elasticities for two reasons. First, I only have eleven years of data from 2000 through 2010. Second, this period does not cover a complete business cycle; oil production is strictly increasing over the timeframe.

literature as a measure of the income tax base.[10] North Dakota uses federal taxable income, minus various deductions, as its income tax base. Federal taxable income is equal to AGI minus personal exemptions and itemized deductions. The sales and income tax bases as well as the value of oil produced are measured in real 2010 dollars, adjusted for inflation using the Consumer Price Index (CPI).

Panel A of Table 6 presents summary statistics for the entire sample period. North Dakota is a relatively small state; according to the 2000 Census, its population was 642,000. From column 1, the average population per county is nearly 11,000, and per capita income is approximately $22,000. Throughout the period of interest, counties in the state experienced average annual increases in sales tax base of 2.6 percent, respectively. The average value of oil produced in each county was nearly $200 million.

V. Identification Strategy

There are two empirical challenges that arise in estimating the relationship between economic conditions, as measured by oil production, and the tax base. First, sales tax policy endogeneity will bias my results if sales tax rates are reduced in response to increases in the value of oil produced. Second, oil production is a function of wage rates (income tax base); this link leads to an endogeneity problem as increases in the price of labor will put downward pressure on oil production.

To overcome these challenges, I estimate the parameters in (2) using an IV strategy following closely the approach of Black et al. (2002) and Vachon (2014a and 2014b). This strategy is based on natural variation in county-level oil reserves. The oil reserve data used in

[10] "Most states use something close to federal adjusted gross income as the base for state income taxes, so this measure closely approximates the state income tax base" (Sobel and Holcombe. 1996).

this analysis come from the 2004 EIA assessment of the Bakken formation of the Williston Basin. I calculate oil reserves using EIA shape files and MapInfo software. I use midpoint estimates for each oil field, as the reserves are listed in ranges, then aggregate to the county level. Based on this method, in North Dakota, there are 16 counties that have oil reserves, and 37 counties that have no reserves. From column 2 of Table 6, the average oil county has over forty-eight million barrels of oil reserves. I calculate the value of oil reserves by multiplying county-level reserves by the price of West Texas Intermediate (WTI) crude oil. From Panels B and C of Table 6, the average price per barrel of WTI crude oil increased from $37 to $76 between the early and later years of the oil boom. I use the value of oil reserves as an instrument for the value of oil produced to econometrically capture the impact of the oil price increases on the value of oil produced.[11]

Figures 8 through 11b present a visual depiction of my identification strategy. Estimates are based on data from 2000-2010. Figure 8 shows the level of oil reserves for counties in North Dakota. These reserves depict the portion of the Bakken formation of the Williston Basin that falls within the state's boundaries. The counties with the darkest shading have the highest levels of oil reserves; those areas that are white have no oil reserves. The darkest shaded counties have between 50 and 217 million barrels of oil. The counties shaded in dark gray have between 5 and 50 million barrels of oil. The counties shaded in the light gray have less than less than 5 million barrels of oil (but more than zero). Figure 9 presents the quartile of average annual oil production. The areas with the darkest shading have the greatest annual production over the timeframe. The first through fourth quartiles represent production below 90 thousand barrels,

[11] During the late part of the oil boom from 2005 through 2010, oil production in the Bakken increased from 1 million to 5 million barrels per month. In 2009, oil production in the Bakken was approximately 3 percent of the US total monthly oil production. From 2009 to 2012, oil production in the Bakken increased from 5 million to 22 million barrels per month. In 2012, oil production in the Bakken represented approximately 10 percent of the US total monthly oil production (Federal Reserve Bank of Minneapolis, 2012).

between 380 thousand and 1 million barrels, between 1 million and 4.6 million barrels, and above 4.6 million barrels of oil per year, respectively. The county with the lowest annual oil production extracted an average of 650 barrels per year; the county with the highest production extracted over 10 million barrels per year.

Figures 10a and 10b depict quartiles of average annual growth in the sales tax base for the pre-boom (2000-2004) and boom (2005-2010) periods, respectively. Areas with the darkest shading have the highest growth. For the pre-boom period in Figure 10a, the first through fourth quartiles represent sales tax base growth below -4.3 percent, between -4.3 percent and -1.8 percent, between -1.8 percent and 0.5 percent, and above 0.5 percent, respectively. The county with the lowest sales tax base growth experienced a 13.5 percent decrease; the county with the highest growth experienced a 5.4 percent increase. For the boom period in Figure 10b, the first through fourth quartiles represent sales tax base growth below 1.9 percent, between 1.9 percent and 3.6 percent, between 3.6 percent and 6.1 percent, and above 6.1 percent, respectively. The county with the lowest sales tax base growth experienced a 2.5 percent decrease; the county with the highest growth experienced a 34.8 percent increase.

Figures 11a and 11b depict quartiles of average annual growth in the income tax base for the pre-boom (2000-2004) and boom (2005-2010) periods, respectively. Areas with the darkest shading have the highest growth. For the pre-boom period in Figure 11a, the first through fourth quartiles represent income tax base growth below -1.9 percent, between -1.9 percent and -0.9 percent, between -0.9 percent and 0.9 percent, and above 0.9 percent, respectively. The county with the lowest income tax base growth experienced a 9.7 percent decrease; the county with the highest growth experienced a 4.6 percent increase. For the boom period in Figure 11b, the first through fourth quartiles represent income tax base growth below 3.5 percent, between 3.5

percent and 4.9 percent, between 4.9 percent and 6.9 percent, and above 6.9 percent, respectively. The county with the lowest income tax base growth experienced a 0.7 percent decrease; the county with the highest growth experienced a 32 percent increase.

Figures 8 and 9 represent the first-stage relationship between oil reserves and growth in the value of oil produced. Those counties with high growth in the value of oil produced have the highest levels of oil reserves, as evidenced by the dark shading on both maps. Figures 8, 10a, and 10b represent the reduced-form relationship between oil reserves and the sales tax base. Figures 8, 11a, and 11b represent the reduced-form relationship between oil reserves and the income tax base. These reduced-form relationships depict a positive relationship between oil reserves and growth in the sales and income tax bases. Those areas with high levels of oil reserves have high growth in the tax bases, especially during the boom period. This is evidenced by the fact that high oil reserve counties are more darkly shaded while low tax base growth counties are lightly shaded.

VI. Estimation and Results

The first-stage of the IV estimation is:

(3) $$\Delta ln(B_{it}) = \alpha_0 + \alpha_1 \Delta ln(R_{it}) + \theta_{it},$$

where the instrument, $\Delta ln(R_{it})$, represents the natural logarithm of the value of county oil reserves for each year in 2010 dollars. Table 7 presents estimates of α_1 from (3). These estimates represent the first stage relationship between growth in the value of oil reserves and growth in the value of oil produced. As illustrated in Table 7, these estimates suggest that a doubling in the value of county-level oil reserves increases the value of oil produced by 139 percent. The associated F-statistic is 15.6, suggesting that the instrument is relatively strong.

Table 8 presents estimates β, the elasticity of the tax base with respect to oil production, from (2). The estimate in Column 1 of Table 8 indicates an elasticity of the sales tax base with respect to the value of oil produced is 0.18. This elasticity suggests that a doubling in the value of oil produced increases the county-level sales tax base by 18 percent. Column 2 presents estimates of the elasticity of the retail sales with respect to the value of oil produced. I find an elasticity of 0.13, suggesting a doubling in the value of oil produced will increase retail sales by 13 percent. Column 3 of Table 8 presents the elasticity of the income tax base with respect to the value of oil produced. I find an elasticity of 0.16. The point estimate suggests that a doubling in the value of oil produced increases the county-level income tax base by 16 percent. In reality, average annual increases in the value of oil produced were approximately 23 percent in oil counties from 2005 through 2010. This suggests the oil boom led to a 25 percent increase in the sales tax base and a 22 percent increase in the income tax base for oil counties compared to counties without oil.

Finally, changes in county-level local option sales tax rates could impact my estimates of β. To account for this, I add the change in county-level sales tax rates as a control variable in Table 9. The inclusion of sales tax rates to results in estimates of β that are quantitatively the same as those in Table 8. In addition, the coefficient on the tax rate variable is insignificant.

VII. Summary, Caveats, and Implications

In this paper, I exploit exogenous variation in local economic conditions due to a boom in oil production to estimate the relationship between economic growth and the tax base for counties in North Dakota. The boom in oil production in the Bakken formation impacting western North Dakota created an unexpected, positive shock for local economies, particularly for oil-rich counties. Overall, my estimates suggest a statistically significant and positive relationship between the value of oil produced and the tax base. I find elasticities of the tax base with respect to the value of oil produced of 0.18 and 0.16 for the sales and income tax bases, respectively. From 2000 through 2010, the value of oil produced in North Dakota nearly doubled, suggesting oil counties experienced increases in sales and income tax bases of 18 percent and 16 percent, respectively.

The current paper builds upon the previous literature in three important ways. First, I rely on an IV strategy to overcome the identification challenges. Second, the use of a natural experiment is a novel approach that provides new causal evidence of the impact of economic booms on the tax base in North Dakota. I use this approach because the national boom in oil and natural gas production was an exogenous shock that differentially impacted resource-abundant counties. Despite a long history of research in this area, we have few causal estimates of the relationship between local economic conditions and the tax base. Finally, this paper contributes to the growing literature examining impact of natural resources on local economic conditions (Acemoglu et al., 2013; Aldy, 2014; Allcott and Keniston, 2014; Black et al., 2002; Black et al., 2005; Carrington, 1996; Cascio and Narayan, 2015; Feyrer et al., 2014; Marchand, 2012; Vachon, 2014a and 2014b; Weber, 2012). The estimates in this paper may serve to shed light on the impact of booms in natural resource extraction, particularly fracking, on the fiscal position of state and local governments

In addition, the new estimates of the elasticity of the tax base with respect to changes in local economic conditions that I provide in this paper can provide insight into how changes in the price of oil will impact both production and the tax base. Between June 2014 and February 2015, oil prices fell by just over 50 percent from $106 to $51 per barrel. Based on my first stage estimates, this decrease in prices should reduce the value of oil produced by 70 percent. From my estimates of β, a 70 percent reduction in the value of oil produced at the county level will reduce the sales and income tax bases by 13 percent and 11 percent respectively.

While my findings suggest large impacts of oil production on the sales and income tax bases, there is an important limitation to this study. North Dakota is less populous and more rural than the rest of the United States. As such, caution should be taken when attempting to generalize these estimates to other areas impacted by the recent boom in oil and natural gas production. This caveat provides a natural avenue for future research. Expanding this county-level analysis beyond North Dakota to other areas impacted by the national shale boom is important as it may further inform the debate over the impact of fracking on local economic conditions.

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Figure 1 – Petroleum Geology and Extraction

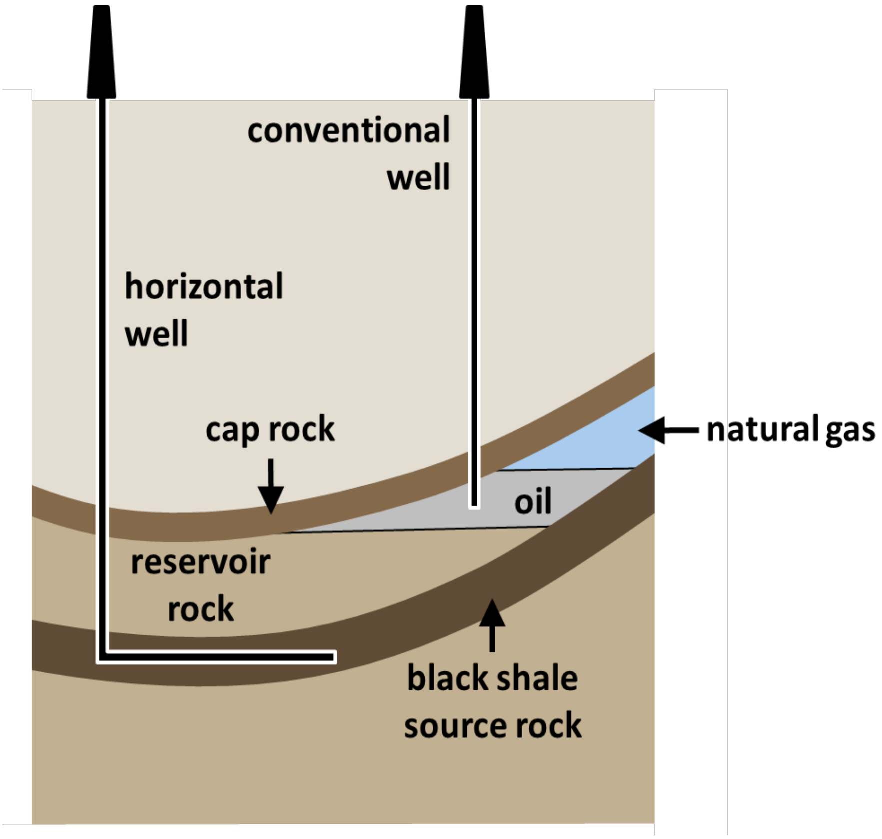


Figure 2 – Historical North Dakota Oil Production and Prices

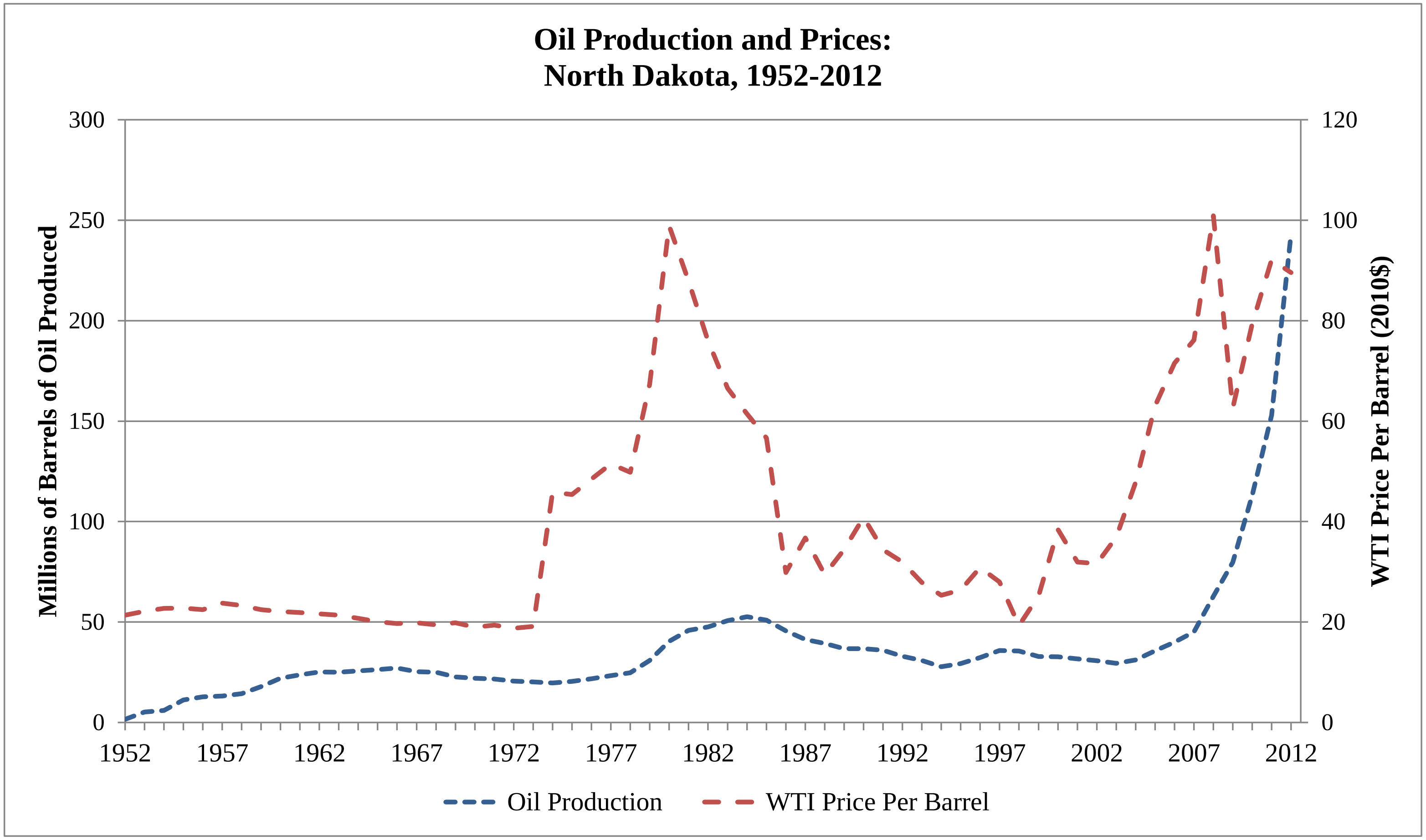


Figure 3a – Tax Revenues and Oil Production

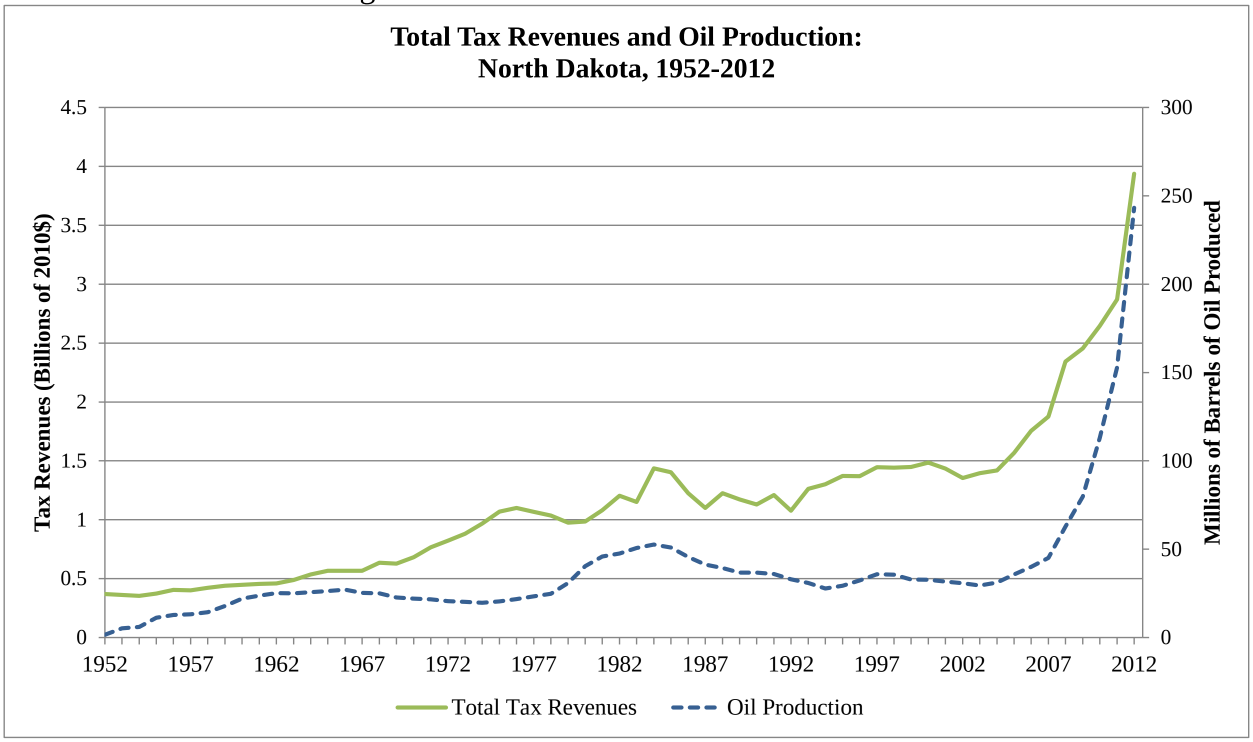


Figure 3b – Tax Revenues and Oil Prices

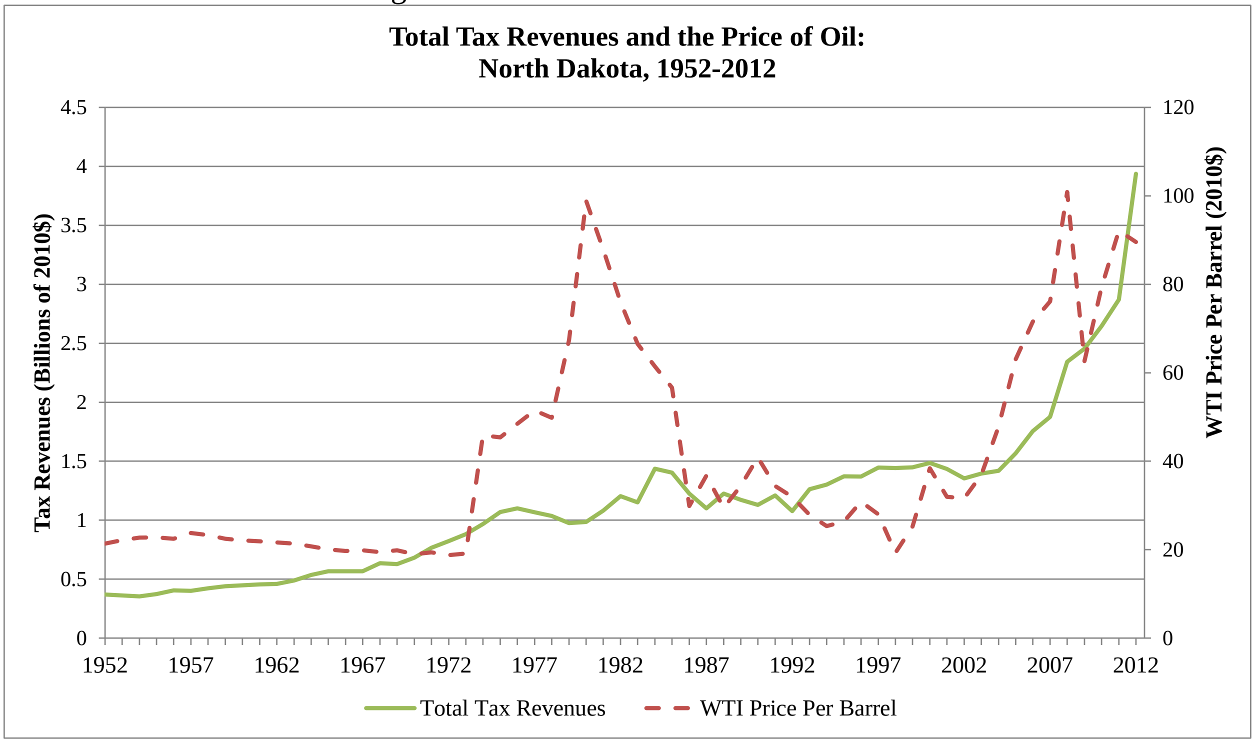
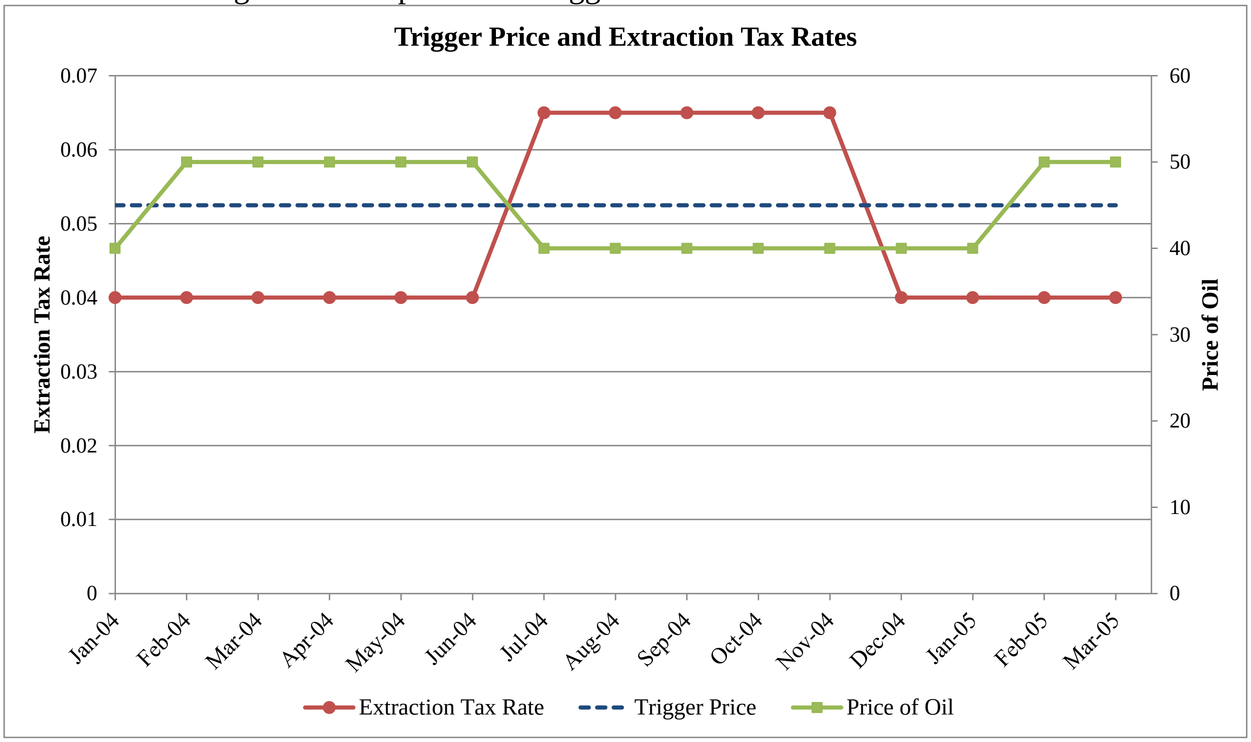


Figure 4a – Depiction of Trigger Prices and Extraction Tax Rates



4b – Depiction of Extraction Tax Rate Reductions for Horizontal Wells

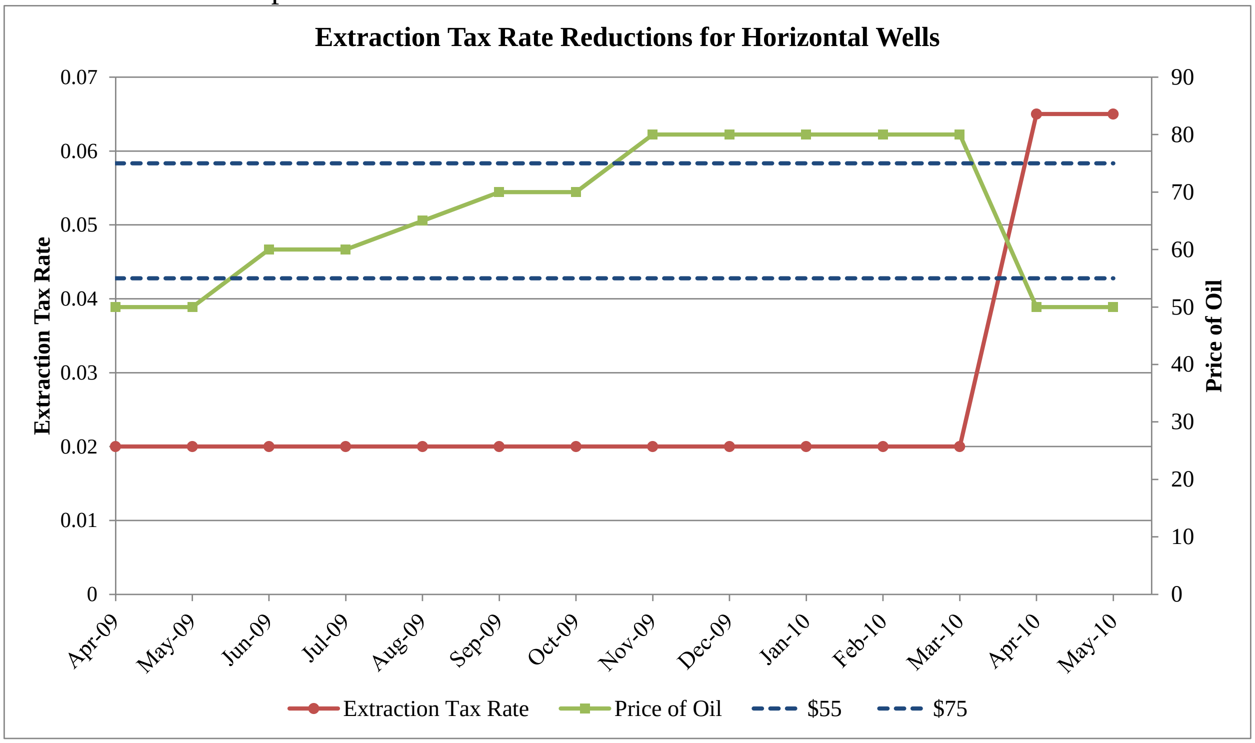


Figure 5a – Time Series of Severance Tax Revenues and Oil Production

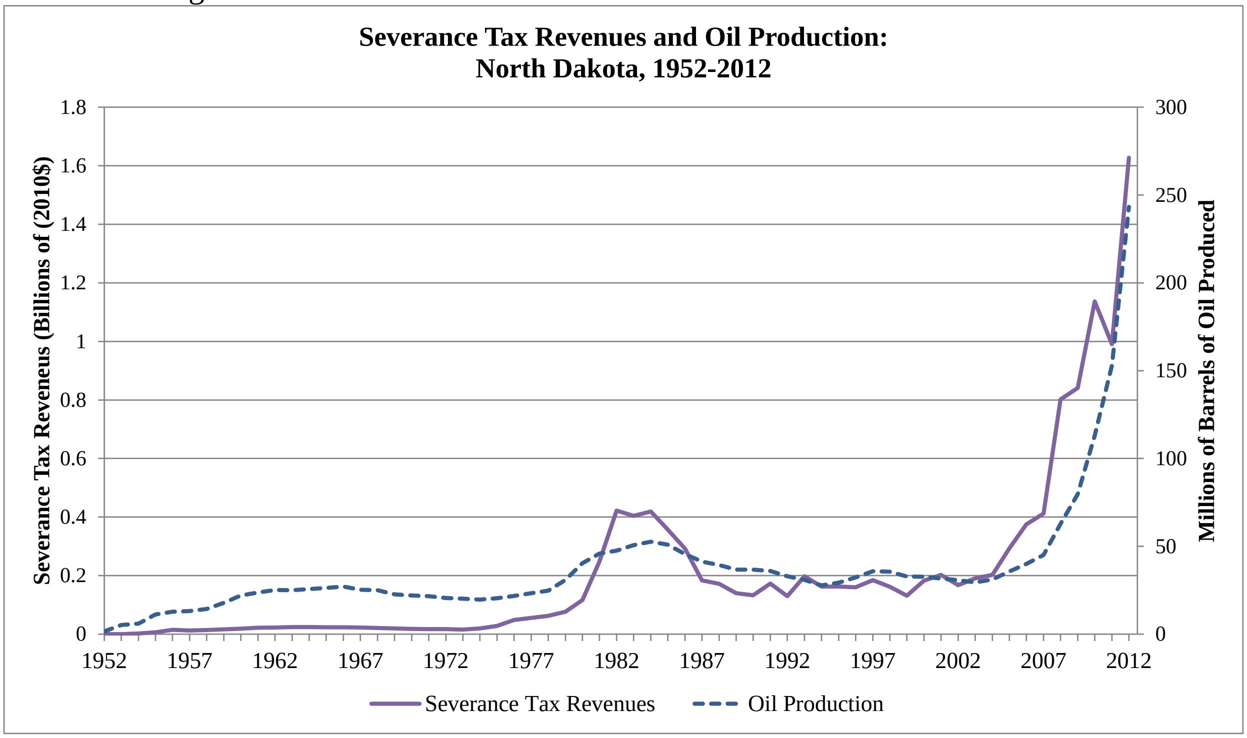


Figure 5b – Time Series of Severance Tax Revenues and Oil Prices

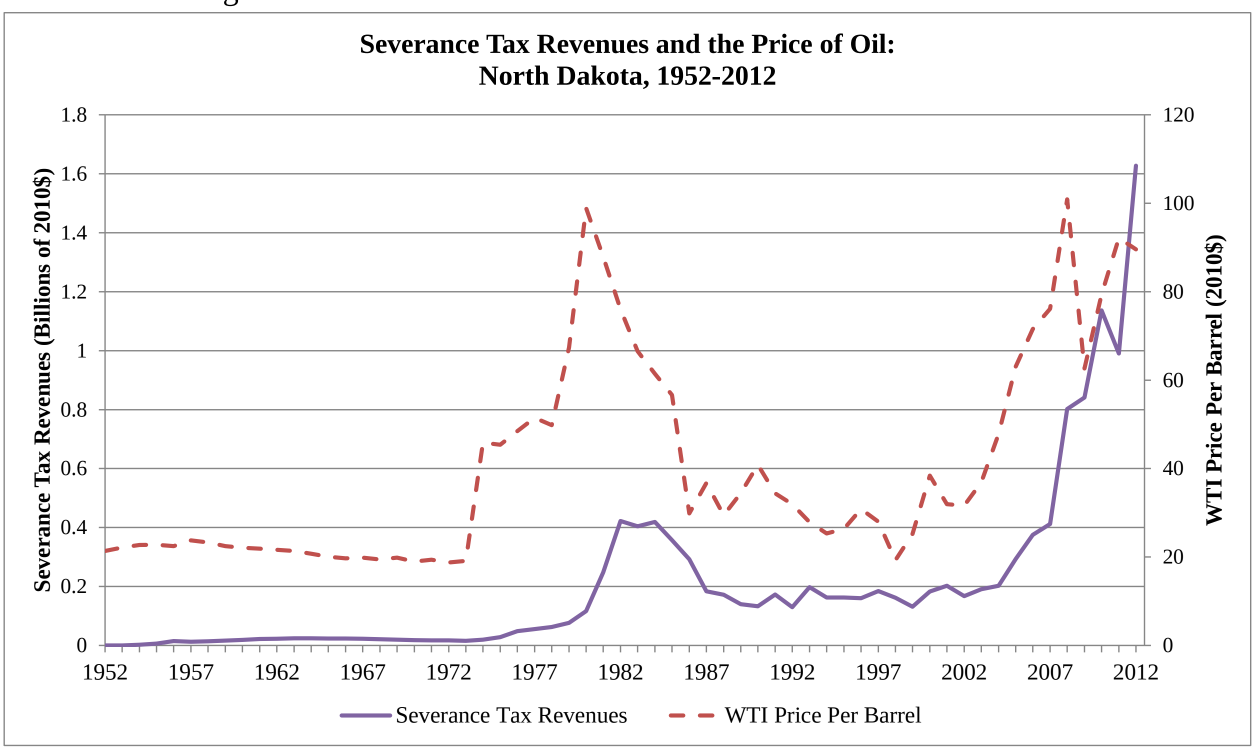


Figure 5c – Severance Tax Revenues by Source

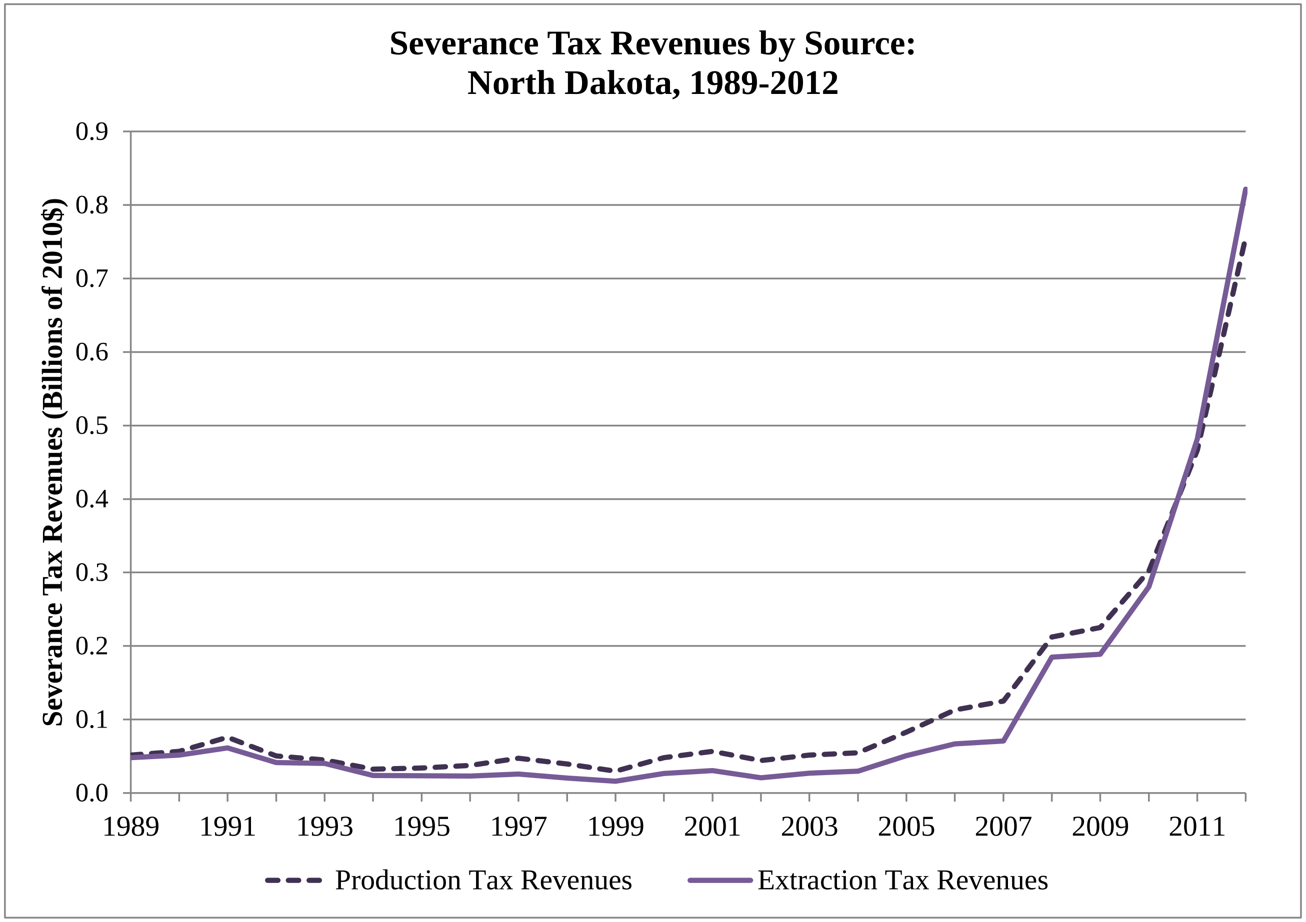


Figure 5d – Share of Severance Tax Revenues and Oil Production

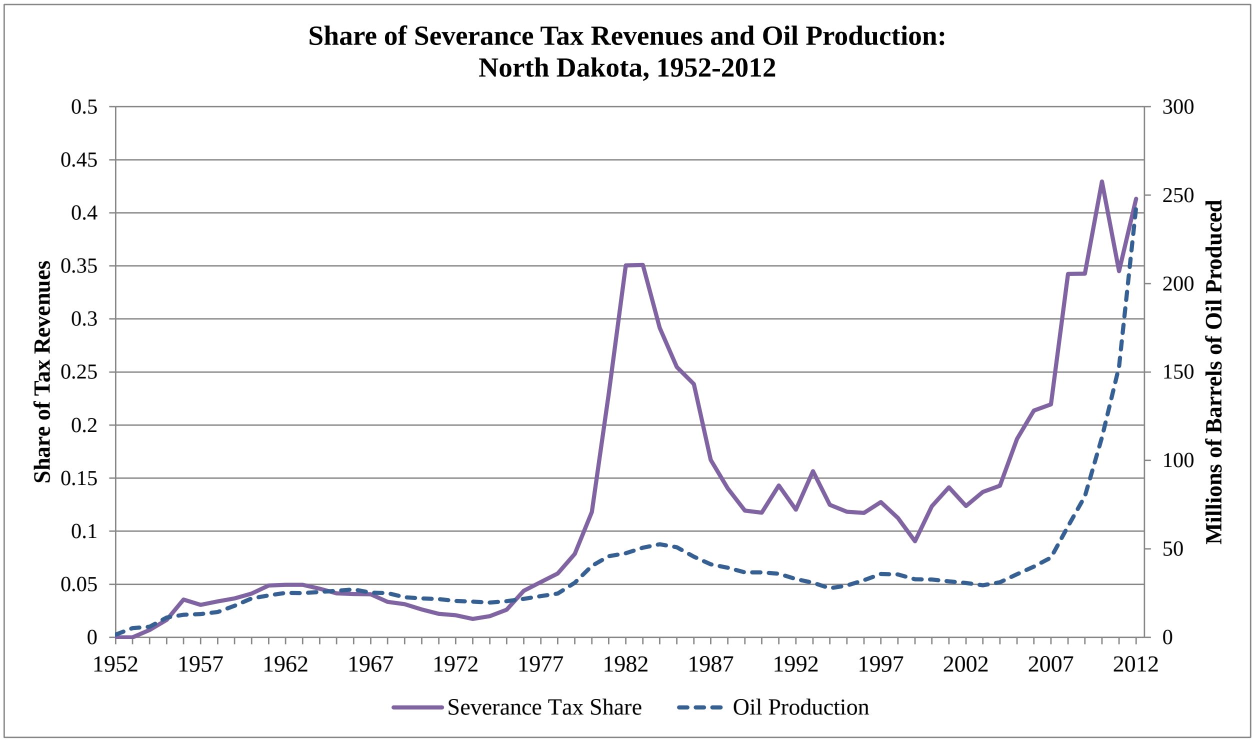


Figure 5e – Share of Severance Tax Revenues and Oil Prices

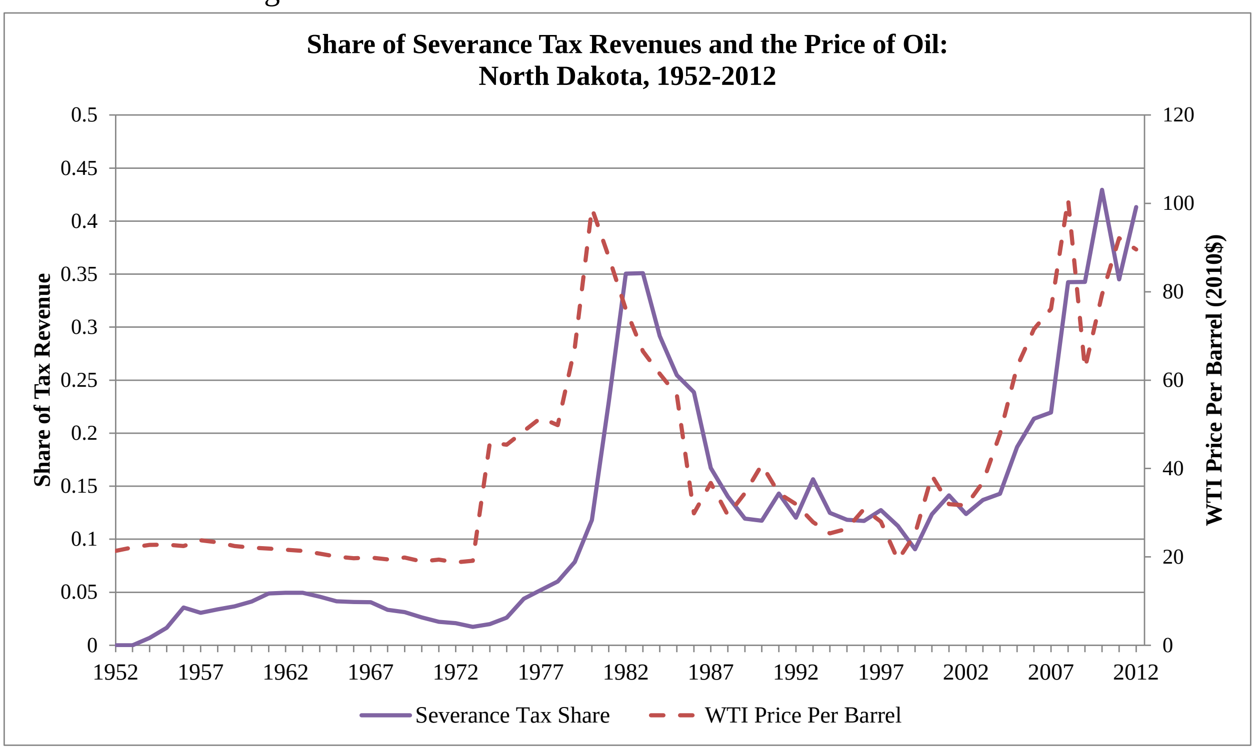


Figure 6a – Sales Tax Revenues and Oil Production

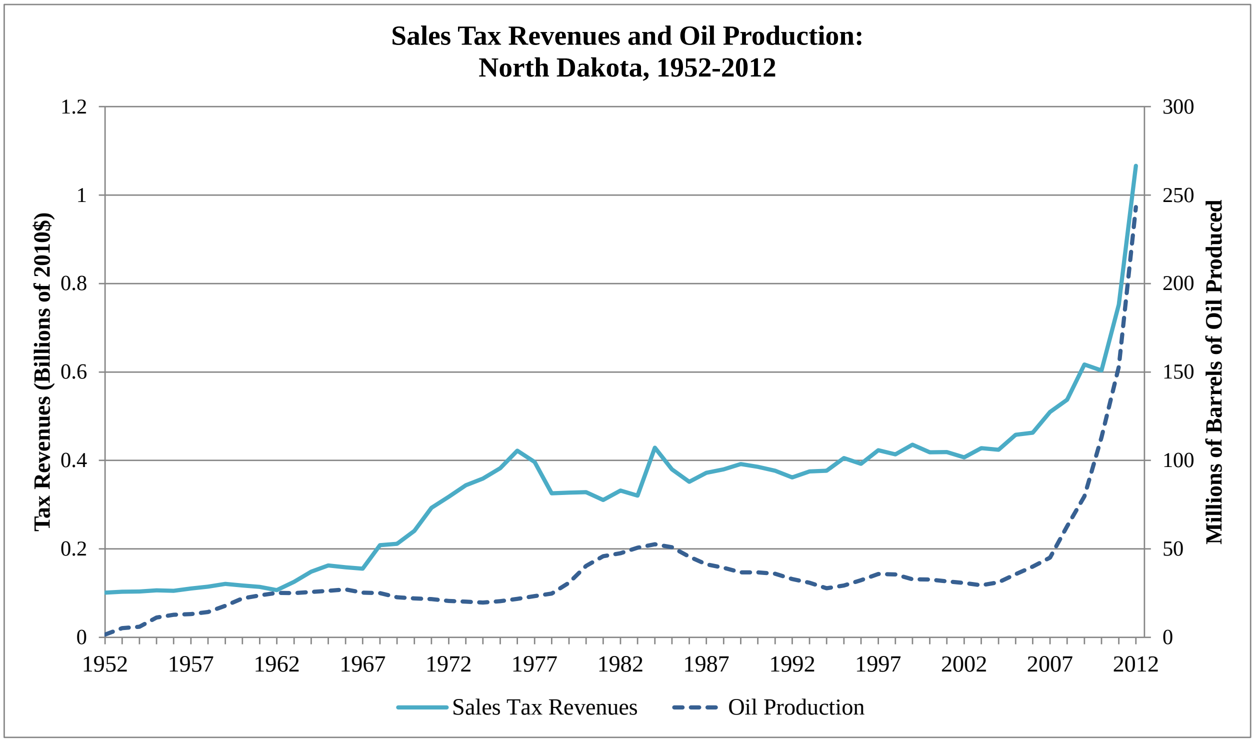


Figure 6b – Sales Tax Revenues and Oil Prices

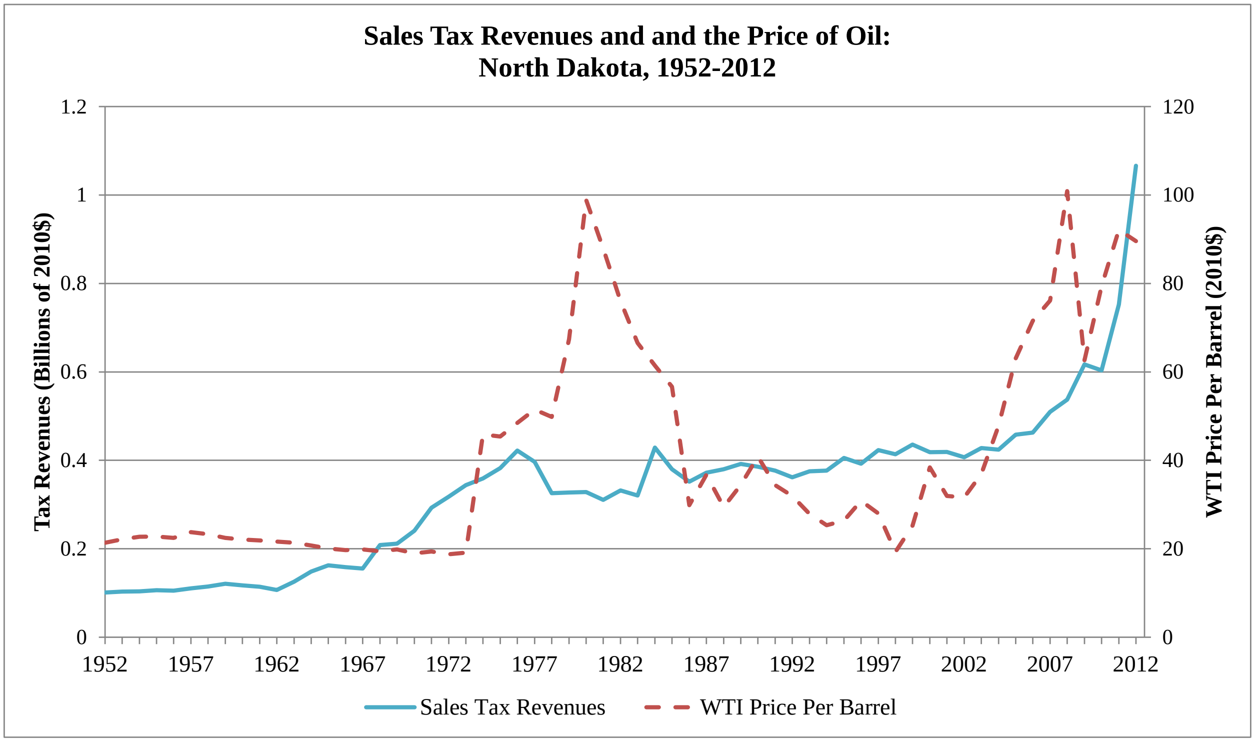


Figure 6c – Share of Sales Tax Revenues and Oil Production

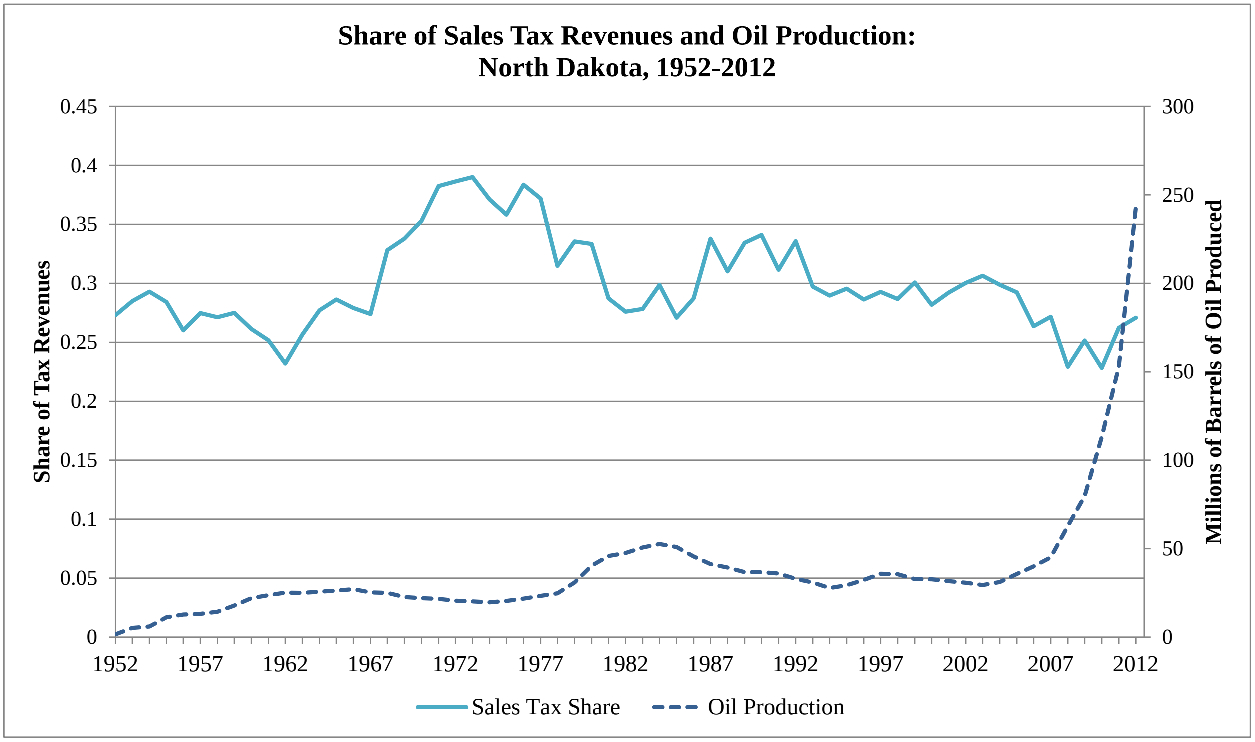


Figure 6d – Share of Sales Tax Revenues and Oil Prices

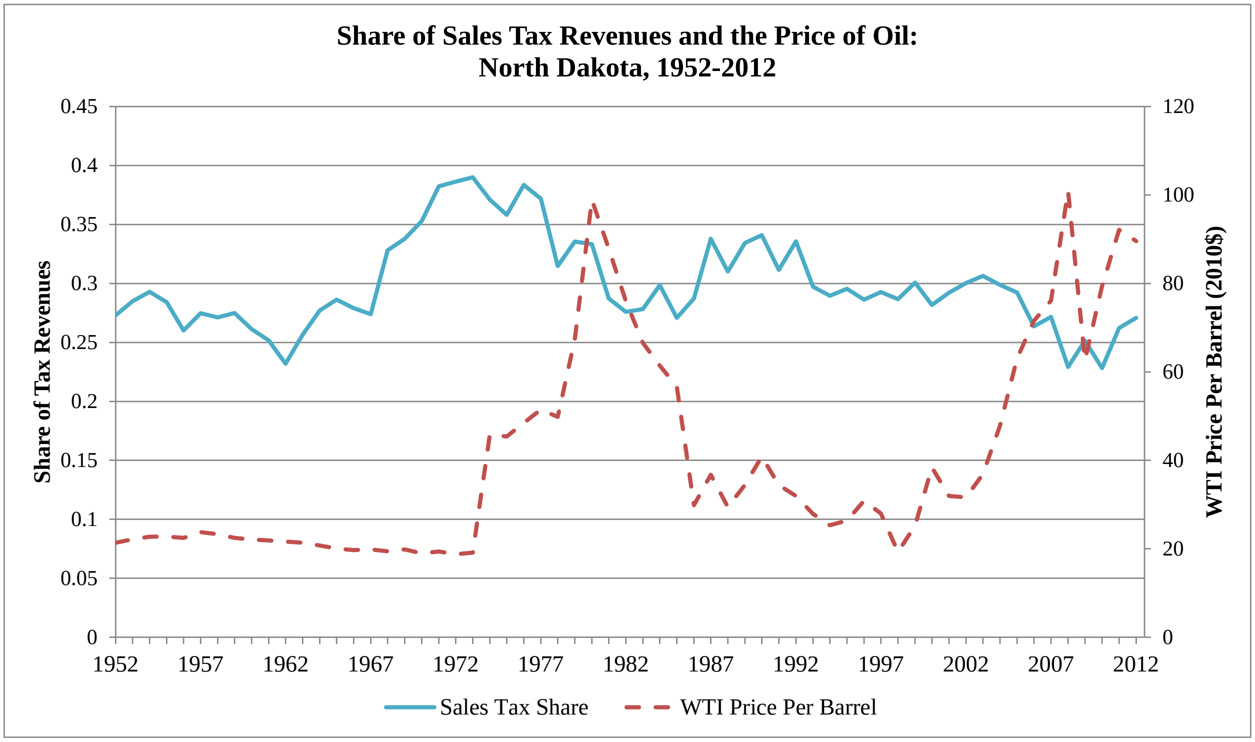


Figure 7a – Income Tax Revenues and Oil Production

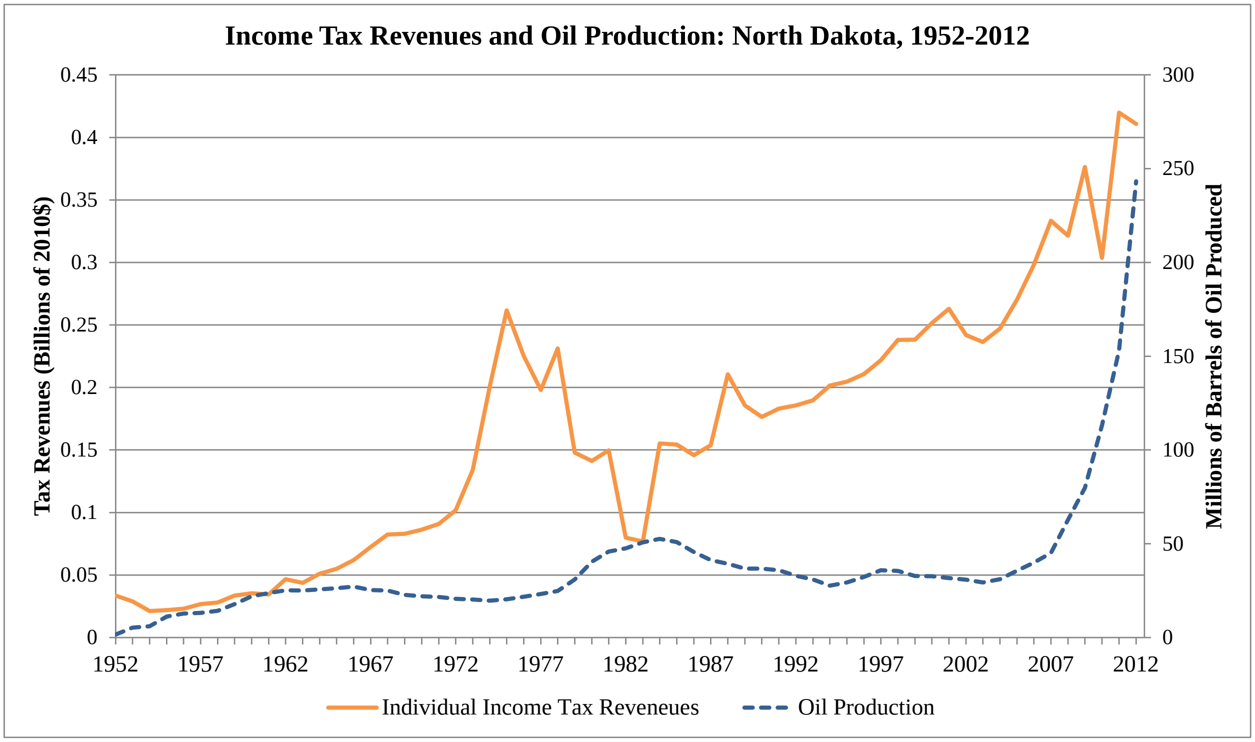


Figure 7b – Income Tax Revenues and Oil Prices

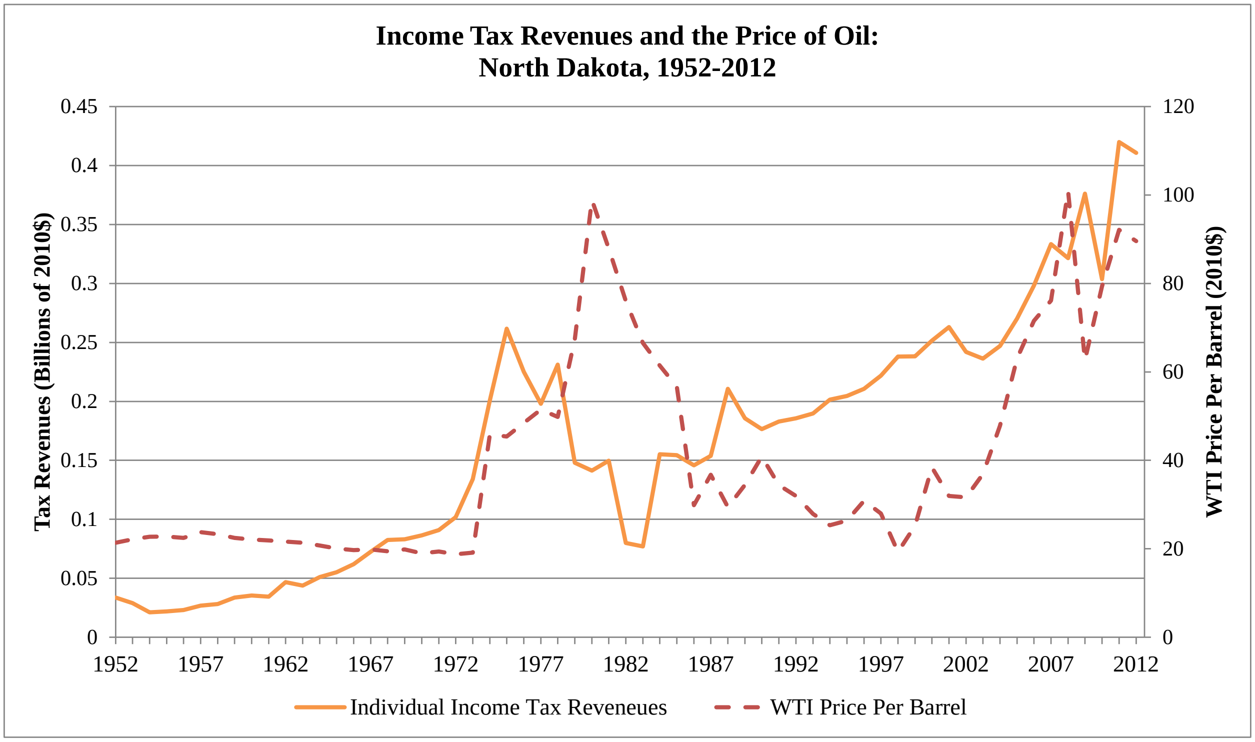


Figure 7c – Share of Income Tax Revenues and Oil Production

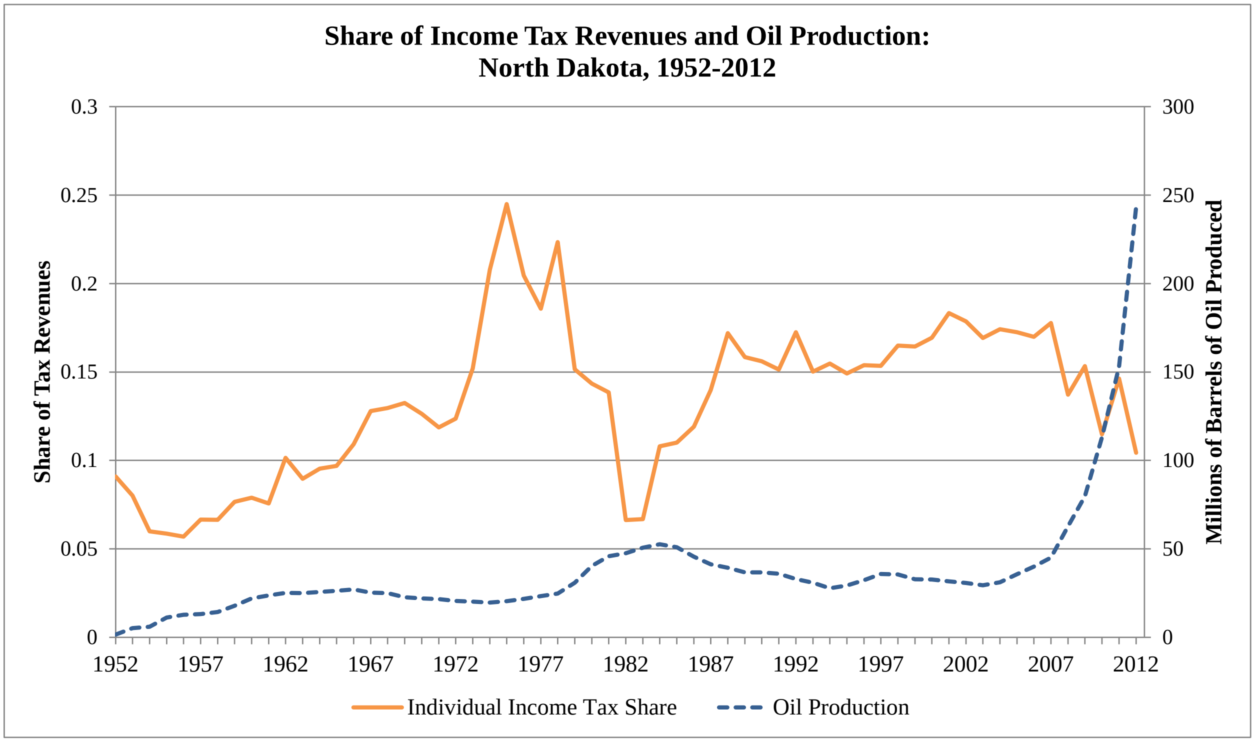


Figure 7d – Share of Income Tax Revenues and Oil Prices

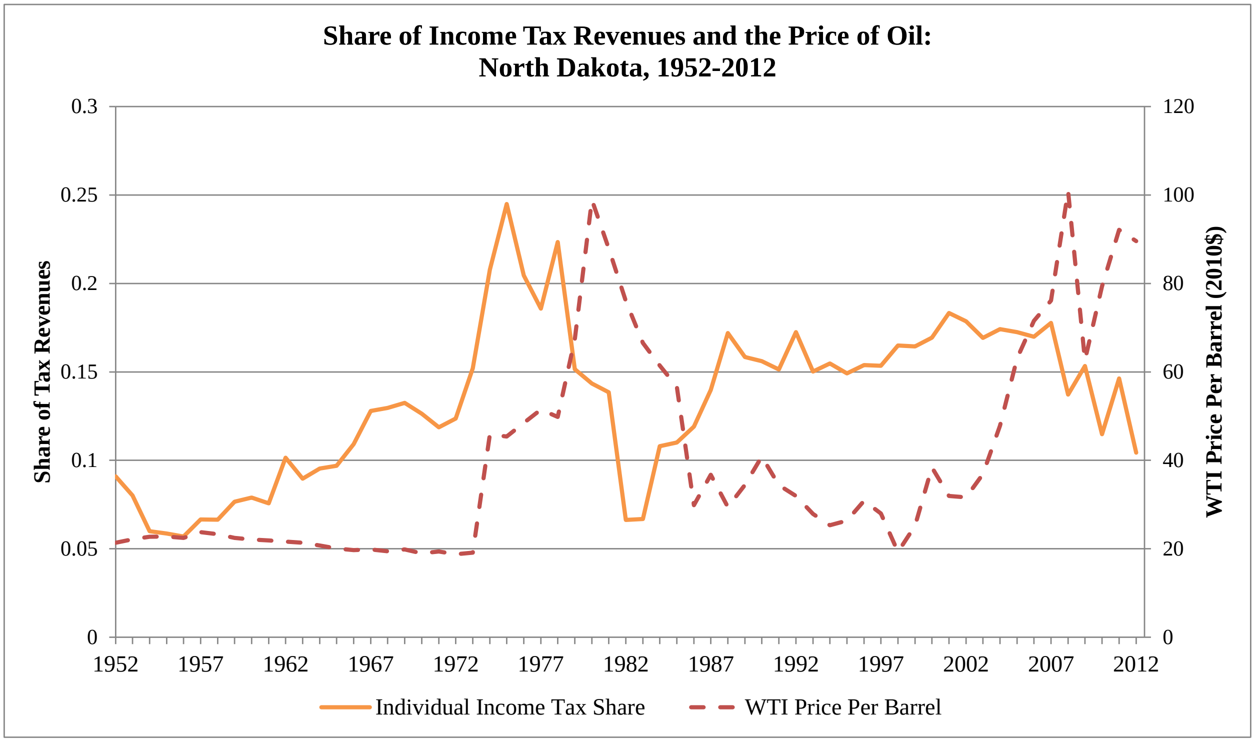


Figure 8 - Oil Reserves in North Dakota

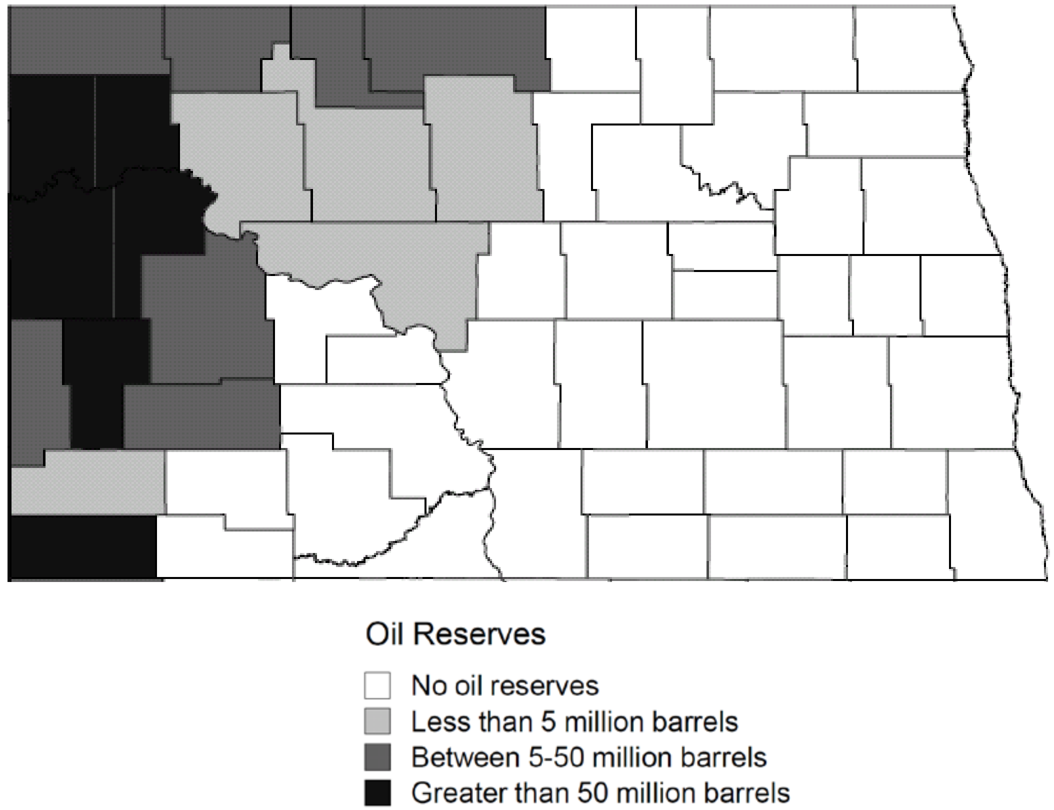


Figure 9 – Quartile of the Average Value of Oil Produced:
North Dakota, 2000-2010

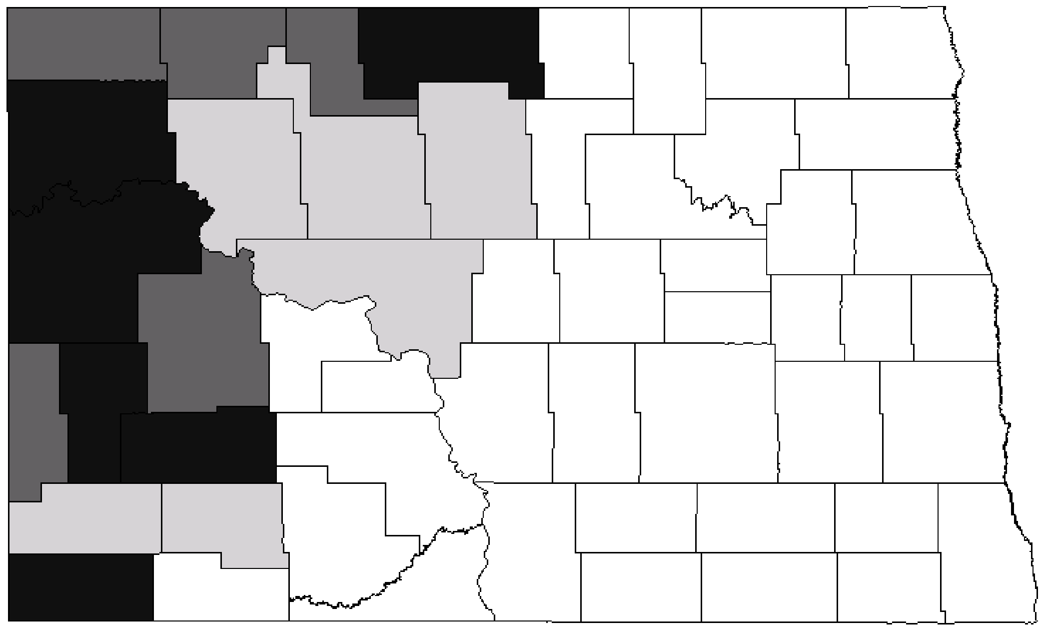


Figure 10a – Quartile of Average Annual Growth in the Sales Tax Base:
North Dakota, 2000-2004

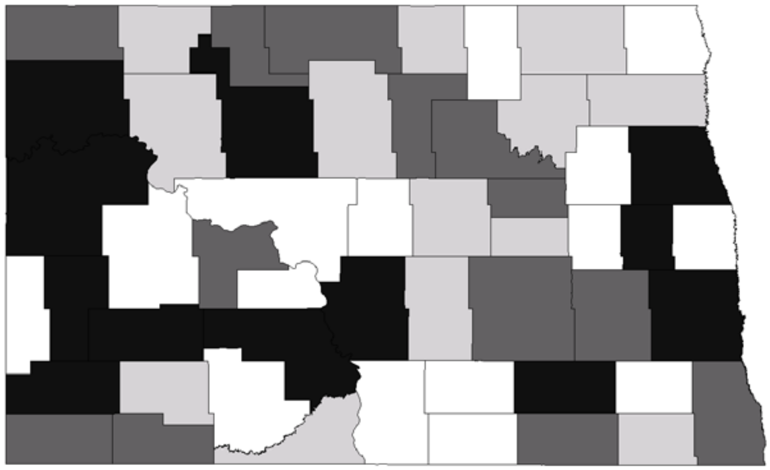


Figure 10b – Quartile of Average Annual Growth in the Sales Tax Base:
North Dakota, 2005-2010

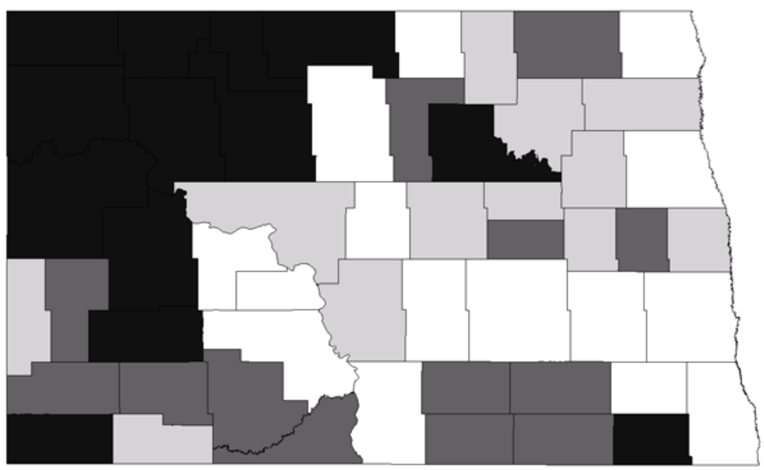


Figure 11a – Quartile of Average Annual Growth in the Income Tax Base: North Dakota, 2000-2004

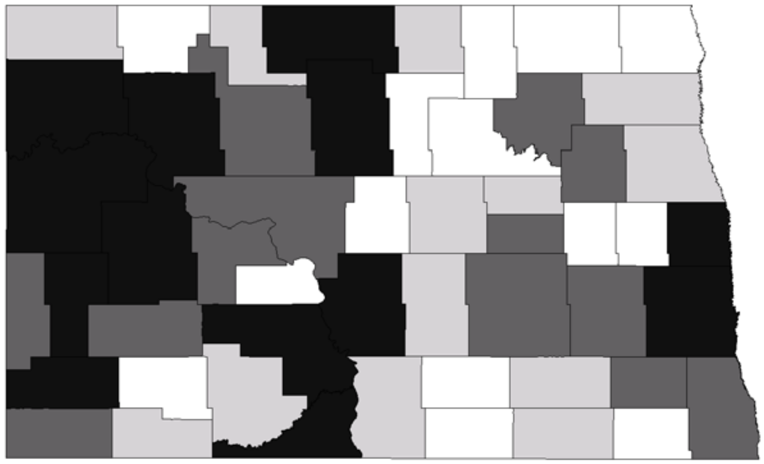


Figure 11b – Quartile of Average Annual Growth in the Income Tax Base: North Dakota, 2005-2010

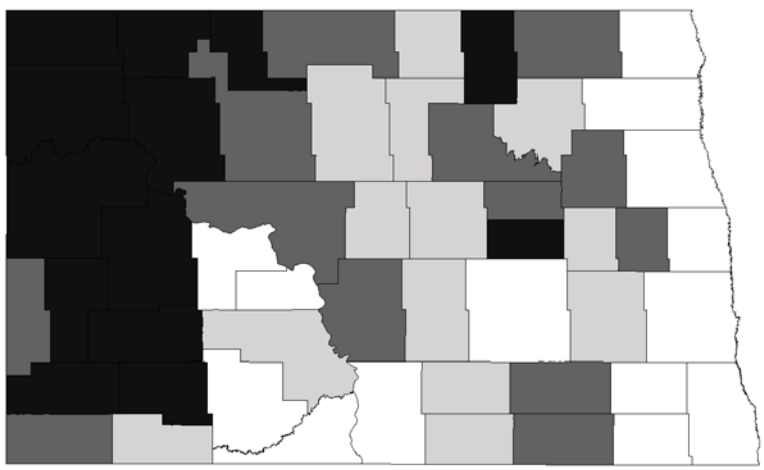


Table 1 - State Sales and Income Tax Revenues as a Percent of Total Revenues by Period: North Dakota, 2000-2004 and 2005-2012

Total Tax Revenues (Billions of 2010$) (1)	Sales Tax Revenues (2)	Individual Income Tax Revenues (3)	Severance Tax Revenues (4)	Corporate Income Tax Revenues (5)	Other Tax Revenues (6)
Panel A: 2000-2012					
2.0	27.3	15.8	24.3	5.6	27.0
Panel B: Pre-Boom (2000-2004)					
1.5	29.6	17.5	13.4	5.1	34.5
Panel C: Oil Boom (2005-2012)					
2.7	25.9	14.7	31.2	5.8	22.4

Table 2 - Nominal and Real Trigger Price:
North Dakota, 2000-2012

Year	Nominal Trigger Price	Real Trigger Price (CPI-Adjusted)
2000	33	-
2001	35.50	35.50
2002	35.50	36.07
2003	35.50	36.90
2004	35.50	37.88
2005	35.50	39.15
2006	35.50	40.42
2007	35.50	41.58
2008	35.50	43.16
2009	35.50	33.86
2010	35.50	43.73
2011	35.50	45.10
2012	35.50	46.04

Source: ND OSTC (2000, 2002, 2004, 2006, 2008, and 2010)

Table 3 - Changes to the State Sales Tax:
North Dakota, 2000-2010

Year	State Sales Tax Rate	Law Change
2001	0.05	“The 1.5% tax rate on used farm machinery and repair parts was extended through June 30, 2002 and thereafter exempt from sales tax. Car rentals became subject to the state’s 5% sales tax and to a special 3% sales tax surcharge. Sales of computers and telecommunications equipment to a new primary sector business, or as a result of an economic expansion of an existing primary sector business, became exempt from sales tax” (NDOSTC, 2013 p. 6).
2005	0.05	“Legislation was enacted that adopted the national Streamlined Sales Tax Project definitions and policies. The 2005 Assembly granted sales tax exemptions for purchases made by emergency medical service providers and sales to licensed assisted living facilities. It also authorized the sale of alcoholic beverages on Thanksgiving Day” (NDOSTC, 2013 p. 6).
2007	0.05	“Legislation was enacted that reduced the sales tax rate on natural gas to 1% effective July 1, 2007, and repealed the sales tax on natural gas entirely effective July 1, 2009. The 2007 Assembly also removed the sales tax on Bingo cards and certain materials used to construct power plants that utilize 'waste' heat” (NDOSTC, 2013 p. 6).
2009	0.05	“Legislation was enacted that created an exemption for repair parts used in irrigation systems. The 2009 assembly also created an exemption for purchases of tangible personal property used to construct or expand telecommunication infrastructure in the state” (NDOSTC, 2013 p. 6).

Table 4 - Changes to the Income Tax Rate Schedule: North Dakota, 2000-2010

Tax Year	Rate	Income Schedule			
2000	14	Flat Tax on Federal Income Tax Liability			
		Single		*Married Filing Jointly*	
2001	2.1	0	27,050	0	45,200
	3.92	27,050	65,550	45,200	109,250
	4.34	65,550	136,750	109,250	166,500
	5.04	136,750	297,350	166,500	297,350
	5.55	297,350		297,350	
		Single		*Married Filing Jointly*	
2009	1.84	0	33,950	0	56,750
	3.44	33,950	82,250	56,750	137,050
	3.81	82,250	171,550	137,050	208,850
	4.42	171,550	372,950	208,850	372,950
	4.86	372,950		372,950	

Source: ND OSTC (2010)

Table 5 - Tax Base Elasticities from the Previous Literature

Study	Data Source	Time Period	Geographic Area	Outcome(s) of Interest	Explanatory Variable(s)	Tax Instrument	Elasticity Estimates	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Groves and Kahn (1952)	*Report of the Taxation Committee of the Legislative Council* , State of Wisconsin	1930-1950	Various US States	Tax Revenues	Aggregate Income	Sales	0.99 (OH) - 1.11 (CA, IL, OK)	
						Individual Income	1.54 (MD) -1.81 (NC)	
						Corporate Income	1.50 (WI)	
						Alcohol	0.33 (WI)	
						Cigarrette	0.63 (WI), 0.73 (OH)	
						Motor Fuel	0.36 (WI)	
Wilford (1965)	Comptroller of Public Accounts for the State of Texas	1947-1960	Texas	Tax Revenues	Aggregate Income	Corporate Income	1.63	
						Alcohol	0.51	
						Cigarrette	0.48	
						Motor Fuel	1.12	
						Inheritance	1.46	
					Per Capita Income	Corporate Income	2.16	
						Alcohol	0.68	
						Cigarrette	0.69	
						Motor Fuel	1.40	
						Inheritance	2.15	
							Short-Run	*Long-Run*
Williams, Anderson, Froehle, and Lamb (1973)	Various State Tax Authorities	1952-1970	Various US States	Tax Revenues	Aggregate Income	Sales	0.81	1.37
						Individual Income	1.08	2.08
						Corporate Income	1.87	1.34
						Alcohol	0.51	1.01
						Cigarrette	0.63	1.48
						Motor Fuel	0.34	1.02

Table 5 (continued) - Tax Base Elasticities from the Previous Literature

Study	Data Source	Time Period	Geographic Area	Outcome(s) of Interest	Explanatory Variable(s)	Tax Instrument	Elasticity Estimates	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Fox and Campbell (1984)	Tennessee Deprtment of Revenue	1975-1982	Tennessee	Tax Revenues	Aggregate Income	Sales	Estimates range from 0.16 in 1976 to 0.92 in 1979.	
							Short-Run	*Long-Run*
Sobel and Holcombe (1996)	Internal Revenue Service (IRS) Statistics of Income (SOI)	1951-1990	United States	Tax Base	Aggregate Income	Sales	1.08	0.69
						Individual Income	0.74	0.98
						Corporate Income	0.52	0.69
	Statistical Abstract of the United States					Alcohol	-0.02	0.26
						Motor Fuel	0.73	1.10
							Short-Run	*Long-Run*
Bruce, Fox, and Tuttle (2006)	United States Bureau of the Census, State Government Finances	1967-2000	United States	Tax Base and Revenues	Per Capita Income	Sales	Estimates range from -2.19 (MO) to 3.29 (WV).	0.81
						Individual Income	Estimates range from -1.69 (NY) to 8.37 (NM).	1.83

Table 6 - Sample Means by Period: North Dakota, 2000-2004 and 2005-2010

	All Counties (1)	Oil Counties (2)	No Oil Counties (3)
Panel A: Sample Means (2000-2010)			
Population	10,808.7	8,612.6	11,758.3
Income per Capita (Thousands of 2010$)	21.8	23.4	21.2
Logarithmic Difference in the Sales Tax Base	0.026	0.067	0.008
Logarithmic Difference in the Income Tax Base	0.034	0.069	0.018
West Texas Intermediate Crude Oil Price per Barrel (2010$)	58.3		
Oil Reserves (Thousands of Barrels)		48,237.4	
Value of Oil Produced (Billions of 2010$)		197	
Logarithmic Difference in the Value of Oil Reserves		0.073	
Logarithmic Difference in the Value of Oil Produced		0.146	
Panel B : Pre-Boom (2000-2004)			
Population	10,561.6	8,415.4	11,489.6
Income per Capita (Thousands of 2010$)	19.3	18.8	19.5
Logarithmic Difference in the Sales Tax Base	-0.021	-0.009	-0.026
Logarithmic Difference in the Income Tax Base	-0.007	0.010	-0.014
West Texas Intermediate Crude Oil Price per Barrel (2010$)	37.4		
Oil Reserves (Thousands of Barrels)		48,237.4	
Value of Oil Produced (Billions of 2010$)		73	
Logarithmic Difference in the Value of Oil Reserves		0.055	
Logarithmic Difference in the Value of Oil Produced		0.016	
Panel C: Oil Boom (2005-2010)			
Population	11,014.6	8,776.9	11,982.3
Income per Capita (Thousands of 2010$)	23.95	27.28	22.51
Logarithmic Difference in the Sales Tax Base	0.057	0.118	0.031
Logarithmic Difference in the Income Tax Base	0.061	0.109	0.040
West Texas Intermediate Crude Oil Price per Barrel (2010$)	75.7		
Oil Reserves (Thousands of Barrels)		48,237.4	
Value of Oil Produced (Billions of 2010$)		301	
Logarithmic Difference in the Value of Oil Reserves		0.084	
Logarithmic Difference in the Value of Oil Produced		0.233	
Number of Counties	53	16	37

Table 7 - First-Stage Relationship between the Value of Oil Reserves and Production: North Dakota, 2000-2010

	Value of Oil Produced
Change in the Value of Oil Reserves	1.386 (0.351)
F-statistic	15.6
Observations	530

Table 8 - IV Estimates of the Relationship between Oil Production Value and the Tax Base: North Dakota, 2000-2010

	Taxable Sales and Purchases (1)	Taxable Sales (2)	Adjusted Gross Income (1)
Change in the Value of Oil Produced	0.182	0.131	0.155
	(0.075)	(0.057)	(0.049)
Observations	530	530	530

Table 9 - IV Estimates of the Relationship between Oil Production Value and the Sales Tax Base: North Dakota, 2000-2010

	Taxable Sales and Purchases (1)	Taxable Sales (2)
Change in the Value of Oil Produced	0.182	0.131
	(0.075)	(0.056)
Change in the County-level Sales Tax Rate	0.441	0.693
	(1.132)	(1.342)
Observations	530	530