A Quantitative Description of State-Level Taxation of Oil and Gas Production in the Continental U.S.

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FORTHCOMING IN *ENERGY POLICY*

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Abstract We provide a quantitative description of state-level taxation of oil and gas production in the Continental U.S. for 2004 to 2013. Aggregate revenues from production taxes nearly doubled in real terms over the period, reaching $10.3 billion and accounting for 20 percent of tax receipts in the top ten revenue states. The average state had a tax rate of 3.6 percent; nationally, the average dollar of production was taxed at 4.2 percent. The oil-specific rate estimated for the study period is $2.4 per barrel or $5.5 per ton of carbon. Lastly, state-level tax rates are two-thirds higher in states excluding oil and gas wells from local property taxes, suggesting that the policies are substitutes for one another.

Key Words: state policy, oil and gas taxation, effective tax rates

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1. Introduction

Debates about state taxes on oil and gas production suffer from a lack of clarity on facts like the typical rate of taxation across the U.S. The lack of clarity muddles policy debates, with proponents and opponents of higher taxes able to make selective comparisons of rates to advance their position. We are aware of no study that quantifies patterns in state policy across the continental U.S. One can readily find stated tax rates for most states, however, the rate stated in policy documents may differ from the rate applied to the typical dollar of production. Some states have high stated rates but apply them to only a subset of production. Other states have multiple rates, each of which is applied differently.

Basic empirical questions regarding oil and gas taxes have grown in importance in recent years. With more revenue at stake, the historic growth in oil and gas production from shale formations has brought renewed attention to state tax policies (Brown, 2013; IFO, 2014; U.S. EIA, 2015; Campoy, Peters, and Phillips, 2015). This is particularly true of states that previously had low, if any, taxes on production (e.g. Ohio and Pennsylvania). Moreover, interest in taxing production at the federal level such as President Obama's proposed $10 per barrel tax provides an additional motivation for understanding state-level taxation.

Most prior literature on state taxation of oil and gas seeks to estimate the effects of taxes on production or welfare (e.g. Yücel, 1989; Deacon, 1993; Kunce, 2003; Kunce et al, 2003; Chakravorty et al., 2010). We aim for the more modest–but nonetheless worthy–goal of quantitatively describing the taxation of oil and gas production for the decade 2004-2013. We collect state-level data on oil and gas production and the revenue generated by it, focusing on production taxes set and administered by state governments in the continental U.S. Using these data, we answer five empirical questions:

1) How much state revenue do production taxes generate?
2) What is the effective tax rate applied by the typical state, and what is the rate applied to the typical dollar (or British Thermal Unit) of production?
3) Have tax rates changed with the surge in production from shale formations in the 2010-13 period?
4) What are the typical oil and gas specific tax rates?
5) Are state-level taxes and local property taxes substitutes for one another?

The first two questions are foundational for understanding the economic importance of such taxes and the central tendency in their rates, yet there are no published estimates in either case. Changes in tax rates over time (Question 3) is of interest because the growth in production over the study period stems from the extraction of oil and gas from relatively impermeable formations such as shale using unconventional methods, namely the fracturing rock with liquids ("hydraulic fracturing"). If some states view production taxes as a means to address the public and environmental costs of extraction, we might expect rates to have increased if unconventional production involves greater public costs than conventional production, which some research suggests that it does (Jenner and Lamadrid, 2013).

The differential taxation of oil and gas (question 4) is relevant to climate change and carbon policy debates. When burned, oil-based products such as gasoline and heating oil emit about one-third more carbon dioxide than natural gas (U.S. EPA, 2015). State taxation of production is not motivated by emissions considerations, nevertheless, policies favoring extraction of oil over gas or vice versa could affect investment, prices, consumption, and emissions in the same way that Federal energy policy favors some energy sources over others via the tax code (Metcalf, 2009; Metcalf, 2010). Estimating fuel-specific rates permits calculating the carbon tax rate represented by state-level taxes on production. It also permits comparing state-level taxes to the proposal made by President Obama in February of 2016 to impose a $10 per barrel tax on oil.

Lastly, states may levy taxes on oil and gas in place of allowing local schools and governments to tax wells as property or vice versa (question 5). If such a substitution effect exists, it raises the question of which level of taxation is most desirable. Property taxes are local taxes and will therefore generate more revenue in areas with more drilling, a desirable quality since much of the public costs and disamenities from shale development occur near wells. Indeed, recent studies have shown how taxation of oil and gas wells as property in Texas has generated windfalls for schools and local governments, affecting local tax rates, public debt, and housing values (Marchand and Weber, 2015; Weber, Burnett, and Xiarchos, 2016). State-level taxes, in contrast, spread windfalls from extraction more broadly but potentially leave jurisdictions where extraction occurs unable to fully address the local public costs of drilling.

We find that aggregate revenues from state-level production taxes reached $10.3 billion in 2013 and accounted for 20 percent of tax receipts in the top ten revenue states. Over the period the average state had a tax rate of 3.6 percent while the average dollar of production was taxed at 4.2 percent. The rate applied to the typical dollar of production did not change as production from shale increased in the years 2010-13. The oil-specific rate estimated for the study period is equivalent to a tax of $2.4 per barrel tax or $5.5 per ton of carbon. Lastly, state-level taxes are two-thirds higher in states excluding oil and gas wells from local property taxes, suggesting that these policies are substitutes for one another.

2. Why Do States Tax Oil and Gas Production?

Motivations for taxing oil and gas production usually stem from an interest in preserving wealth for future generations, addressing externalities, and put simply, generating revenue. In Hotelling's seminal 1931 paper on the economics of exhaustible resources, he described the political support in his day for policies to regulate and reduce the exploitation of resources, which were presumably being exploited at too rapid of a rate, leaving too few resources for future generations. State trust funds are based on a similar motivation: while the physical resource will not be passed to future generations, states can pass on the financial wealth generated by it. Examples of trust funds with oil and gas tax money include North Dakota's Legacy Fund, Texas' Permanent University Fund, and New Mexico's Severance Tax Permanent Fund.

Another justification for taxing production is to address negative externalities, which are costs of production borne by the public but not energy producers. These may include wells leaking oil or gas into the environment or the industry's excessive use of public goods to drill, hydraulically fracture, and maintain the wells (e.g. McKenzie et al, 2012; Abramzon et al, 2014), which can translate into greater public expenditures (Newell and Raimi, 2015). Through taxes, policy makers can cause producers to face the full cost of production. A production tax could be specified as a Pigouvian Tax where the magnitude of the tax is set equal to the marginal social cost of extraction (Pigou, 1920). Though not designed as a Pigovian Tax, Pennsylvania's Impact Fee, for example, was created to address costs generated but not borne by the natural gas industry. The Fee goes primarily to local governments to fund investments like road repairs and environmental restoration.[4]

Lastly, states tax oil and gas production because it is a convenient and potentially efficient source of revenue. A tax on production can be an administratively straight-forward tax on an industry often perceived by the public as having deep pockets capable of contributing more to the state's coffers. Elected officials in turn may find it politically advantageous to raise revenues through taxing oil and gas rather than through raising income taxes. Moreover, the fixed nature of oil and gas endowments can allow resource owners to earn above-normal profits on their holdings. Through taxes on extraction the state can capture some of these economic rents while potentially having little effect on investment and production.

3. The Diversity of State Policies

Thirty-three U.S. states had some oil or natural gas production in May of 2015.[5] Almost all states tax extraction in some way, but the names of the taxes and their workings vary considerably (see Appendix Table A1). Most states name their tax an oil/gas severance or production tax. A few states, such as Utah or Alabama, have additional taxes labeled a privilege tax or conservation fee. Other states, such as Arizona, California, and South Dakota, have a broad tax that applies to all minerals extracted from the State's subsurface. South Dakota, for instance, calls its tax an "energy mineral tax". In such cases, each mineral is taxed and reported individually but all fall

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[4] For more information on Pennsylvania's Impact Fee, including the permitted uses of the funds, see the Pennsylvania Public Utility Commissions FAQs document: http://www.puc.state.pa.us/NaturalGas/pdf/MarcellusShale/Act13_FAQs.pdf

[5] This can be seen by looking at the Energy Information Administration's ranking of states by oil production and by natural gas production: http://www.eia.gov/state/rankings/?sid=US#/series/46 and http://www.eia.gov/state/rankings/?sid=US#/series/47.

under this umbrella tax. Pennsylvania is a notable exception to the previous taxes; it assesses a per-well tax labeled an impact fee.

In addition to tax rates varying across states, the quantity or value on which the taxes are levied also vary. States such as Texas and Wyoming tax the value of production, either at the wellhead or the point of sale. California, Indiana, and Ohio base their taxes on the quantity of production, and other states such as Arkansas have both value and quantity-based taxes.

Additional tax policy specifics also vary across states. Two states may have the same stated rate, but one exempts production from particular types of wells while the other applies its rate to all wells. Stated rates can also depend on variable like market prices, well productivity, well age, extraction methods (horizontal or vertical well), production practices (whether gas is vented to the atmosphere or not), geographic location, or the particular subsurface strata the well draws from. Alabama, Arkansas, and Louisiana, for example, levy a different rate on wells that exceed a certain depth. Mississippi and Montana further base their rates on when the permit for the well was issued while Texas provides a lower rate for “high cost” wells.

Our brief description of state oil and gas tax policy highlights the value of collecting data on production and the associated tax revenues, which permit a transparent calculation of how much each unit in production generates in state tax revenue.

4. Methodology

4.1 Aggregate Revenues from Oil and Gas Production Taxes (Question 1)

This question is readily answered by simply aggregating revenues across states for each year.

Central Tendency in Effective Rates (Question 2)

Because stated (or statutory) rates vary in their application, they do not necessarily reflect the rate that oil and gas producers effectively pay. A common approach to measuring effective tax rates is to model the tax treatment of a prototypical well (Goldsmith, 2005; Headwater Economics and Oklahoma Policy Institute, 2013; Independent Fiscal Office, 2014). The model-based approach involves specifying market prices and characterizing the typical well in all the dimensions on which the tax liabilities depend. The analysis by the Independent Fiscal Office (2014), for example, specified a typical well for each state, making assumptions about its ultimate recovery, lifespan, and year when production drops below a certain threshold. Similarly, the findings of the study by Headwater Economics were based on the production profile of the typical horizontal well from a particular field in Montana.

Model-based approaches have their greatest value in simulating the revenue effect of changes in policy or market conditions (e.g. Goldsmith, 2005). If, however, the goal is to estimate how much states have actually taxed oil and gas production in the past, a more transparent approach that relies on fewer assumptions is available. Production and revenue data permit the straightforward calculation of an effective average tax rate in a given state and year: dividing total tax revenues by the total value of production gives the percent of each dollar of production paid to the state. Kunce and Morgan (2005) used this approach to estimate effective tax rates on oil and gas production. Their analysis covers eight states, and the most recent data used were from 1997. Using more recent data, the Covenant Consulting Group (2012) estimated effective rates for eight states in one year.

In addition to covering more years and states than prior studies, we calculate three different measures of central tendency in effective tax rates, each of which has a different weighting scheme. The first measure is the effective tax rate averaged across all state-year observations:

$$Average\ State\ Rate_{VP} = \tau_{A\_VP} = \frac{1}{ST}\sum_t^T \sum_s^S \frac{R_{st}}{P_r \cdot Q_{st}} \tag{1a}$$

$$Average\ State\ Rate_{Q} = \tau_{A\_Q} = \frac{1}{ST}\sum_t^T \sum_s^S \frac{R_{st}}{Q_{st}} \tag{1b}$$

The rate in (1a) is based on dividing tax revenues (R_{st}) by the value of production in the state ($P_r \cdot Q_{st}$), which is the price (either at the state or regional level) multiplied by the quantity of production. The rate in (1b) is based on dividing revenues by the quantity of production, with quantity measured in millions of British Thermal Units (MMBtus). The averages rates indicate what is typical from the perspective of the state, with each state-year observation given the same weight regardless of how much production or revenue is involved.

The second measure is a production-weighted effective tax rate, where the average state rates in (1a) and (1b) are weighted by the share of production (across all years and states) accounted for by the particular state-year observation:

$$Production - Weighted\ Rate_{VP} = \tau_{PW\_VP} = \frac{\sum_t^T \sum_s^S (\tau_{A\_VP} \cdot P_r \cdot Q_{st})}{\sum_t^T \sum_s^S P_r \cdot Q_{st}} \tag{2a}$$

$$Production - Weighted\ Rate_{Q} = \tau_{PW\_Q} = \frac{\sum_t^T \sum_s^S (\tau_{A\_Q} \cdot Q_{st})}{\sum_t^T \sum_s^S Q_{st}} \tag{2b}$$

The production-weighted rate most reflects the policies of states with substantial production or revenues. It treats the entire country as one large state and gives the state revenue generated by the typical unit of oil and gas production. This can be seen by noting that (2a) and (2b) could be written as total revenue across all states and years divided by total production across all states and years.

The third measure is the regression-based effective tax rate. Mathematically, total revenue collected by state *s* in year *t* equals the state's effective tax rate (τ) multiplied by production in that state and year. We use this identity as the basis for the following simple regression pooling all state-year observations and regressing revenues on production (and only production):

$$R_{st} = \tau_{R\_VP} \cdot (P_r \cdot Q_{st}) + \varepsilon_{st} \tag{3a}$$

$$R_{st} = \tau_{R\_Q} \cdot Q_{st} + \varepsilon_{st} \tag{3b}$$

Because OLS gives more weight to observations that contribute more to the sum of squared errors, the OLS estimate of the regression-based rate, τ_R, will most reflect the policies of states with substantial revenue and production. In this sense, the regression-based tax rates from (3a) and (3b) are similar to the production-weighted rates. We also note that regression-based rate is best understood as an average rate instead of a marginal rate; it is the rate that best predicts total revenues given total production. Even though the first few barrels of oil may be taxed at a different rate than the last few barrels, the rate estimated by (3a) and (3b) is akin to the rate applied to the typical barrel.

An alternative specification for equations (3a) and (3b) is to include state fixed effects, but this approach is unappealing for our descriptive purposes. A state fixed effect would allow some states to always collect more revenue than other states even though they have the same level of production. We interpret more revenues from the same level of production as indicating a higher effective tax rate and therefore omit a state fixed effect, which would remove this variation from our estimate of the regression-based rate.

For all statistically testing with the regression-based rates, we use robust standard errors clustered at the state level.

4.2 Changes in Tax Rates over Time (Question 3)

Growing oil and gas production from shale formations has prompted some states to reconsider their tax policies. Explicit changes in tax rates or greater efforts to collect revenues may have caused effective tax rates to change over time. To show general trends in rates over the study period, we calculate and graph the value-based and quantity-based rates for each year. We also calculate the rates averaged across two periods, the 2004-09 period and the 2010-13 period. The 2010-13 period represents the period with substantial oil and gas production coming from shale formations. For natural gas, production from hydraulically fractured wells, which is a proxy for shale wells, first accounted for at least half of all natural gas production in 2010; for oil, the share of total production from hydraulically fractured wells only saw large increases after 2010 (U.S. EIA, 2016a,b).

For the average rate and the regression-based rate we also test for a statistically significant change in rates from the 2004-09 period to the 2010-13 period. (The production-weighted rate does not lend itself to testing). For the average rate, this is simply a test of whether the difference in two group means is statistically distinguishable from zero. For the regression-based rate, we estimate

$$R_{st} = \tau_{R\_VP} \cdot (P_r \cdot Q_{st}) + \beta_{VP}(P_r \cdot Q_{st} \cdot Y_{10-13}) + \varepsilon_{st} \tag{4a}$$

$$R_{st} = \tau_{R\_Q} \cdot Q_{st} + \beta_Q \cdot (Q_{st} \cdot Y_{10-13}) + \varepsilon_{st} \tag{4b}$$

where Y_{10-13} is a binary variable that equals one if the observation is from the 2010-13 period. The coefficient β measures the difference between the regression-based rate for 2004-09 (captured by τ_R) and the rate for 2010-13, with the standard error of the difference allowing for hypothesis testing.

4.3 Oil and Gas Specific Tax Rates (Question 4)

Most states report revenues for oil and gas together, which does not allow us to directly calculate distinct rates. We therefore use the regression-based approach to uncover oil and gas specific tax rates:

$$R_{st} = \tau_{R\_VP}^{oil} \cdot \left(P_r^{oil} \cdot Q_{st}^{oil}\right) + \tau_{R\_VP}^{gas} \cdot \left(P_r^{gas} \cdot Q_{st}^{gas}\right) + \varepsilon_{st} \quad (5a)$$

$$R_{st} = \tau_{R\_Q}^{oil} \cdot Q_{st}^{oil} + \tau_{R\_Q}^{gas} \cdot Q_{st}^{gas} + \varepsilon_{st} \quad (5b)$$

Estimating (5a) and (5b) with OLS recovers the oil and gas-specific tax rates that best fit the data as measured by the least squares criterion. A test of equality of coefficients can then determine if the estimated oil tax rate is statistically different from that of natural gas.

4.4 State and Local Taxes as Substitutes (Question 5)

Although conceptually well defined, our focus on taxes set and collected by state governments has at least one limitation. State tax policy may respond in part to whether state law allows local governments to tax oil and gas wells as property. For example, a state may have a high tax rate and then distribute some of the revenues to local governments in the lieu of property taxes, which can generate more revenue than severance taxes (Raimi and Newell, 2014). Alternatively, where oil and gas wells are taxed as property, schools would need less state revenues to meet their budgets.

To gauge how much state tax rates depend on property tax policy, we calculate different rates for states with and without local property taxes on oil and gas. For the average rate and the regression-based rate we test for a statistically significant difference in rates across the two groups. As when looking at changes over time for the average rate, this is a test of a difference in group means. For the regression-based rate, we use the same approach illustrated by equations (4a) and (4b), but replacing the period dummy variable with a dummy variable for whether the state has oil and gas property taxes.

5. Data and Sample

Our empirical questions are answered with state-level data on tax revenues and oil and natural gas production. Data on revenues come from state departments of revenue. We only consider revenues generated by taxes or fees related to oil and gas extraction and that are set and collected by state governments. Taxes or fees associated with transmission, processing, or distribution of oil and gas or their derivatives are excluded. Revenues from local taxes such as property taxes are also excluded since they are set and collected by local governments, not state governments. Appendix Table A1 describes the policies that generated the revenue in our data. Some states complement their production taxes with minor fees for purposes such as covering administrative costs. Revenue data from such fees in four states was unavailable. These states and fees are listed in Table A2. In all cases the fee rates are so low that they would not materially alter estimates; for example, Wyoming's conservation fee is less than one-tenth of one percent of the value of production.

Monthly oil and gas production data come from the U.S. Department of Energy, Energy Information Administration (EIA). Monthly production data permit calculating production for each state's fiscal year, which is July to June in most cases. To convert oil production into dollars, we use state first-purchase prices for crude oil. Valuing natural gas production is more difficult because wellhead natural gas prices are not available at the state level. To capture regional variation in pricing, we use regional spot market price data from Platt's Inside FERC's Gas Market Report. For each region we calculate the percent difference between each regional spot market price and the average U.S. spot market price.[6] Each region's price is then defined as the EIA's national wellhead price adjusted by the regional differences indicated by the spot market prices. For example, if a region's spot market price was 5 percent lower than the national spot price, then 0.95 multiplied by the national wellhead price was used to value the state's production. As with production data, monthly price data permit calculating an average price for each state's fiscal year.

State production quantities include oil and gas produced on Federal land within the state since state taxes on extraction apply to such production. We exclude production from Federal waters off the coast of a particular state because states do not have the authority to tax production from Federal waters (Walls, 1993). On the revenue side, the Federal government shares with states some of the royalties it receives from production on Federal lands and waters. These royalty-based revenues are excluded from our state revenue data because they are not generated by a state tax.

Our study covers the 2004 to 2013 period and includes 23 states, giving 230 observations. We exclude Alaska from the sample because of its uniqueness; almost all exploration and production occurs on state or Federal lands and waters, and the state captures a share of the value

[6] The regions and corresponding spot market prices are OH, PA, WV, VA (Dominion); MI, IN, KY (Upper Midwest Chicago City Gate), CO, CA, MT, ND, SD, UT, WY (Kern River), LA, AR (SONAT Louisiana), TX, NM, (West Texas WAHA), OK, KS, NE (Panhandle Eastern TX OK), AL, MS (TRANSCO Zone 4 MS/AL).

of production unparalleled in the lower 48 states.[7] Arizona is excluded because it reports oil and gas revenues along with revenues from a variety of mining activities while Illinois lacked revenue data for most study years. Other excluded states had little to no oil and gas production.

Table 1 provides descriptive statistics for sample states. All monetary values are in 2010 dollars. The average state had $8,329 million in oil and natural gas production in the typical year, with natural gas accounting for 53 percent of the total value. In terms of British Thermal Units (BTUs), the share of production accounted for by natural gas was larger, at 75 percent, which reflects the lower per BTU price for natural gas compared to oil. In the typical year, production-based taxes generated $349 million in revenue for the average state. Average values, however, mask the skewness in the distribution of production and revenues across states. Some states produced no oil or gas in given year, and the median state-year observation had just $80 million in revenues from $2,880 million in production.

6. Findings

6.1 Aggregate Revenues from Oil and Gas Production Taxes (Question 1)

Figure 1 shows aggregate tax revenues and the value and quantity of oil and gas production for the study period. Revenue from oil and gas production taxes increased by roughly 80 percent from 2004 to 2008, to nearly $10 billion. The decline in natural gas prices in 2009 more than offset the continued increase in production, causing revenues to drop in 2009 and 2010. Continued growth in production, however, caused revenues to hit their highest level in 2013, at $10.3 billion. The production growth over the entire period was substantial, growing by 63

[7] For the fiscal year ending in June of 2010, Covenant Consulting Group (2012) estimated that Alaska had an effective tax rate of 25.1 percent, more than three times the highest effective rate found for states in the continental U.S.

percent. The value of production grew even more, at 78 percent (for the exact numbers, see Table A3).

To put the revenues in perspective, state governments had $240 billion in gross tax receipts in 2013 (in 2010 dollars) (O'Sullivan et al., 2014). State taxes on oil and gas therefore represent 4.3 percent of receipts. This, however, masks considerable variation across states in both oil and gas production and total tax receipts. Treated as a whole, in 2013 oil and gas tax revenues accounted for 20 percent of tax receipts for the top ten revenue states (=$9.77 billion in oil and gas revenue / $484 billion in total tax receipts) (the top ten states are TX, ND, NM, LA, WY, OK, PA, MT, CO, KS).

6.2 Central Tendency in Effective Rates (Question 2)

Figure 2 shows the estimates of the effective tax rate for the three measures, with each presented as a percent of the value of production or as dollars per Million British Thermal Units (MMBtus). The percent measure can also be interpreted as the cents in revenue generated for each dollar of production. Over the study period the average state had an effective tax rate of 3.6 percent (standard error of 0.18). The production-weighted rate was higher, at 4.2 percent, meaning that the average dollar of oil and gas generated 4.2 cents of revenue for state governments. The regression-based rate was also 4.2 (standard error of 0.10). The aggregate and regression-based rates both give more weight to state-year observations with more production, indicating higher effective rates in states with substantial production. In terms of revenue per MMBtu, the measures indicate a rate ranging from 23.5 to 29.6 cents per MMBtu. Similar to the value-based estimates, the average rate was the lowest rate, and the production-weighted and regression-based rates were the same.

Figure 3 shows scatter plots of revenue and production along with the best-fit regression line that gives the regression-based rates. The plots show how state-year observations with substantial production influence the slope of the regression line, which is the estimate of the regression-based rate. At the same time, the scatterplots reveal a consistently linear relationship and no clearly erroneous data.

To give an indication of how much taxation varies across states, for each state, *s*, we also calculate an average effective rate by averaging the rates observed in each year during the study period. Rates vary substantially across states (Appendix Table A3). Two states had an average rate of 0.1 percent or less while two states had rates of 8.0 percent or more. Montana had the highest rate in terms of dollars of production (8.6 cents per dollar) while North Dakota had the highest rate in terms of MMBtus ($0.88 per MMBtu). Virginia has no state tax on gas extraction and therefore had the lowest rate. Of states with some state tax, California had the lowest in per dollar terms, bringing in just one tenth of one cent for each dollar of production.

A comparison of effective and stated rates is attractive but not possible for most states because most states have various stated rates. Four states essentially have just one rate that it reportedly applies to all production of oil and gas (Indiana, Kansas, Kentucky, and South Dakota). In two cases the stated rate is nearly identical to the estimated average rate (for Kentucky, 4.5 percent compared to 4.7 percent; for Indiana, 1.0 percent compared to 0.9 percent). In the other two cases, the stated rate was much higher: 8.0 percent versus 3.8 percent in Kansas and 4.5 percent versus 2.8 percent in South Dakota.

6.3 Changes in Tax Rates over Time (Question 3)

The previous section estimated effective tax rates pooling the years 2004 to 2013. Figure 4 shows the estimated rates for each year of the study period. The value-based rates are steady until 2009. In general, the average rate appears to have increased over time while the production-weighted and regression-based rates were similar in the beginning and ending years of the period. The quantity-based rates, especially the production-weighted and regression-based rates, are lower in the second half of the period than in the first.

Looking at the value-based rates during 2004-09 and 2010-13 reveals an increase in the average rate from 3.4 percent to 3.9 percent while the other two rates decreased or stayed the same. For the average rate and the regression-based rate the changes were statistically insignificant at the 10 percent level. For the quantity-based rates, the average rate was unchanged while the other two rates declined substantially. The regression-based rate fell from 0.32 to 0.26 dollars per MMBtu, a change that was statistically significant at the 1 percent level.

The most natural explanation for the decline in the two quantity-based rates is the considerably lower natural gas prices of the later period (from roughly $7 to less than $4 per Mcf). For states where taxes are based on the value of production, the decline meant that the same quantity of natural gas would generate less revenue in the later period than the earlier period. The lack of a decline in the average rate should be viewed in light of the increase in the average rate in value terms, albeit a statistically insignificant increase, which potentially reflects changes in policy such as Pennsylvania's introduction of its impact fee on wells.

6.4 Oil and Gas Specific Tax Rates (Question 4)

For each measure of production (dollars or MMBtus), we estimate a base regression where oil and gas are combined and then three regressions based on equations (5a) and (5b), where oil production and gas production are separate independent variables. The third and fourth regressions are the same as the second regression but are based on state-year observations with substantial production, the first requiring at least $1 billion in production and the second requiring at least $5 billion. For all regressions, the dependent variable is dollars of revenue while the independent variables are oil and gas production in dollars or in MMBtus. The coefficients therefore have the same interpretation as the effective rates previously estimated (percentage or dollars per MMBtu).

The regressions give an oil rate of 3.6 percent and a gas rate of 4.7 percent, with the difference statistically insignificant (p-value of 0.57) (Table 2). Limiting the analysis to states with substantial production has little effect on the results, which highlights how the regression-based rate primarily reflects the policies of major oil and gas producing states. The bottom half of Table 2 shows the results when measuring production in MMBtus. Here, oil is taxed at a higher rate ($0.42 per MMBtu compared to $0.25), which reflects its higher market value. The imprecision of the estimates, particularly for oil, does not permit rejecting the hypothesis that oil and gas are taxed at the same rate despite the one rate being 23 percent higher than the other. Again, the results change little when limiting the sample based on production.

The greater imprecision of the Btu-based estimates relative to the dollar-based estimates is in part because revenue collections in most states are based on the value of production, not the quantity of production. This means that revenues may increase or decrease while holding the quantity of production constant. Econometrically, this translates into larger standard errors on the coefficient on production. The imprecision also reflects greater collinearity between the quantity of oil and gas than between the value of oil and gas. Over the study period the relationship between oil and gas prices weakened even though the two continued to be produced jointly in many regions. Unsurprisingly, the correlation coefficient between the quantity of oil and the quantity of gas is 0.81 compared to 0.65 for the value of oil and the value of gas.

Despite its statistical imprecision, the best estimate of the tax rate applied to the typical quantity of oil produced over the study period is $0.42 per MMBtu. With 5.8 MMBtu per barrel of oil and 0.43 metric tons of carbon dioxide per barrel (U.S. EPA, 2015), the state-level tax rate translates into $2.4 per barrel (=$0.42 x 5.8 MMBtu) or $5.5 per ton of carbon (=$2.4 / 0.43 tons). The value-based estimate of the oil tax rate, which is more precisely estimated than the quantity-based measure (rate of 3.6 percent, standard error of 1.1), gives similar per barrel and per ton rates. At the period average oil price of $63 per barrel, a tax rate of 3.6 translates into $2.3 per barrel or $5.3 per ton of carbon.

6.5 State and Local Taxes as Substitutes (Question 5)

Looking at the value-based rates, states without oil and gas property taxes had an average state rate of 4.7 percent while states with them had a rate of 2.8 percent (Figure 6a), a difference that is statistically significant at the 10 percent level. The production-weighted and regression-based rates show a similar divergence in state-level taxes for states with and without local property taxes on wells. For the production-weighted rate, the comparison was 6.0 to 3.6 percent; for the regression-based rate it was 6.4 to 4.0 percent, with the difference statistically significant at the 5 percent level.

Figure 6b shows the quantity-based rates, which further indicate higher rates in states without oil and gas property taxes. The average quantity-based rate was \$0.38 and \$0.19 per MMBtu for states without and with oil and gas property taxes, with the difference significant at the 10 percent level. The production-weighted and regression-based rates show a similar pattern, though the difference in regression-based rates was not statistically significant.

Figure 7 shows the revenue and production scatter plots for states with and without oil and gas property taxes. Panels (a) and (b), which are based on the value of production, clearly show a steeper slope between production and revenue for states without property taxes. Panel b also shows the influence of Texas, which has property taxes and is the largest producing state. The results, however, are not driven by Texas; the regression-rate is still markedly different in the two groups even when dropping Texas (significant at the 5 percent level). The quantity-based regressions in panels (b) and (c) show a similar but less precise pattern.

Across the three types of rates and the quantity and value-based measures, the central tendency in rates is always higher in states without oil and gas property taxes. On average, the effective rate in states without property taxes is two-thirds higher than those with them.

7. Discussion

In generating \$10.3 billion in revenue in 2013, oil and gas production clearly serves as important source of revenue for various state governments in the continental U.S. This revenue number is particularly impressive when considering that it excludes revenues generated for local schools and governments through property taxes on oil and gas wells.

At the same time, our data highlight the volatility of these revenue sources. From 2008 to 2010, state-level oil and gas tax revenues declined by about 40 percent despite increases in production. This is a perennial issue facing states that rely on oil and gas tax revenues for an economically important part of their budget and has been repeated in the 2014-2016 period. As reported by the EIA, the WTI price of oil decreased from $105 per barrel in June of 2015 to $29 by the end of January of 2016, a decrease of more than 72 percent. The volatility underscores the risk associated with funding current expenditures using current tax revenues based on the value of oil and gas production.

7.1 *Our Tax Rate Estimates as Benchmarks*

Our estimates provide benchmarks that allow states to compare their policies to those of the typical state or those that are applied to the typical barrel of production. We presented three different measures of central tendency: the average state rate, the production-weighted rate, and the regression-based rate. The average state rate best captures the policy of the typical state because it gives equal weight to minor and major producing states. The aggregate rate and the regression-based rate better reflect the policy governing the typical dollar of production because they give more weight to major producers. If states are considering their ability to attract oil and gas investment, which occurs mostly in states with lots of production, then the policy governing the typical dollar of production is arguably most relevant. Of course, producers consider the overall tax burden and other state-specific attributes when making investment decisions. This study only quantifies state policy along one dimension, state-level production taxes, not the general tax or regulatory environment for oil and gas producers.

7.2 Local and State Tax Substitution

Our analysis shows that state-level tax rates tend to be two-thirds higher in states without oil and gas property taxes, which is about 2.4 percentage points for the value-based rates. If such states generate roughly 2.4 percent of the value of production in property taxes, the total local property tax revenue generated in 2013 would be around 1.7 billion dollars. However, the data on revenues collected from oil and gas property taxes in several states suggest that local taxation of oil and gas often generates much more revenue than state-level taxes, indicating a higher local effective tax rate. Raimi and Newell (2014) show that Texas generated 2.3 billion dollars in local property tax revenue from oil and gas in 2012, which is about double the revenues from the state's severance tax. For the other two states with oil and gas property taxes that they examined (Arkansas and Wyoming), the revenue generated by local property taxes was also multiple times higher than the revenue from severance taxes.

We find evidence that state-level taxes and local property taxes serve as substitutes in practice even though they are clearly not equivalent in their economic and political motivations or consequences. Conceptually, their motivations have different roots. One justification for severance taxes on nonrenewable resources is that they promote intergenerational fairness by funding endowments to benefit generations of state residents who live after the exhaustion of the resource. Alaska, Texas, New Mexico, North Dakota are examples of states with such endowments, known as permanent funds. Property taxes, in contrast, generate revenues to pay for current costs of local public services, namely roads, parks, and primary and secondary education. In this sense, the justification for taxing oil and gas wells as property is the same as that for taxing real property of any kind.

The two taxes are also different from a fiscal federalism perspective, with severance taxes collected by state governments and property taxes collected and spent by local governments. As Glaeser (2012) notes, there are reasons to prefer having substantial resources and responsibilities vested with local institutions, one of which is that they presumably better represent local preferences. In the case of oil and gas extraction, an additional reason is that taxing wells as property ensures that revenues are collected and spent by the local jurisdiction where the well is located and where most costs associated with extraction occur. Costs may include traditional public costs such as road deterioration and increased demand for emergency services. In more rural areas, it may also include the increasing cost that schools face to attract and retain teachers in the midst of new lucrative jobs associated with a drilling boom. Marchand and Weber (2015), for example, show how schools districts in Texas' shale oil formations experienced greater teacher turnover as private sector wages increased.

If all oil and gas revenue is instead collected and allocated by the state government, the allocations may poorly match the geographic incidence of costs from drilling. Moreover, because property tax revenue does not go through the state government, it likely comes more quickly and in a more predictable manner than if it passed through the state. And if a state had a higher severance tax rate in lieu of property taxes, it might eventually divert revenues away from local governments, particularly in times of state budget deficits.

7.3 Oil-Specific Tax Rates

We estimate that the typical barrel of oil produced over the study period paid $2.4 in state-level taxes. This is much less than President Obama's proposed $10 per barrel national tax. Combined, however, the state and federal taxes would amount to 25 percent of the value of production at oil prices of $50 per barrel and half that at $100 a barrel. In carbon terms, combining the state-level taxes with the federal tax would amount to a $29 per ton tax on carbon (=5.7+23.3). This is close to the federal government's recent estimate of the social cost of carbon for 2010 of $33 per ton (in 2010 dollars, at a discount rate of 3.0 percent) (Interagency Working Group on the Social Cost of Carbon, 2015). Adding local property taxes on oil wells would probably put the rate above the estimated social cost of carbon. Surprisingly, then, a $10 per barrel federal tax on oil combined with existing state taxes would result in a plausibly efficient level of taxation of oil from a carbon perspective.

8. Conclusion and Policy Implications

Growth in oil and gas production in the continental U.S. has generated new interest in state taxation of extraction. We provide a quantitative description of state-level tax policy across the continental U.S. for the 2004-2013 period. Using state-level data on production and tax revenues, we find that the average state had a tax rate of 3.6 percent while the average dollar of production was taxed at 4.2 percent. The rate applied to the typical dollar of production did not increase over time, indicating that production from newly-developed shale formations is being treated similar to conventional production.

We estimate an oil-specific tax rate of $2.4 per barrel or $5.5 per ton of carbon. In this sense, the U.S. has a carbon tax on at least one major source, even though state taxes are not motivated by global externalities. If the federal government adopted a national $10 per barrel tax on oil, as proposed by President Obama, combined state and federal taxes on oil production would amount to a nearly $29 per ton tax, a rate not far from some estimates of the social cost of carbon.

Lastly, we find that state-level tax rates are two percentage points higher in states without property taxes on oil and gas wells, suggesting that these policies are substitutes for one another. This is not to say that taxes at different levels of government have the same economic or political implications; they most likely are quite different. With the growing importance of production from shale formations, which involves considerable local public costs, the tradeoffs of state versus local taxation merits more attention.

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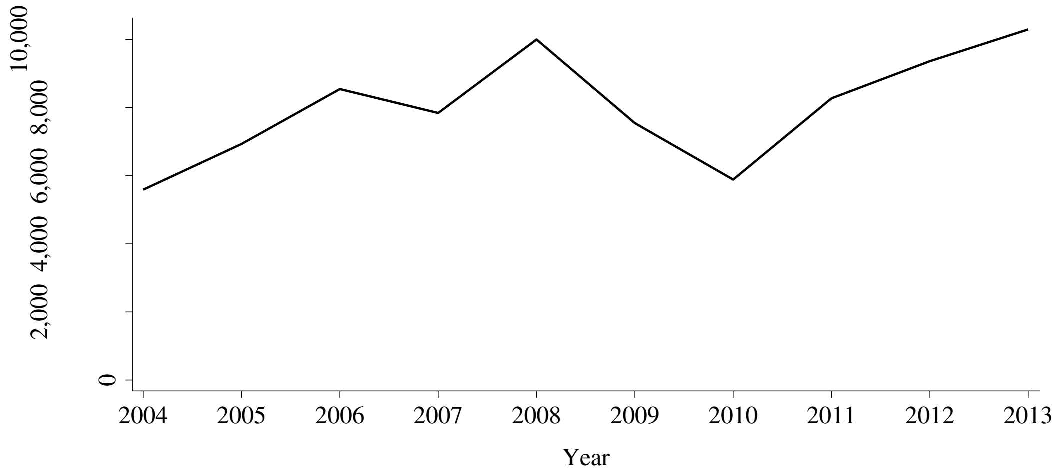
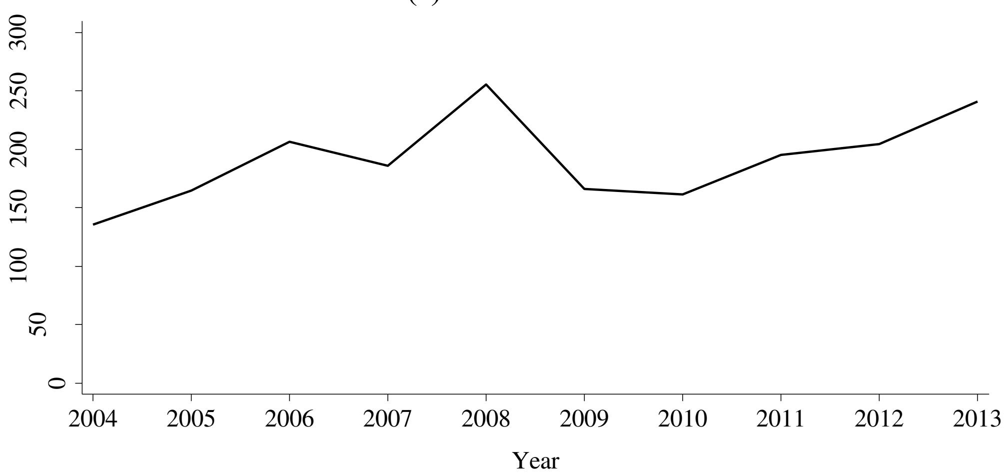
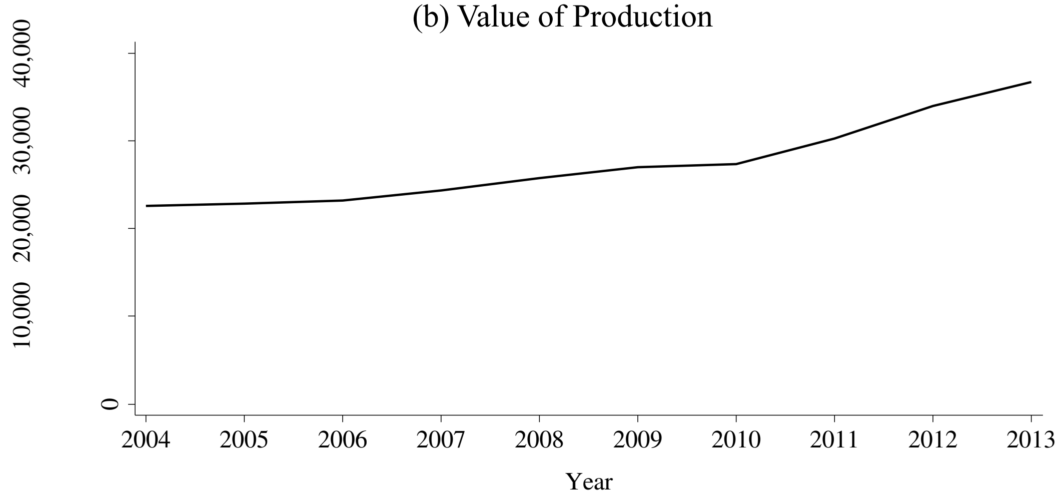
Figures



(a) Revenues

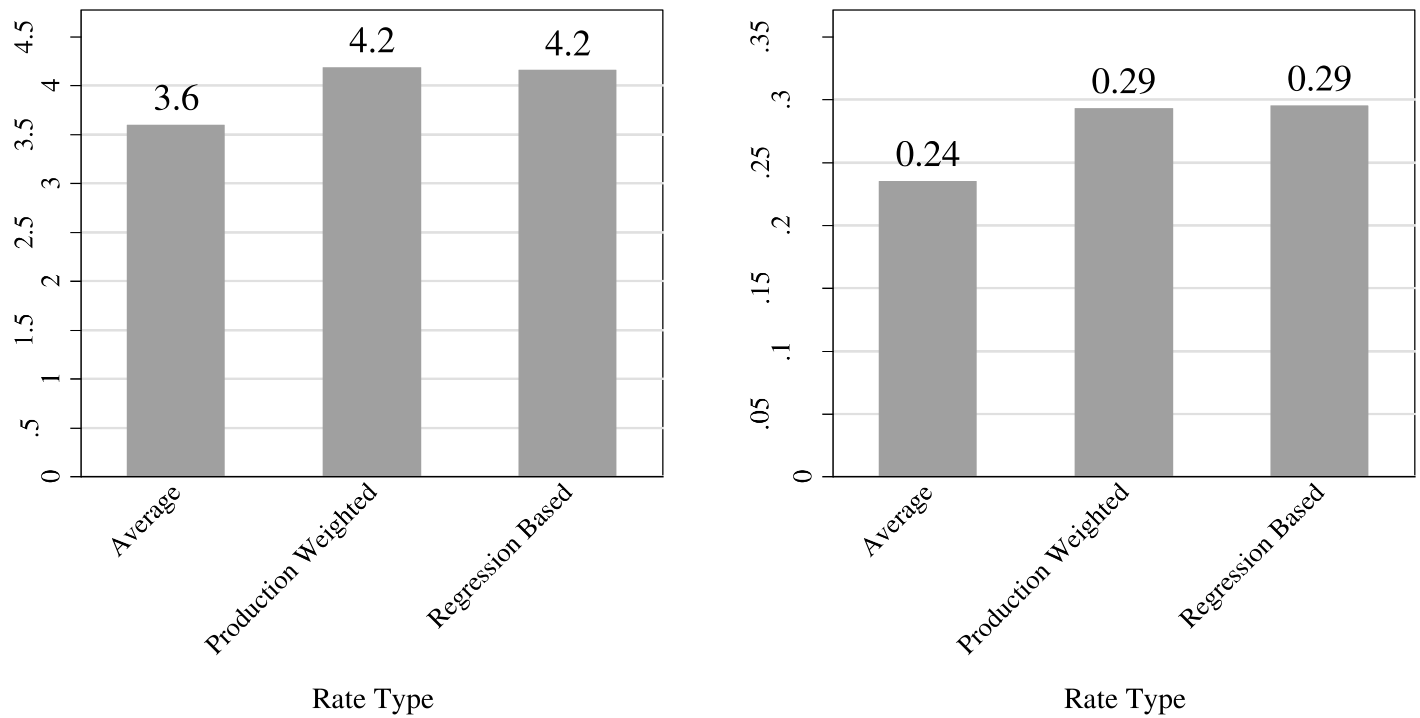


(b) Value of Production



(c) Quantity of Production

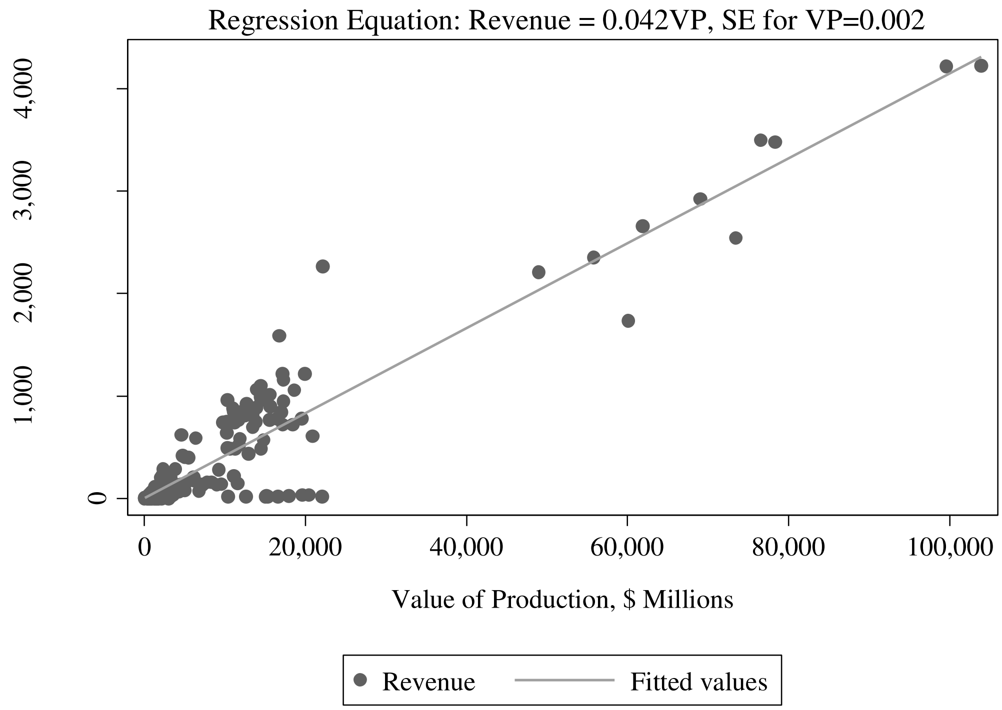
Fig. 1. Oil and gas tax revenues and production, 2004-2013.



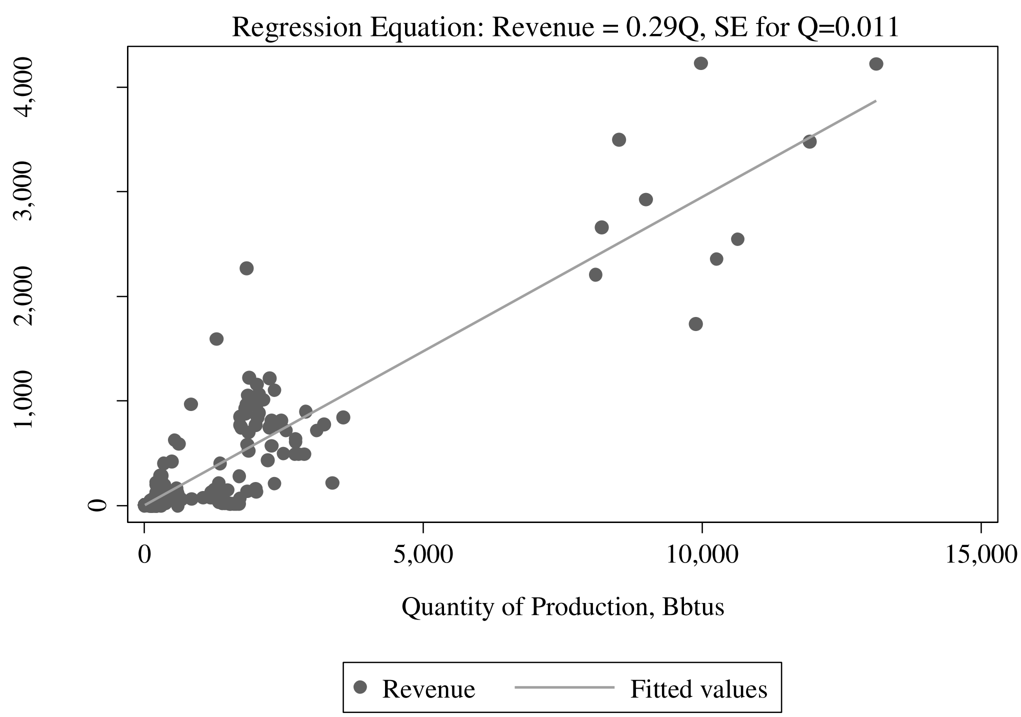
(a) Value-Based Rates

(b) Quantity-Based Rates

Fig. 2. Effective tax rates for oil and gas

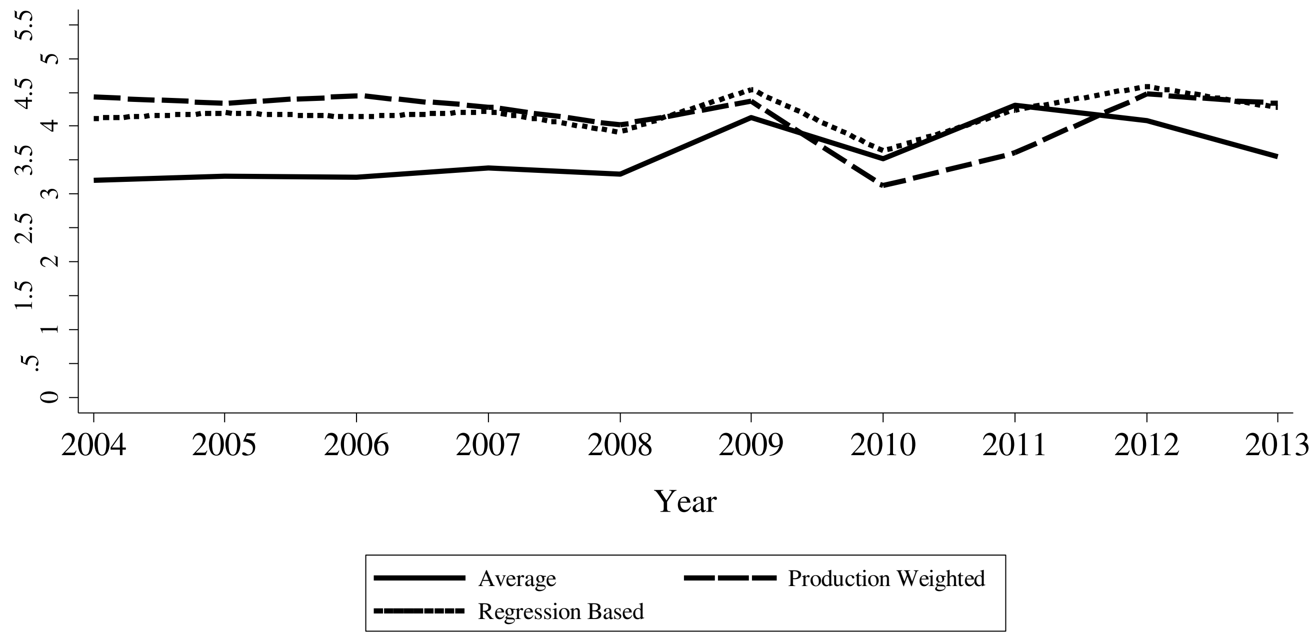


(a) Tax Revenues and the Value of Production

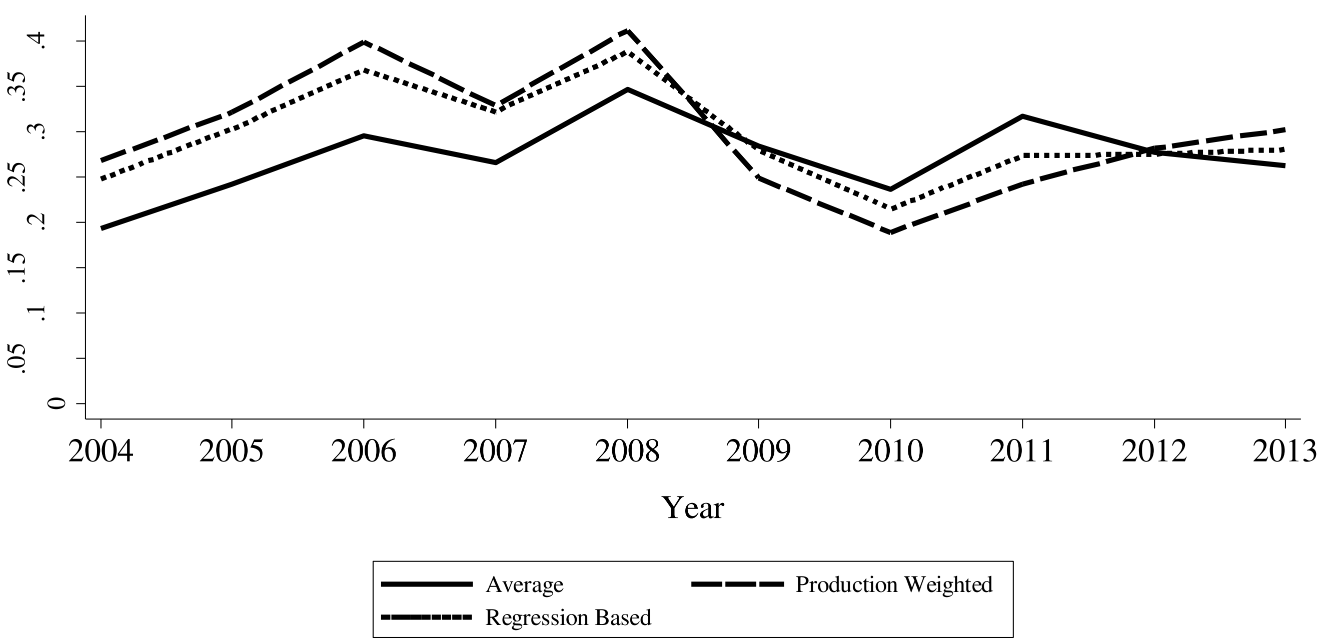


(b) Tax Revenues and the Quantity of Production

Fig. 3. Oil and gas tax revenues and the value or quantity of production.

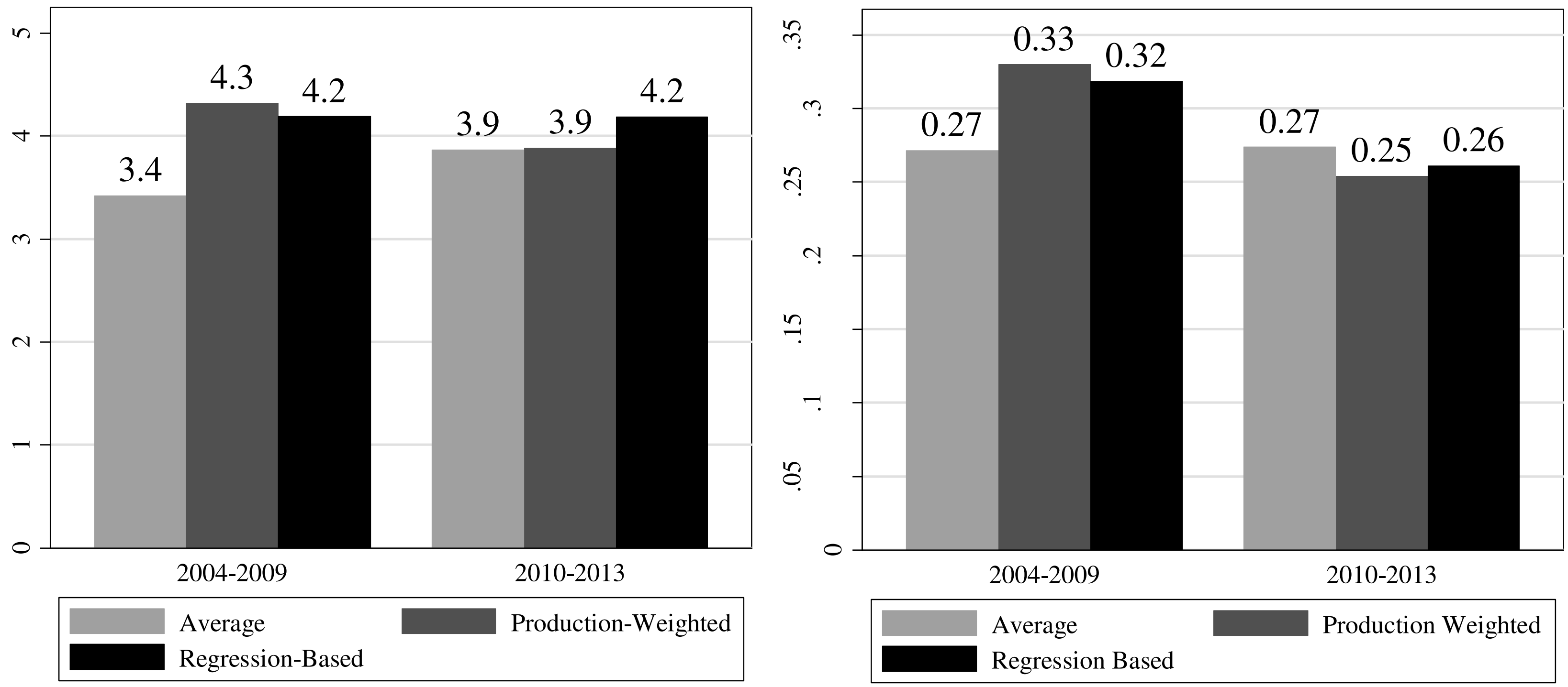


(a) Value-Based Effective Rates



(b) Quantity-Based Effective Rates

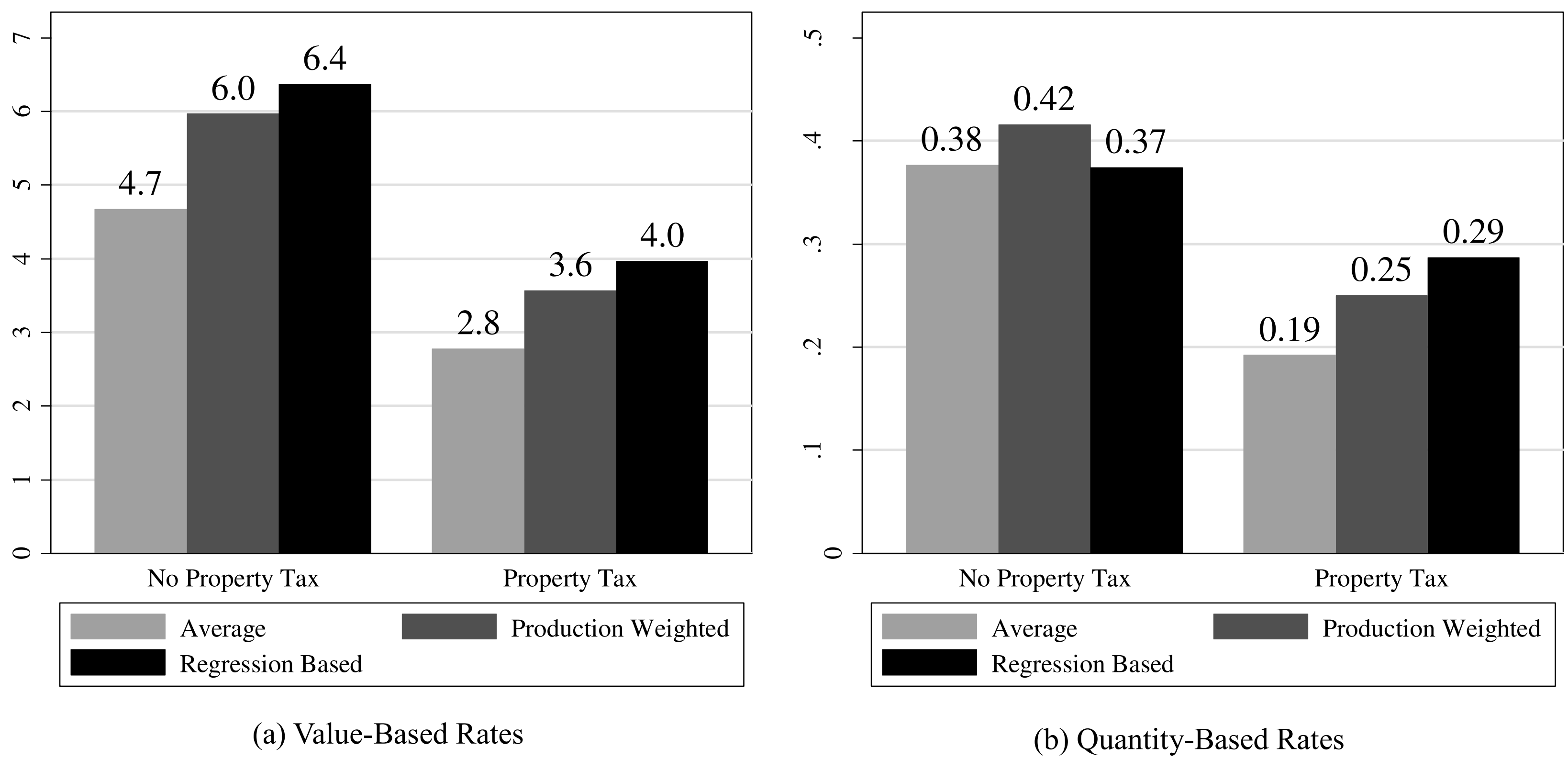
Fig. 4. Effective tax rates over time.



(a) Value-Based Rates

(b) Quantity-Based Rates

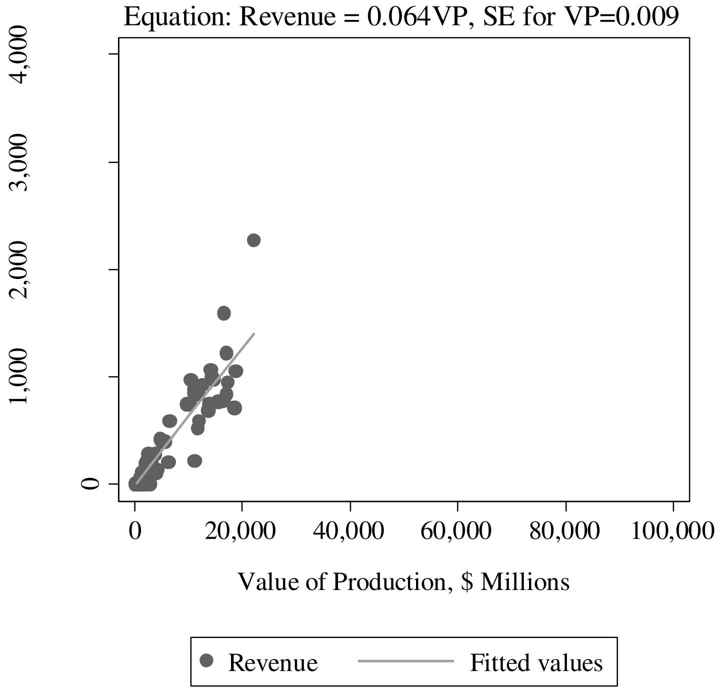
Fig. 5. Effective oil and gas tax rates by period.



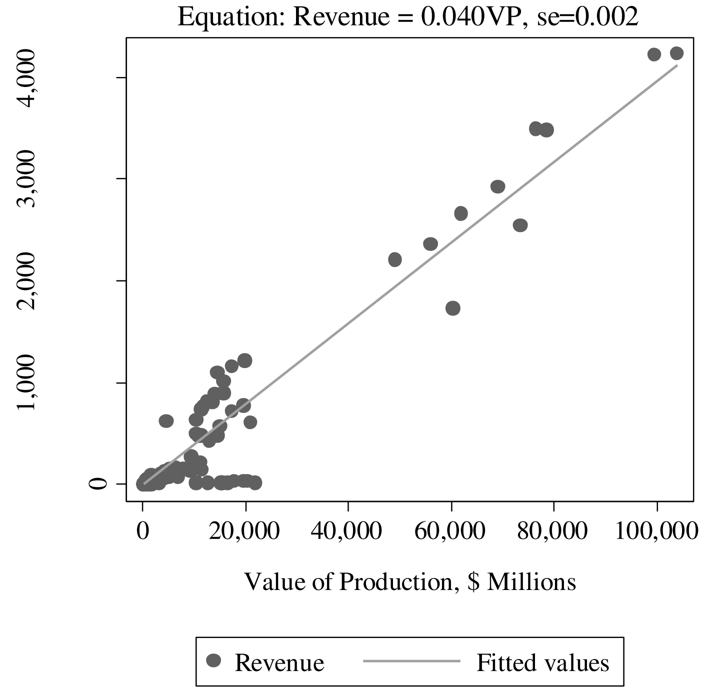
(a) Value-Based Rates

(b) Quantity-Based Rates

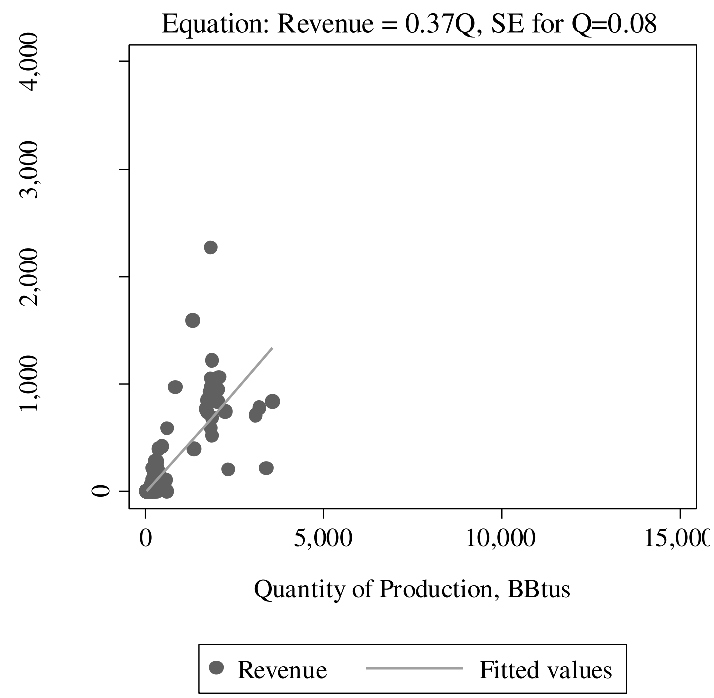
Fig. 6. Effective oil and gas tax rates by property tax policy.



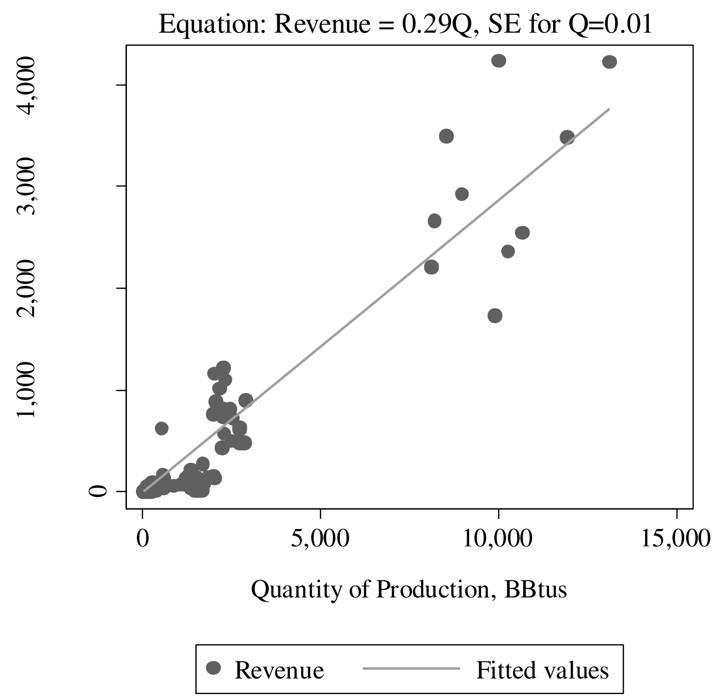
(a) Value of Production – No Property



(b) Value of Production – Property Taxes



(c) :Quantity of Production – No Property Taxes



(d) Quantity of Production – Property Taxes

Fig. 7. Regression lines for states with and without oil and gas property taxes.

Tables

Table 1. Oil and Gas Production and the Associated State Revenues For The Typical Study Year (2004-2013)

	Mean	SD	Median	Min	Max
Oil and Gas Production ($ Millions)	8,329	15,351	2,880	83	103,872
Oil	3,896	8,661	983	1	75,853
Gas	4,432	8,214	1,516	3	61,532
Oil and Gas Production (BBtus)	1,190,523	2,085,875	362,972	12,554	13,122,986
Oil	295,911	596,307	103,279	50	4,733,817
Gas	894,613	1,573,854	278,857	1,089	8,389,169
Revenue ($ Millions)	349	680	80	0	4,227

Authors' calculations based on revenue data are from state agencies, production and price data from the Energy Information Administration, and natural gas price data from Platts. Monetary amounts are in 2010 dollars.

Table 2. Oil and Gas Are Taxed at Statistically Similar Rates

	Y=Dollars of Revenue			
	O&G Combined	O&G Separate	Trimmed Sample[a]	Trimmed Sample[b]
Oil and gas production ($)	0.042***			
	(0.002)			
Oil production ($)		0.036***	0.036***	0.035**
		(0.011)	(0.011)	(0.012)
Natural gas production ($)		0.047***	0.047***	0.048***
		(0.008)	(0.009)	(0.009)
Observations	230	230	170	80
Adjusted R2	0.902	0.904	0.904	0.907
	Y=Dollars of Revenue			
Oil and gas production (MMBtu)	0.295***			
	(0.011)			
Oil production (MMBtu)		0.418	0.418	0.362
		(0.270)	(0.273)	(0.295)
Natural gas production (MMBtu)		0.253***	0.253***	0.278**
		(0.085)	(0.086)	(0.096)
Observations	230	230	170	80
Adjusted R2	0.858	0.861	0.861	0.869

Statistical significance at the .01 level (***); .05 level (**); and .1 level (*). Robust standard errors clustered by state are in parenthesis. In all cases, the difference in coefficients between oil and gas is statistically insignificant at the 10 percent level.

[a] State-year observations with at least $1 billion in production.

[b] State-year observations with at least $5 billion in production.

Appendix

Table A1. State Taxes Included in the Analysis

State	Tax Name	Rate	Explanation
AL	Production Tax	1 - 2%	Applied to the price of the first buyer.
	Privilege Tax	2 - 8%	
AR	Natural Gas Severance Tax	1.25 - 5%	Applied to the price for the first buyer minus the cost for dehydrating, treating, compressing, and delivering the gas to the first purchaser.
	Oil Severance Tax	$0.005 - $.02	Applied per barrel
		4 -5%	Applied to the price for the first buyer
CA	Rate of Assessment Tax	Changes Yearly	Assessed as a flat fee per Mcf or per barrel
CO	Oil and Gas Severance Tax	2% on $500 - 5% over $299,999	Applied to gross income
	Oil Shale Severance Tax	Between 1 and 4%	Applied on assessed value at the wellhead
IN	Petroleum Severance Tax	1% of Natural Gas Value or $.03 per Mcf	Applied to the price (or volume) for the first buyer
		1% of Oil Value or $.24 per BBL	
KS	Mineral Tax	8%	Applied to the price for the first buyer
KY	Mineral Severance Tax	4.50%	Applied to the price for the first buyer
LA	Oil Severance Tax	3.17% - 12.5%	Applied to the higher of either the price of the first buyer or the assessed field price minus trucking, barging, and pipeline fees.
	Natural Gas Severance Tax	$0.013 - $.03	Applied per Mcf
		Changes Yearly	
	Oil Field Restoration Fee	$0.015	Applied per Barrel

		$0.003	Applied per Mcf
MI	Oil Severance Tax	4 - 6.6%	Applied on assessed value at production
	Natural Gas Severance Tax	4 -5%	
	Oil and Natural Gas Privilege Fee	1%	
MS	Oil Severance Tax	0 - 6%	Applied to the price for the first buyer.
	Natural Gas Severance Tax	0 - 6%	
MT	Oil Production Tax	0.5 - 12.5%	Applied on assessed value at production
	Natural Gas Production Tax	0.5 - 14.8%	
	Oil and Gas Conservation Tax	0.09%	
NE	Oil and Gas Severance Tax	0 -3%	Applied to the price for the first buyer.
	Oil and Gas Conservation Tax	0.30%	
NM	Oil and Gas Severance Tax	0 – 3.75%	Applied to the price for the first buyer minus royalties paid to state, federal, and Indian governments, trucking expenses, pipeline transportation expenses, and possible processing costs.
	Oil and Gas Conservation Tax	0.19 - .43%	
	Oil and Gas Emergency School Tax	1.58 - 3.15%	
ND	Gross Production Tax	0 - 5%	Applied to the price for the first buyer of the oil minus transportation costs
	Oil Extraction Tax	4 - 6%	Applied to the price for the first buyer.
OH	Severance Tax	$0.10	Applied per barrel
		$0.025	Applied per Mcf
OK	Severance Tax	2 – 7%	Applied to the price for the first buyer.
	Petroleum Excise Tax	.095 of 1%	
	Energy Resource Assessment	$0.0035	Applied per Barrel

		$0.00015	Applied per Mcf
PA	Impact Fee	Varies Yearly	Dependent on how many years have passed since 2011 and what the price of natural gas is for the particular year.
SD	Energy Minerals Severance Tax	4.50%	Applied to the price for the first buyer minus royalty payments to South Dakota's state government or the federal government.
	Conservation Tax	$0.0024	
TX	Oil Production Tax	0 - 4.6%	Applied to the price for the first buyer
		$0.008125	Applied per barrel.
	Gas Production Tax	0 - 7.5%	Applied to the price for the first buyer minus marketing costs
		$0.000333	Applied per Mcf
UT	Severance Tax	0 - 5%	Applied to the price for the first buyer.
	Conservation Fee	0.20%	
WV	Severance Tax	0 - 5%	Applied to the price for the first buyer minus costs for transmission, transportation, and any refining process.
	Workers' Compensation Debt Reduction Act Natural Gas Severance	$0.047	Applied per Mcf.
WY	Severance Tax	1.5 - 6%	Applied between the well-head and a transfer to an interstate pipeline price.

The range of tax rates for a given state reflects varying rates based on well characteristics or other details related to production.

Table A2. Relevant State Taxes/Fees Whose Revenue Is Excluded from the Analysis

State	Name of Tax	Description	Source
Arkansas	Oil and Gas Assessment	For the Oil Assessment, the tax is per barrel and can't exceed 50 mills and for the Gas Assessment, the tax is per Mcf and can't exceed 10 mills. This tax is levied on the producer.	http://www.aogc.state.ar.us/onlinedata/forms/rules%20and%20regulations.pdf
Colorado	Conservation Mill Levy	Seven-tenths mills per dollar sale value ("market value at the well") of the sale of gas and oil from producers in the state. This tax is levied on the producer or the purchaser, according to the statue.	§ 34-60-122 https://cogcc.state.co.us/RR_Docs_new/rules/AppendixV.pdf
Kansas	Oil and Gas Conservation Fee	91.00 mills per barrel and 12.90 mills per McF. This is imposed on the producer.	http://www.ksrevenue.org/taxnotices/notice00-00.pdf
Wyoming	Oil and gas Conservation Fee	Up to .0008 per dollar on the sale price of gas and oil to be paid by the producer.	30-5-116 (b) http://legisweb.state.wy.us/NXT/gateway.dll?f=templates&fn=default.htm

Information on these various taxes came from the respective state agencies.

Table A3. Aggregate Revenues and Production by Year

Year	Revenue ($ Millions)	Value of Production ($ Millions)	Production (BBtus)
2004	5,581	135,536	22,529,799
2005	6,921	164,836	22,821,896
2006	8,549	206,513	23,200,104
2007	7,831	185,706	24,293,968
2008	9,998	255,295	25,751,613
2009	7,540	165,869	26,955,946
2010	5,873	161,405	27,330,815
2011	8,272	195,163	30,242,142
2012	9,365	204,127	33,987,638
2013	10,302	241,119	36,706,459
Average	8,023	191,557	27,382,038

Aggregate numbers are based on revenue data from state agencies, and production and price data from the Energy Information Administration, and price data from Platts. Monetary amounts are in 2010 dollars.

Table A4. Average Effective Rates By State

	Rate (%)		$ per MMBtu	
	Mean	SD	Mean	SD
AL	6.0	0.8	0.41	0.09
AR	0.9	0.6	0.05	0.03
CA	0.1	0.0	0.01	0.00
CO	1.7	0.6	0.10	0.04
IN	0.9	0.1	0.09	0.02
KS	3.8	3.4	0.31	0.29
KY	4.7	0.8	0.31	0.08
LA	5.3	1.0	0.37	0.13
MI	4.8	1.2	0.34	0.08
MS	3.0	0.4	0.22	0.05
MT	8.6	1.6	0.80	0.18
NE	2.6	0.3	0.29	0.08
NM	6.9	1.0	0.47	0.09
ND	8.1	1.5	0.88	0.30
OH	0.3	0.1	0.02	0.00
OK	6.2	1.1	0.41	0.12
PA	1.2	2.4	0.04	0.09
SD	2.8	0.8	0.22	0.06
TX	4.1	0.5	0.30	0.08
UT	2.0	0.3	0.13	0.03
VA	0.0	0.0	0.00	0.00
WV	4.2	0.9	0.24	0.08
WY	4.4	1.0	0.24	0.05
Mean	3.4		0.27	
Median	3.8		0.24	
Minimum	0.0		0.00	
Maximum	8.6		0.88	

To calculate the rate for each state, we calculate an effective rate for each year and then average across years.