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Does Resource Ownership Matter? Oil and Gas Royalties and the Income Effect of Extraction*

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Abstract

We study how subsurface ownership shapes the income effects of oil and gas extraction. For the average U.S. county with growth in extraction from 2000 to 2014, we find that royalty income and its multiplier effect accounted for 70 percent of the total income gain, with each royalty dollar generating an additional 49 cents of local income. A county where residents own the subsurface captured 28 cents more of each dollar in production than one with absentee ownership. Nationally, oil and gas production increased U.S. personal income in 2014 by $67 billion (0.5 percent) more than if all royalties accrued abroad. Areas with the same resource abundance can therefore experience contrasting economic outcomes because of differences in ownership.

Keywords: resource ownership; oil and gas; royalties; income multiplier

JEL Classification Numbers: D23, R11, Q32, Q33

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1 Introduction

Whether considering gold in Africa or coal in Appalachia, it is intuitive to expect a region's natural resources to further the prosperity of its residents. The intuition weakens when realizing that residents may not own their region's resources. This may matter because resource owners can experience financial windfalls caused by new extraction technologies or demand shocks that cause prices to spike. If accruing to local residents, the windfalls increase income directly and may stimulate local consumer demand or entrepreneurship. If accruing to non-residents, producing regions may find themselves as resource colonies, with extraction creating local environmental damages (e.g., Muehlenbachs et al. (2015)) while most economic benefits flow elsewhere. The contrasting scenarios have a bearing on state and local policy debates about extraction, which are often framed as a question of economic gains for residents relative to disamenities from extraction. In the case of shale oil and gas development, different answers to the question have led to bans on fracking in some places (Denton, Texas; New York state) and industry tax breaks in others (Texas and Oklahoma).

Literature on the economic effects of oil and gas development or natural resources in general has said little about issues of resource ownership, theoretically or empirically. The seminal theoretical work linking a booming resource sector to the broader economy focuses on workers moving across sectors and expenditures of additional income from higher wages (Corden and Neary, 1982). The model is silent on ownership and how the windfall created by the booming resource sector propagates through the economy. Following this lead, empirical research on extractive booms, which has boomed in recent years, has focused on labor markets, with almost no studies explicitly considering payments to resource owners (Marchand and Weber, 2018). This is surprising because such payments can be large. Buoyed by the U.S. shale boom, payments to owners of oil and gas rights grew by nearly 75 percent from 2010 to 2014, totaling $177 billion over the period and reaching nearly every county in the United States.[1]

Using 2.2 million private oil and gas leases collected from public records, we estimate royalties paid to county residents from production within the county and from production

[1]The estimates of royalty income from 2010 to 2014 are based on the data and methods described in the paper.

elsewhere in the lower 48 states. We then estimate the multiplier effect of royalties on local income by exploiting shocks to national energy production and prices that affected counties differently based on past royalty levels. Combined the estimates permit identifying the income effect of extraction that is attributable to royalties.

We find that ownership-related income accounts for a large share of the total income effect of extraction. For counties with growth in oil and gas extraction, royalty income and its multiplier effect accounted for 70 percent of the total local income gain. A county with complete local ownership of the subsurface captured 28 cents more of each dollar in production than one with absentee ownership. Royalties also have broad distributional effects locally, decreasing the number of low income tax returns and increasing the number of high income returns. Nationally, oil and gas production increased U.S. personal income in 2014 by $67 billion more than if all royalties accrued abroad.

2 Literature

2.1 Natural Resources and the Economy

A large literature summarized by Van der Ploeg (2011) uses cross-country comparisons to understand the relationship between a country's dependence on natural resources and economic growth over a subsequent period. More recent research avoids cross-country heterogeneity by performing a similar analysis, but with variation across states or counties instead of countries (Papyrakis and Gerlagh, 2007; James and Aadland, 2011; Partridge et al., 2013). Although contested by some (e.g., Brunnschweiler and Bulte (2008)), a common finding is that areas more dependent on the resource sector grow more slowly. A limitation of these analyses, however, is that resource dependence can reflect trends or shocks in other sectors, making it hard to interpret correlations with subsequent growth.

A more informative and empirically transparent line of subnational research has shifted from a focus on dependence on resources and instead estimates the effects of extraction or endowments on local economies and allows the effects to vary through booms and busts in commodity prices (Black et al., 2005; Michaels, 2011; Jacobsen and Parker, 2016; Allcott and Keniston, 2017). All studies show major economic change with extraction, but there is no consensus on whether busts are more severe than the booms are beneficial, or whether long-run effects are positive.

The above literature focuses heavily on resources and income per capita or related measures. Other work seeks to understand specific channels through which natural resources affect the economy and welfare (e.g., Caselli and Michaels (2013)). One channel that has received attention is education and how booms in extraction affect schooling decisions (Black et al., 2005; Cascio and Narayan, 2015; Rickman et al., 2017; Marchand and Weber, 2017) or public resources and spending on education (Papyrakis and Gerlagh, 2007; James, 2015; Marchand et al., 2015). Using the recent U.S. shale boom, other research focuses on changes in local welfare linked to income and housing values (Bartik et al., 2017; Jacobsen, 2018; Muehlenbachs et al., 2015; Boslett et al., 2016; Weber et al., 2016).

Most of the subnational literature lacks explicit treatment of institutional differences across regions that might cause two places with similar resource endowments to have different outcomes. Such differences include formal policies governing resource taxation and spending or patterns of resource ownership.

2.2 Resource Ownership and the Shale Boom

In places where the government owns most or all of the resource, the returns to ownership largely stay in the economy, and their effects are implicitly captured in a general economic analysis because revenues from extraction accrue to the government and are available to fund investment, social spending, or tax cuts. This is true of the study by Mideksa (2013), which estimates how petroleum resources affected the national income of Norway, as well of that by James (2016), which estimates the effect on the Alaskan economy of the discovery of oil deposits at Prudhoe Bay—a state-owned resource.

In places with primarily private resource ownership, resource owners may live far from where the resources are located. The United States is unique in the world insofar as private individuals own most of the subsurface resources and typically profit from ownership by leasing their rights to energy firms (Fitzgerald and Rucker, 2016). The lease specifies a share of the value of production—a royalty rate—to be paid to the resource owners, wherever she lives, in exchange for granting access to the resource. Once signed and production begins, leases generally remain in effect until production ends (Fitzgerald, 2014).

Research on natural resources and the local economy has overwhelmingly focused on labor markets (Marchand and Weber, 2018) and this is true of studies of the U.S. Shale Boom (Weber, 2012; Brown, 2014, 2017; Fetzer, 2014; Komarek, 2016; Maniloff and Mastromonaco, 2017; Feyrer et al., 2017). The emphasis is consistent with the seminal theoretical work of Corden and Neary (1982), and more recently Allcott and Keniston (2017), linking a booming resource sector to the broader economy, which focuses on workers moving across sectors and spending income from higher wages.

Two recent studies, however, suggest that returns to resource owners may be a primary channel through which extraction affects the broader economy. Brown et al. (2016) report that six major shale formations generated $39 billion in gross production royalties in 2014 and that local ownership rates vary extensively across the country. Feyrer et al. (2017) estimate the non-wage income effect in an analysis of the full income effect of shale development. Using IRS Statistics of Income data, they find that each million dollars in production generated $80,000 in wage income and $132,000 in non-wage income within the county where production occurred. Royalties may account for a large part of the growth in non-wage income; they may also be the underlying cause for some of the wage growth.

2.3 Multiplier Effects

There is good reason to expect royalties to have broad economic effects by stimulating demand and spending. Evidence from tax rebates suggests that households spend $0.4 to $0.9 of each dollar in the subsequent year (Johnson et al., 2006; Agarwal et al., 2007; Parker et al., 2013). As greater royalty payments cause people to demand more home renovations, restaurant meals, and the like, the associated sectors demand more labor and pay more wages. This applies to unanticipated payments. Anticipated payments, in contrast, should have little effect on spending in the period when they are received. Hsieh (2003), for example, studies the highly anticipated payments from the oil-and-gas-funded Alaska Permanent Fund and finds no evidence that households adjust their consumption in response to the payments.

The total income effect of a dollar in additional royalty income is conceptually similar to the multiplier effect of a dollar of government spending that occurs as a transfer payment, such as an extension of unemployment benefits, or a tax expenditure, such as a new tax credit. Most relevant to our study is Hausman (2016), who uses state and city variation in receipts of the 1936 veteran's bonus to infer an income multiplier of 1.7, meaning that each dollar in bonus payment led to \$0.7 in income beyond the bonus dollar itself. Though not directly comparable, this is in line with fiscal multipliers estimated using cross-sectional variation, which typically show a multiplier of around 1.8, suggesting that each \$1 in transfer income creates about \$0.80 in additional income (Chodorow-Reich, 2017).

3 Estimating Royalty Income Multiplier Effects

Quasi-experimental approaches with easily-understood identification strategies have become popular in the empirical literature on the effects of income shocks (Jappelli and Pistaferri, 2010). In this spirit, we use a first-differenced model where the change in income is regressed on the change in gross royalty income:

$$\Delta Y_{it} = \theta_{st} + \lambda \Delta Royalties_{it} + \varepsilon_{it}, \tag{1}$$

where θ_{st} is a state-year fixed effect and $\Delta Royalties_{it}$ is the change in gross royalty income received by county residents from production *anywhere* in the contiguous United States. Because of variation in the size of county economies, we normalize income and gross royalties by the previous year's population. The coefficient λ indicates the change in the income measure Y_{it} for each dollar increase in gross royalty income.

Resource owners can anticipate some of the change in gross royalty income. Assuming a constant output price, royalties will be greatest in a well's first year of production and then decline afterwards, often in a predictable manner. Anticipation of changes in royalty income might shift the consumption response and its economic effect to earlier periods, thereby biasing λ towards zero. In addition, incomplete leasing data, among other reasons, means that our royalty income estimate is measured with error, which would also bias λ towards zero.

To address anticipation of royalty income and measurement error, we use an instrumental variable approach that exploits annual variation in royalty income caused by shocks to national energy production and prices. Define royalty income as the product of the acre-weighted mean royalty rate on acreage owned by residents of county i anywhere in the contiguous United States (ρ_i), gross production from that acreage (Q_{it}), and the average price in year t (P_t):

$$Royalties_{it} = \rho_i \times Q_{it} \times P_t. \tag{2}$$

Holding constant the royalty rate, which is fixed by lease contracts, the change in royalty income from year $t-1$ to t is:

$$\Delta Royalties_{it} = Royalties_{it-1} \times \left((1 + \%\Delta P_t) \times (1 + \%\Delta Q_{it}) - 1 \right). \tag{3}$$

Individual resource owners cannot influence national prices or consistently predict their growth, otherwise they could make a fortune in trading energy commodities. Some of the change in production, in contrast, is likely anticipated because owners have parcel-specific knowledge of drilling activity and the production trajectory of existing wells. Anticipation of production growth driven by industry-wide change is less likely. Again, individual owners cannot influence national production trends. Moreover, rapid and hard-to-predict productivity growth occurred across the industry over the study period, with new production per drilling rig increasing several-fold in many regions (Energy Information Administration, 2017). To capture production growth driven by industry-wide change, we replace the percentage change in production on acreage owned by county residents with the percentage change in national production, excluding production from county i (thus the $-it$ subscript on Q).[2] The royalty income shock is then defined as:

$$Royalty\_Shock_{it} = Royalties_{it-1} \times ((1 + \%\Delta P_t) \times (1 + \%\Delta Q_{-it}) - 1). \tag{4}$$

For counties in states that primarily produce oil, we use the national change in oil prices and production. For those in states primarily producing natural gas, we use natural gas prices and production. For counties in states without oil and gas production, we base national changes on combined oil and gas prices and production measures using thermal equivalence. This combined with equation (4) motivates a first-stage regression of the form:

$$\Delta Royalties_{it} = \theta_{st} + \alpha Royalty\_Shock_{it} + \varepsilon_{it}. \tag{5}$$

A threat to the validity of the instrument–the royalty income shock–is a correlation between it and local drilling or mining-related employment. Local expansion in the oil and gas industry will have its own effect on local income through employing more people and paying more wages and also by stimulating labor demand in related firms such as concrete manufacturers and trucking companies. A potential correlation between the royalty shock and local drilling is because the shock depends in part on the lagged quantity of production on acreage owned by county residents, some of which likely occurs in the recipient's home county. Lagged local production may in turn be correlated with subsequent drilling, particularly in periods of increasing energy prices. Such a correlation would cause our IV approach to overstate the multiplier effect of royalty income.

We address this potential threat to validity in three ways. First, we control for shocks to mining earnings (NAICS 21, which includes oil and gas extraction) and shocks to drilling. The variables are constructed by multiplying the lagged level of mining earnings or wells

[2] Our instrumental variable approach follows the spirit of a Bartik approach, which has become a popular identification strategy (Goldsmith-Pinkham et al., 2018). In its original form, the Bartik approach estimates the effects of local labor demand shocks by instrumenting local employment by a variable defined as the interaction between local industry employment shares and their respective industry-specific national growth rates. The analogous approach in our context would be to instrument the local change in income with the local shares of royalty and non-royalty income interacted with the national growth rates in these variables. The approach, however, would give us the income multiplier associated with a generic change in income, not one driven by changes in royalties. Given our focus on the royalty multiplier, we instead apply the essence of the Bartik approach and interact the lagged local level of royalties with the national growth rate in its components (production and prices).

drilled with the percentage change in energy prices (the same $\%\Delta P_t$ as in (4)). Including shocks to mining earnings or drilling accounts for local income growth linked to the extractive sector. Other studies have used variations of both variables to measure a resource boom and its broader economic effects (Fetzer, 2014; Maniloff and Mastromonaco, 2017). Including both of them is useful because the location of firms and the location of extraction can differ. In a later section, we show that conditional on these variables, our instruments are uncorrelated with growth in drilling or mining earnings.

The second approach to avoiding confounding the royalty income effect with a local drilling effect is to estimate distinct multiplier effects for royalties generated by production within the county, which we call local royalties, and royalties generated by production in other counties, which we call absentee royalties. The third approach is similar and involves excluding shale-rich counties and their neighboring counties.

Because counties with greater initial royalty income might be unique in other ways, we also explore whether counties receiving more royalties at the start of our study period had similar levels or growth in total income prior to the expansion in domestic drilling in the mid 2000s.

4 Data

We provide an overview of data sources and construction of key variables as well as details on the estimation of royalty income in the appendix.

4.1 Lease Data

We obtained information about individual oil and gas leases across the United States from private data provider Drillinginfo. The lease dataset is extensive but not exhaustive, including leases from 575 counties across 17 major oil and gas producing states. Combined, the counties accounted for 90 percent of onshore oil and gas production (at thermal equivalence) from private leases in 2014 according to the Drillinginfo production data.[3]

[3]Details are provided in the data appendix.

We exclude all leases with federal, state, or local governments, leaving only private leases. Each observed lease contains important details including the royalty rate, the date signed, the location of the parcel, and the address of the parcel owner. We exclude duplicate leases, those appearing to be between related parties, and those between known oil and gas operators. In cases where fractionated ownership resulted in multiple leases for a single parcel, we divide ownership equally.

4.2 Oil and Gas Production, Drilling, and Prices

Information from Drillinginfo was used to build a county-level panel dataset of oil and gas production and drilling for 2010 to 2014. County-level tabulations were used because lease-level production and drilling were not available from Drillinginfo. Moreover, additional adjustments were required to only capture production from private leases.

Economically important production occurs on federal and state estates, with royalties paid to respective government coffers. To focus on private royalties, we net out federal production as reported by the Office of Natural Resource Revenue, and aggregated to the county-year level by the U.S. Extractive Industries Transparency Initiative. We also net out state production, which we collected directly from responsible state agencies. To determine the local value of production, we value oil production using the state-level first purchase price of oil available from the Energy Information Administration (EIA). For natural gas, we used a state-level wellhead price series, also from the EIA.

4.3 Estimating Royalty Income to County Residents

One of the unique features of oil and gas leasing data is the locational information on the physical acreage as well as the location of the resource owner. For every lease, we can determine the county of the parcel and the county of the owner.

We calculate acre-weighted mean royalty rates for every pair of producing and receiving counties that we observe. This gives the royalty rate governing payments from acreage in each producing county to residents in each receiving county, with the royalty rate unique to each producing-receiving county pair. The royalty rate multiplied by the value of production in county i payable to county j in year t gives the royalty income paid from i to j in year t.

Having calculated the royalties from every producing county to every other receiving county, which includes the royalties that are locally retained in the producing county, we tabulate the sum of the flow of royalties to residents in each county of the lower 48 U.S. states. The estimate is made for each year, with annual variation caused by changes in the value of production. The estimate is an upper bound on the net royalty income paid to royalty owners because well operators often deduct transportation allowances and other post-production costs from gross royalties.[4]

The data also allow us to break total royalty income into its two components: local royalties, which are generated by production within the county, and absentee royalty income, which is generated by production in other counties. To be clear, local royalties for county i come from parcels located in county i and owned by residents of county i; absentee royalties are from parcels in other counties but that are owned by residents of county i.

4.4 Income and Wage Data

County-level income data come from the Internal Revenue Service Statistics of Income, which are based on individual tax returns and assigned to counties based on each return's address. We use adjusted gross income as our measure of total income, which is then broken into wage income and non-wage income, defined as total income less wage income. For mining earnings, which we use to construct a control variable, we use data from the Bureau of Labor Statistics Quarterly Census of Employment and Wages. Lastly, annual county population estimates, which are used to put variables on a per capita basis, are from the U.S. Census Bureau.

5 Descriptive Statistics

Table 1 provides descriptive statistics for sample counties, with all variables normalized by lagged population or, in the case of wells drilled, by lagged population measured in

[4]Our measure of royalty income does not include bonus payments as it is not available in the leasing data. However, we focus on the later years (2010-2014) when most leases were already signed in our database, which means that bonus payments would have already been paid in most cases.

thousands. All monetary variables are converted to 2010 dollars based on the Consumer Price Index. The table is based on annual changes calculated from data from 2010 to 2014, meaning that 2010-2011 is the earliest difference. We focus on 2010 to 2014 because the typical lease in most counties was signed before 2010 (90 percent of counties had a mean lease year before 2010). The focus on later years limits the extent that a lease signed in 2012, for example, influences the allocation of royalties in 2010.

Over the period the average county saw an annual increase in gross royalty income of $36 per person, which is almost double the average increase in mining earnings.[5] This average increase in gross royalty income represented about 11 percent of the average increase in total income as measured by adjusted gross income. Looking at particular percentiles reveals that royalty income is quite skewed: the median county saw only a $1 per capita increase, while the counties at the 90th and 95th percentiles saw increases of $50 and $159 per person. Figure 1a shows the geographic distribution of the average annual change in royalty income ($ Per Capita) over the 2010 to 2014 period, with high-royalty-growth counties spread throughout many states.

6 Multiplier Findings

6.1 Instrument Relevance and Validity

We establish the relevance of our instrumental variable–the royalty income shock from national changes in energy prices and production–by estimating equation (5). A $1 increase in the royalty income shock variable led to $0.60 greater royalty income (Table 2), with an associated F-statistic of 24. Similar results are observed when separating local and absentee royalty income, with the local royalty income shock predicting the actual change in local royalties and the same for absentee income. For both types of royalties, the excluded instrument has sufficient statistical strength to limit concerns about weak instrument bias.

The validity of our instrumental variables requires that they not affect local income

[5]Four counties in Texas had exceptionally large increases in royalty payments, with each county experiencing at least a $10,000 per capita increase in royalties in one year or more. We exclude these counties from the analysis.

through channels other than the royalty income multiplier channel. A potential concern is that the royalty shock is correlated with income through an association with local drilling or growth in mining-related firms. Not accounting for the potential correlation could wrongly attribute some of the income effect of drilling to royalties, biasing the multiplier effect upwards. Controlling for shocks to local mining earnings and drilling should reduce such a correlation but may not eliminate it. We therefore regress the change in wells drilled and mining earnings on our instrumental variables, conditional on the control variables.

We find an economically small, negative, and statistically insignificant relationship between royalty income shocks and growth in drilling (Table 3). The same is true for the relationship between the royalty shock and mining earnings, with each $1 in additional royalty income associated with less than $0.01 in additional mining earnings. Breaking the shock into its local and absentee components reveals a weak negative relationship between local royalties and mining earnings and a larger, positive relationship for absentee royalties, though still statistically indistinguishable from zero.

The results in Table 3 suggest that once shocks to mining earning and drilling are controlled for, there is no significant correlation between the royalty shock and changes in wells drilled or mining earnings. There is a strong correlation between the drilling shock and the change in the number of wells drilled: each additional well predicted by the drilling shock variable is associated with 1.84 additional wells actually drilled, with a standard error of just 0.13. We observe a similarly strong and intuitive relationship between the mining earnings shock and the actual change in mining earnings.

A more general concern about instrument validity is that counties with substantial subsurface ownership–and therefore growth in royalty income–are unique in hard-to-observe ways and likely experience distinct income shocks and trends. We explore this possibility by estimating the relationship between a county's level of royalty income in 2010 and its average income over the 1990-2005 period, and in a separate regression, its change in income over the same period. Counties receiving more royalty income in 2010 did not have higher income than other counties before growth in domestic oil and gas production, nor did they systematically have greater income growth over the period (Appendix Table A1). The conclusion holds for local and absentee royalties.

6.2 Multiplier Estimates

Estimating (1) indicates that a \$1 increase in gross royalty income is associated with a \$1.49 increase in total income (Table 4). Properly interpreting the multiplier requires assumptions about differences between gross and net royalty income. Because well operators deduct various costs from royalty payments, royalty owners would receive and report on their taxes less than \$1 in net royalty income for each \$1 in gross royalties. Ignoring deductions gives a conservative estimate of the multiplier effect of net royalty income (but not of gross royalties). For example, if each \$1 in gross royalties leads to \$0.90 in net royalty income, the coefficient of \$1.49 would translate into a multiplier of 1.66 (= 1.49/0.9), meaning that \$0.66 in non-royalty income was created in the local economy. Because we have no data on deductions, which we need to convert gross to net royalties, we report a gross royalty income multiplier, which is a lower-bound estimate of the net royalty multiplier.

The estimated income effect of \$1.49 indicates that each \$1 in gross royalty income received by county residents generates \$0.49 elsewhere in the local economy such that it enters the income of people filing taxes in that county. Breaking total income into its wage and non-wage components shows that each \$1 in gross royalties leads to \$0.38 in additional wage income and \$0.11 in non-wage, non-royalty income, indicating that most of the multiplier effect of comes through greater labor market earnings. This is intuitive: as royalty income is spent in local restaurants and other businesses it increases labor demand and earnings for those working and residing in the county.

Looking at local and absentee royalty income separately shows that both create multiplier effects, with their total, wage, and non-wage multipliers statistically indistinguishable from each other. Both types of royalties increase wage income, and most of the difference in the total income multiplier stems from different non-wage effects, which are more varied than wage income because of erratic business profits and capital gains. In terms of point estimates, the wage income multiplier is largest for absentee royalties, which is the opposite of what would be expected if the local royalty income multiplier estimate were confounded with the wage effects of oil and gas industry activity.

6.3 Robustness

The estimated multipliers are robust to excluding booming shale counties. We re-estimate the model excluding the 280 counties that the U.S. Energy Information Administration has defined as Shale Counties for its publications. Despite dropping many counties with substantial variation in royalty income, the multiplier estimates remain very similar to those from the full sample.

Several studies show that the economic effects of a resource extraction can propagate beyond the county where extraction occurs (Feyrer et al., 2017; James and Smith, 2018). We probe our multiplier estimates in several ways to see if they are affected by accounting for spillovers. In addition to dropping EIA Shale Counties, we further drop the 201 counties contiguous with at least one Shale County. Again, we find a similar royalty-wage multiplier, though a much larger non-wage and therefore total income multiplier (Table 5).

As an alternative approach to accounting for spatial spillovers, we control for the change in royalty income for the average neighboring county as well as the average drilling and mining shock for contiguous counties.[6] There is some evidence that royalties have effects beyond the county in which they were received, but accounting for them reduces the coefficient on the main royalty variable. As a result, the full multiplier effect of royalty income, which include local and spillover effects, is similar to what was estimated when ignoring spillovers (Appendix Table A2).

As a type of falsification test, we check if plausibly-anticipated royalties have a similar multiplier effect. Because consumers respond more to unanticipated income shocks than anticipated shocks (Jappelli and Pistaferri, 2010), using plausibly anticipated variation in royalty income should give smaller estimates. This is the case: OLS gives a smaller wage-multiplier estimate than the estimate based on shocks to national production and prices (Table 6). Some of the smaller effect, however, may reflect measurement error in the observed annual change in royalty income, which would attenuate the multiplier to zero. To better identify the effect of anticipated royalty income shocks, we construct an instrument that captures quantity-driven changes in royalties, which would be easier for royalty owners to

[6] We define neighbors as those counties which share borders as in queen contiguity. The instrument for the growth in neighboring royalties is analogous to the other instruments.

anticipate to the extent that they have a sense of drilling activity, the age of producing wells, and typical decline curves. The instrument is defined as the product of the lagged level of royalties and the percentage change in the quantity of oil and gas produced on leases owned by county residents (see the Appendix for details on the instrument's construction).

The quantity-based estimates show that $1 in additional royalty income increases wage income by $0.09, far less than the effect unanticipated royalties ($0.39). The smaller multiplier effect for anticipated royalties is probably because royalty owners adjusted spending well before the anticipated royalties arrived, thereby reducing the multiplier effect observed for the period when the royalties were received. This is consistent with the findings of Hsieh (2003) who finds that consumers did not adjust consumption in response to highly anticipated payments from the Alaska Permanent Fund but they did respond to harder-to-predict tax refund payments.[7]

6.4 Comparison with Spending Multipliers

Our estimated multipliers are associated with increases in income, not spending, which is how multipliers are typically reported. Assuming a particular marginal propensity to consume, however, permits estimating an implied spending multiplier. Estimates for the marginal propensity to consume tax rebates range from about 0.4 to 0.9 (Johnson et al., 2006; Agarwal et al., 2007; Parker et al., 2013). The marginal propensity to consume out of royalty payments is likely lower because royalty payments are generally larger than tax rebates, and they go to households that are probably wealthier than the average U.S. household. We are aware of only one study that estimates household spending of royalty income. For a sample of 244 households receiving royalty payments in Pennsylvania, Hoy et al. (2017) find that households spent about one-third of royalties in the year that were received.

[7]The quantity-based estimates also show that $1 in additional royalty income increases non-wage income by only about $0.30. This is striking given that the royalty dollar itself should appear in non-wage income and give a coefficient closer to 1, which we observed for the unanticipated royalty shock. The key to understanding this result is that total income is based on what people report to the IRS as their adjusted gross income, which means that it is net of certain deductions and business losses. Expecting more royalties, a household could offset greater income by taking capital losses or shifting future business expenses to the current year. A farm household, for example, could buy a tractor and depreciate all of it in the year purchased, leading to a net loss for the farm, and lower non-wage income overall. Unfortunately, the publicly-available IRS data do not provide breakouts for farm income or income from partnerships or S corporations, which is where such losses likely occur.

If households spend half of each royalty dollar in the year received, our main multiplier estimate indicates a royalty-spending multiplier of about one (=0.49/0.50). If only a quarter of each dollar is spent, the spending multiplier is around 2 (= 0.49/0.25).[8] A spending multiplier in the range of 1 to 2 is consistent with fiscal multipliers estimated using cross-sectional variation, which typically show a multiplier of around 1.8 (Chodorow-Reich, 2017).

6.5 Who Benefited from Royalty Income?

To understand who benefited from royalty income and its multiplier effect, we look at the effect of royalties on the number of returns by income category and the effect on total, wage, and non-wage income, also by income category. We break returns into six income categories, with the lowest income category including returns with less than $25K in total income and the highest income category reporting $200K or more in income. (These are the basic categories provided by the IRS except that it also has a less than $1 group, which we merge into the less than $25K group).

Royalty income had no significant effect on the total number of returns filed but shifted the income distribution upward (Panel A in Table 7). This suggests that net migration as a result of income shocks from royalties was negligible. This result is consistent with Brown (2017) who finds that over 90 percent of consumer debt response to local drilling shocks came from residents who lived in the area prior to the drilling. Our results show that each $100,000 in royalties received by county residents reduced the number of low-income returns by 0.40, and the effect on the number of returns increases over each of the next five income groups before declining slightly for the >$200K group. The estimates for the middle-income groups suggest that they gained people from lower groups but lost others to higher groups,

[8]We expect more spending if recipients responded to what they thought was a long-term income increase. As an extreme example, suppose that royalty income increases by $1 in one period and the higher level of royalties persists indefinitely. At a discount rate of five percent, the flow of higher royalties would have a present value of $20. Subsurface owners who experience a persistent increase in royalty income may therefore be less like a lottery winner and more like the owner of a rental property in a market where the rental rate has increased. To explore the persistence of royalty income growth, we regress the change in royalties on the lagged change, estimating the relationship with OLS and with instrumenting the lagged change in royalties with the lagged royalty shock. The results show that an increase in royalties in one year was associated with another increase in the following year, indicating that higher royalty flows not only persisted but actually grew larger (Appendix Table A3). A caveat to this finding is that oil prices were high during the study period and both oil and natural gas production volumes were increasing. A longer study period could show a very different relationship between current and future royalty growth.

leading to small net changes. The \$100K-\$200K group, on the other hand, experienced the largest increase in returns, indicating that it gained more people from lower groups than it lost to the highest group.

The total income effects by group are consistent with the findings for returns and show a rightward shift in the entire income distribution. Each \$1 in royalties reduced income in the <\$25K group by \$0.14, with little change for the middle categories and a large increase of the highest category.[9] Looking at wage and non-wage income shows that wage income grew for the top three categories but non-wage income only grew for the highest category. This suggests that royalties tended to catapult people to the highest income category whereas wage-effects caused more modest shifts.

7 Resource Ownership and the Income Effect of Oil and Gas Extraction

We combine the multiplier estimate with additional analysis to quantify the role of resource ownership in the local income effects of oil and gas extraction.

7.1 Local Income

7.1.1 The Total Local Income Effect

We quantify how the difference in average income between oil and gas growth and non-growth counties evolved year by year by estimating:

$$Y_{it} = \gamma_i + \theta_{st} + \sum \beta_t (O\&G\ Growth_i \times Year_t) + \varepsilon_{it}, \quad (6)$$

[9]The decline in returns and income in the lowest income category is in part explained by low-income wage earners benefiting from greater labor demand spurred by royalty spending. It is also likely that some low-income filers received royalty income directly. Rural, landowning households can be asset rich but income poor. For a sample of royalty owners in Pennsylvania, Hoy et al. (2017) find that 41 percent had household incomes below \$50,000. Similarly, the USDA Economic Research Service reports that in 2010 median income for farm households was less than \$50,000. In addition, households reporting farm income to the IRS generally show a loss. In 2010 in particular, aggregate net income from schedule F, where farm income is reported, showed a loss of \$11 billion.

where γ_i is a county fixed effect and θ_{st} is a state-by-year fixed effect. The binary variable *O&G Growth* equals one if the combined quantity of oil and gas production in the county increased from 2000 to 2014 according to data reported by Drillinginfo. Figure 1b shows the location of 455 counties that experienced growth in oil and gas production from 2000 to 2014.

The technological breakthroughs that led to the national growth in production only emerged after 2000, with widespread application only occurring after 2005. If non-growth counties provide a credible counterfactual scenario, the two groups of counties should exhibit similar per capita income trends before 2000. To assess prior trends, we estimate (6) for the 1990–2014 period. The magnitude and statistical significance of the interaction between *O&G Growth* and the dummy variables for 1991–1999 will reveal differences in trends prior to the shale boom.

Figure 2 depicts the $\hat{\beta}_t$ coefficients from (6) across three dependent variables: total income, wage income, non-wage income. Oil and gas growth and non-growth counties experienced similar income trends during the 1990s and early 2000s for all three measures. Economically large income differences only emerged after 2005, corresponding to widespread shale development. By 2014, residents of growth counties had per capita incomes $1,792 higher than those in non-growth counties, a 9 percent increase over the average county income in 2000.

Breaking total income into its components reveals that more than two-thirds of the total income effect came from growth in non-wage income. The income effects increase substantially if we drop counties with production growth less than $25 million, and more so if we drop counties with growth of less than $250 million. In both cases, increases in non-wage income account for more than two-thirds of the total income effect. (See Appendix Tables A4–A6 for coefficients and standard errors).

Looking at changes in wage and non-wage income, however, cannot reveal the role of royalties in the total income effect. Non-wage income includes income other than royalties and, perhaps more importantly, some of the increase in wage income may stem from the spending of royalty income. Estimating the role of royalties requires knowing the growth in royalty income and its multiplier effect.

7.1.2 The Role of Royalties

Our leasing and production data indicate that the change in per capita royalty income between growth and non-growth counties over the same period was \$845. Our royalty income multiplier of 1.49 suggests that royalties accounted for \$1,259 in additional income, or 70 percent of the total income effect.

We observe a range of local ownership shares across counties, with an average local ownership share of 24 percent. Our estimates indicate that the income effect of oil and gas development in a county with an average degree of local ownership is 2.4 times higher than in a county with complete absentee ownership, such as counties where the federal government owns the subsurface ($= (1,792/(1,792 - 1,259)) - 1$).

The role of ownership is more pronounced when considering a county with complete local ownership. At the sample production-weighted mean royalty rate of 19 percent, counties with complete local ownership receive \$0.19 for each \$1 of oil and gas production. Our estimate that each \$1 in gross royalties generates \$1.49 in total income implies \$0.28 ($= 0.19 \times 1 \times 1.49$) in income for each \$1 in local production through royalties alone. A county with complete absentee ownership would have none of this royalty-related income effect.

The finding suggests that one can hardly understand the full economic effect of resource extraction without identifying to whom and to where resource rents accrue. Understanding the flow of rents and their effects may go a long way in explaining why natural resources have created enduring economic benefits in some areas and not others, with the diversity of experiences observed across countries (Van der Ploeg, 2011) and across regions within the same country. For example, Michaels (2011) finds that oil fields in the south-central U.S. led to higher per capita income over the 20th century, but Jacobsen and Parker (2016) find a negative long-term effect of the 1970s oil boom on counties in the western U.S. A cursory look at our data suggests that the two study regions, as a whole, have similar production-weighted local ownership shares in the present (33 percent for the Jacobsen and Parker sample and 26 percent for Michaels' sample). However, this may not have been true in the 1970s or for the counties most responsible for conventional oil and gas production in their respective samples.

7.2 National Income

Ownership income can also have important aggregate effects and illustrates one economic consequence of producing oil from North Dakota instead of importing it from Nigeria. Estimates of local income multipliers can be used to infer ranges of national income multipliers and the resulting aggregate implications of income shocks. Chodorow-Reich (2017) argue that cross-sectional fiscal spending multipliers can provide a lower-bound on the national multiplier, particularly when government spending is financed through borrowing. Royalty income shocks are similar to debt-financed spending in that neither is associated with a corresponding increase in the tax burden in the present. We therefore use our local royalty income multiplier to gauge the national income effect of royalty income.

Royalties have a non-negligible effect on the aggregate U.S. economy. Our data indicate that \$44.7 billion in gross private royalties were paid in 2014. To put the number in perspective, royalties are nearly one-fifth of spending from the American Recovery and Reinvestment Act in its peak year.[10] Applying our multiplier to total royalties gives a total stimulus effect of \$66.6 billion ($=44.7 \times 1.49$). The stimulus represents 0.5 percent of aggregate personal income in the U.S. in 2014 as reported by the Bureau of Economic Analysis. A similar effect would have plausibly occurred if all oil and gas resources were publicly owned, in which case the government would spend royalties directly or transfer it to citizens for them to spend it. The same is not true if all royalties accrued abroad and were spent on goods and services produced elsewhere.

Our estimates indicate that energy production and price shocks can have important economic effects through royalties alone, a channel that is almost always ignored when discussing the relationship between energy prices and the U.S. economy. From 2014 to 2015, oil prices declined by about 50 percent, and natural gas prices declined by almost as much. Assuming that a 50 percent decrease in prices would reduce royalty income in the short term by 50 percent, the energy price drop would have reduced growth in aggregate personal income by 0.25 percentage points through royalties alone.

[10] According to the Congressional Budget Office, the American Recovery and Reinvestment Act, enacted in response to the Great Recession, increased Federal government outlays by \$235 billion in 2010, its highest year of spending. For more information on the ARRA, see www.cbo.gov/sites/default/files/114th-congress-2015-2016/reports/49958-ARRA.pdf.

7.3 Resource Ownership Regimes and Implications

Our findings show how the dispersion of ownership shapes the geographic distribution of the income effects of extraction. They do not imply that private ownership of the subsurface makes extraction more desirable or efficient. Harleman and Weber (2017) describe four broad ownership regimes that vary based on public versus private ownership and local versus absentee ownership. Private resource ownership does not guarantee large local income gains. Private-absentee ownership, for example, would generate fewer local benefits than public-local ownership. Even in public-absentee regimes, central governments can redistribute ownership revenues to localities where extraction occurs as the U.K. government has proposed to do with tax revenues generated through shale gas development (Harleman and Weber, 2017).

Revenue-sharing arrangements like the one proposed by the U.K. government are within-country transfers and do not affect the national net benefit of resource extraction. Nor would local versus absentee ownership affect it, assuming all owners live within the country. They would, however, affect net benefits to a particular state or county, which is where bans to hydraulic fracturing have occurred in the U.S. Considerable research has explored the disamenities or risks associated with oil and gas development, especially the recent wave of hydraulic fracturing. Multiple studies have estimated public costs for Pennsylvania residents in particular given the states rapid rise to being the second largest natural gas producer in the U.S. Litovitz et al. (2013) estimate that air quality damages in the state may be as much as $32 million. Wrenn et al. (2016) found that the rise in fracking increased annual bottled water expenditures in the state by almost $20 million. The finding helps explain why Muehlenbachs et al. (2015) find that wells within 1.5 kilometers of a home reduces the value of groundwater-dependent homes by about $30,000 for the average groundwater-dependent home near wells, though other studies suggest that the effects may be temporary or even positive for the average home (Gopalakrishnan and Klaiber, 2014; Boslett et al., 2016).

By comparison, our estimates indicate that natural gas wells generated $3.7 billion in 2014 for Pennsylvania residents living in the same county as the well ($2.5 in direct effects and $1.2 billion in multiplier effects). A cost-benefit analysis of a state ban on hydraulic fracturing would have to consider most of the income as a cost of the policy (and even more income since royalty payments to in-state residents are even larger). The cost would be considerably less if Pennsylvania had the same local ownership share as the Permian Basin in West Texas, in which case the wells would have only generated about $0.8 billion for local residents (according to the ownership shares in Brown et al. (2016)).

8 Conclusion

Our findings demonstrate that it matters whether resources are locally or absentee owned. The receipt and spending of royalty income accounted for 70 percent of the total income effect for the average county with oil and gas production growth between 2010 and 2014. We estimate that a county with complete local ownership captures $0.28 more per dollar of production than a county with complete absentee ownership. The dispersion in local ownership shares across U.S. counties may provide a reason for why the short- and long-term effects of natural resource booms vary by region.

Royalties also matter to the national economy, accounting for an estimated 0.5 percent of aggregate personal income in 2014. Combined, the findings indicate that the overwhelming emphasis on labor markets in prior research may overstate the channel's relative economic importance. Moreover, an important part of the increase in labor earnings stems from the spending of royalty income as opposed to greater labor demand from extraction and related industries.

The growth in royalties from the oil and gas boom provides an opportunity to study other questions related to the short and long-term effects of changes resource extraction and wealth. In various regions, the boom caused oil and gas rights that were once worth a few dollars an acre to increase to tens of thousands of dollars, thus bringing a massive change in wealth to owners. How do such large shocks to wealth affect consumption and investment over the long term and across generations? Is privately-owned wealth from exhaustible resources transfered to future generations through investments in education or bequests or is it largely used by the current generation for consumption? The data used in our analysis could aid in exploring these and other related questions.

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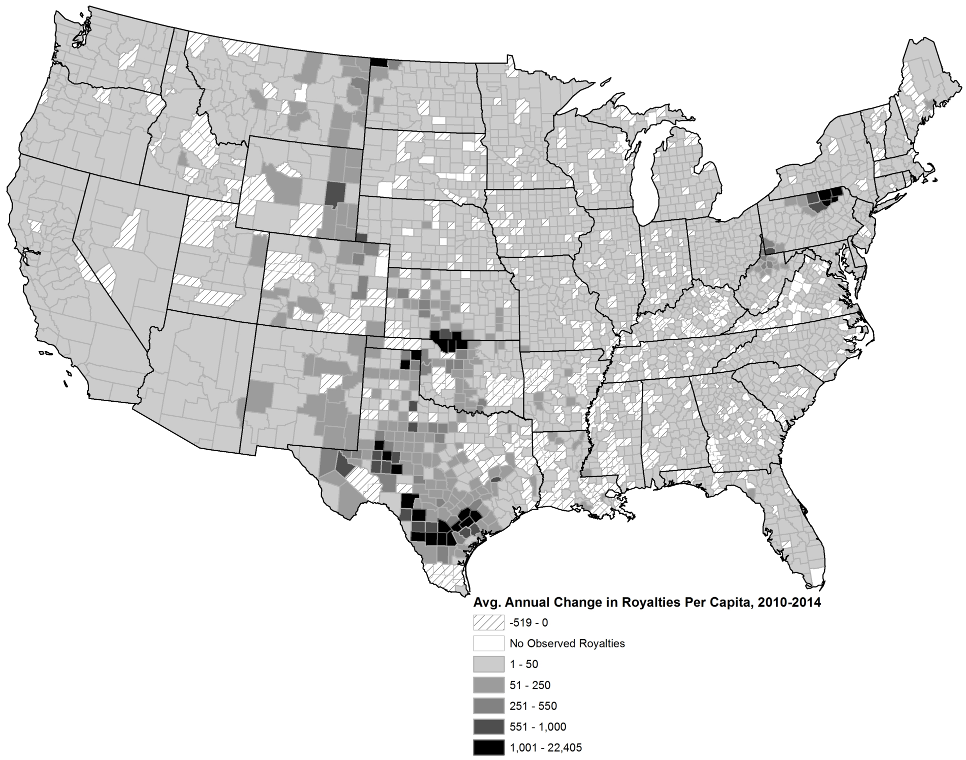
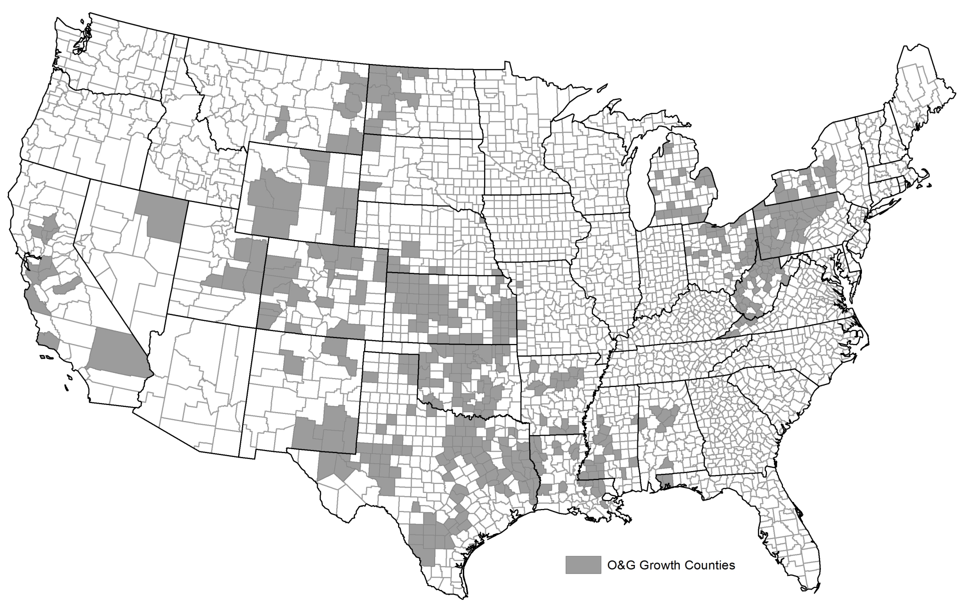


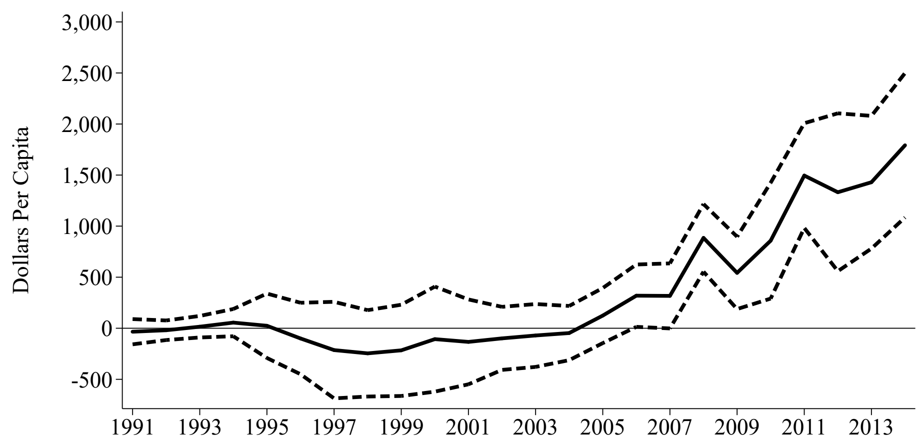
(a) Average Annual Change in Royalties ($ Per Capita), 2010 to 2014



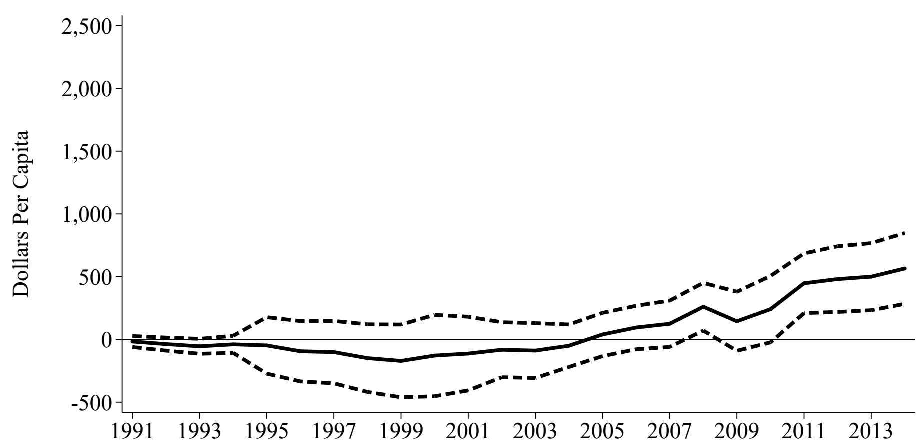
(b) Oil & Gas Growth Counties

Source: Drillinginfo, various State and Federal agencies, Authors' calculations. Oil and Gas Growth Counties are counties where oil and gas production (in British Thermal Units) increased from 2000 to 2014.

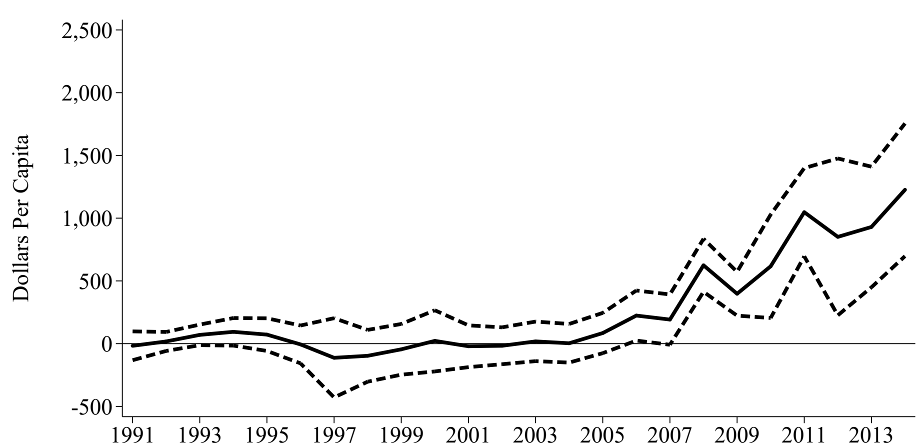
Figure 1: Average Annual Royalties and O&G Growth Counties



(a) Total Adjusted Gross Income



(b) Wage Income



(c) Non-Wage Income

Note: The solid line depicts the $\hat{\beta}_t$ coefficients estimated in (6) using data from 1990–2014. The dashed lines represent 95 percent confidence intervals.

Figure 2: Difference in Per Capita Income of O&G Growth vs. Non-O&G Growth Counties

Table 1: Sample Descriptive Statistics, 2010–2014

	Mean	SD	P50	P75	P90	P95
Δ Royalties	36	305	1	7	50	159
Δ Local Royalties	18	248	0	0	0	31
Δ Absentee Royalties	17	134	1	6	33	93
Δ Mining Wages	20	1,799	0	0	45	209
Δ Wells Drilled (per 1,000 people)	-0	13	0	0	0	0
Δ Total Income	315	2,579	180	683	1,627	2,521
Δ Wage Income	59	600	33	224	453	686
Δ Non-Wage Income	257	2,426	149	585	1,354	2,169
N	11920					

Note: All variables are normalized by the lag of county population. Wells drilled is per 1,000 persons; the other variables are per capita. The statistics are based on annual changes over the 2010 to 2014 period. All monetary values are in 2010 dollars.

Table 2: Changes in Royalty Income ($ Per Capita) Predicted by National Price and Production Shocks

	All Royalties	Local Royalties	Absentee Royalties
Royalty Shock	0.60***		
	(0.12)		
Local Royalty Shock		0.60***	-0.13***
		(0.16)	(0.04)
Absentee Royalty Shock		0.13	0.82***
		(0.16)	(0.17)
Mining Earnings Shock	-0.00	-0.00	0.00
	(0.01)	(0.00)	(0.00)
Drilling Shock	-1.97**	-1.77	-0.40
	(0.69)	(1.06)	(1.06)
R-squared	0.26	0.19	0.36
N	11,920	11,920	11,920

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered by county are in parentheses. All regressions include state by year fixed effects and are based on the years 2010 to 2014. *Drilling Shock* is in wells per 1,000 people. All other variables are in dollars per capita.The F-statistic on the royalty shock in column 1 is 24. It is 13 for local royalties in column 2 and 24 for absentee royalties in column 3.

Table 3: Are Royalty Shocks Correlated with Growth in Drilling and Mining Earnings?

	Δ Wells Drilled		Δ Mining Earnings	
Royalty Shock	-0.00		-0.00	
	(0.00)		(0.07)	
Local Royalty Shock		-0.00		-0.08
		(0.00)		(0.10)
Absentee Royalty Shock		-0.00		0.19
		(0.00)		(0.15)
Mining Earnings Shock	-0.00	-0.00	1.38***	1.38***
	(0.00)	(0.00)	(0.24)	(0.24)
Drilling Shock	1.84***	1.84***	-1.79	-1.91
	(0.13)	(0.12)	(3.24)	(3.38)
R-squared	0.19	0.19	0.18	0.18
N	11,920	11,920	11,920	11,920

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered by county are in parentheses. All regressions include state by year fixed effects and are based on the years 2010 to 2014. *Wells Drilled* and *Drilling Shock* are in wells per 1,000 people. All other variables are in dollars per capita.

Table 4: Instrumental Variable Estimates: Royalties and Total, Wage, and Non-Wage Income ($ Per Capita)

	All Royalties			Local and Absentee Royalties		
	Total	Wage	Non-Wage	Total	Wage	Non-Wage
Δ Royalties	1.49***	0.38***	1.11***			
	(0.34)	(0.10)	(0.30)			
Δ Local Royalties				1.31***	0.37**	0.94**
				(0.35)	(0.12)	(0.29)
Δ Absentee Royalties				2.09*	0.43*	1.66*
				(0.88)	(0.20)	(0.79)
Mining Earnings Shock	0.02	0.03	-0.01	0.02	0.03	-0.01
	(0.09)	(0.02)	(0.09)	(0.09)	(0.02)	(0.09)
Drilling Shock	11.23	6.22***	5.01	10.88	6.20***	4.69
	(8.24)	(0.98)	(8.39)	(8.42)	(0.97)	(8.54)
N	11920	11920	11920	11920	11920	11920

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered by county are in parentheses. All regressions include state by year fixed effects and are based on the years 2010 to 2014. *Drilling Shock* is in wells per 1,000 people. All other variables are in dollars per capita.

Table 5: Instrumental Variable Estimates of the Royalty Multiplier, Excluding Shale Counties and Neighbors

	Excluding EIA Shale Counties			Excluding Shale Counties and Neighbors		
	Total	Wage	Non-Wage	Total	Wage	Non-Wage
Δ Royalties	1.59**	0.51**	1.08*	2.26***	0.50**	1.76**
	(0.49)	(0.16)	(0.43)	(0.65)	(0.18)	(0.59)
Mining Earnings Shock	0.11	0.02*	0.09	0.11	0.02*	0.09
	(0.10)	(0.01)	(0.10)	(0.10)	(0.01)	(0.10)
Drilling Shock	90.06	0.92	89.14	117.83	22.01	95.82
	(100.20)	(25.76)	(81.04)	(168.14)	(42.58)	(139.95)
N	10800	10800	10800	9996	9996	9996

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered by county are in parentheses. *Drilling Shock* is in wells per 1,000 people. All other variables are in dollars per capita. For the first three columns, the 280 EIA Shale counties as defined by the Energy Information Administration are dropped. For columns 4-6, we drop Shale counties and any county contiguous to a Shale county, which drops another 201 counties from the full sample. For the two samples, the first-stage F-statistics on the excluded instrument (Royalty Shock) are 32 and 25.

Table 6: Instrumental Variable Estimates of Royalty Income Multiplier: Plausibly-Anticipated Royalties

	OLS			IV Quantity-Based Change		
	Total	Wage	Non-Wage	Total	Wage	Non-Wage
Δ Royalties	0.37	0.11***	0.27	0.39	0.09***	0.30
	(0.29)	(0.03)	(0.29)	(0.31)	(0.03)	(0.30)
Mining Earnings Shock	0.03	0.03	-0.00	0.03	0.04	-0.01
	(0.09)	(0.02)	(0.09)	(0.09)	(0.02)	(0.09)
Drilling Shock	11.18	6.21***	4.97	11.18	6.21***	4.97
	(10.39)	(0.98)	(10.05)	(10.27)	(0.98)	(9.90)
N	11920	11920	11920	11920	11920	11920

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered by county are in parentheses. All regressions include state by year fixed effects and are based on the years 2010 to 2014. *Drilling Shock* is in wells per 1,000 people. All other variables are in dollars per capita. The instrument for anticipated royalties is based on the change in royalties caused by changes in the quantity of production on acreage owned by county residents. The F-stat on the excluded instrument is over 1,000.

Table 7: Royalty Income Effects by Income Group

(a) Number of Returns

	All	<25K	25K-50K	50K-75K	75K-100K	100K-200K	>200K
Δ Roy. ($100K)	0.06	-0.40**	-0.03	0.01	0.07	0.22***	0.19***
	(0.24)	(0.14)	(0.08)	(0.04)	(0.04)	(0.04)	(0.04)

(b) Total Income

	All	<25K	25K-50K	50K-75K	75K-100K	100K-200K	>200K
Δ Royalties	1.49***	-0.14***	0.02	0.00	0.01	0.14	1.46***
	(0.34)	(0.04)	(0.03)	(0.03)	(0.05)	(0.13)	(0.32)

(c) Wage Income

	All	<25K	25K-50K	50K-75K	75K-100K	100K-200K	>200K
Δ Royalties	0.38***	-0.05***	0.00	0.01	0.07**	0.24***	0.10*
	(0.10)	(0.02)	(0.02)	(0.02)	(0.03)	(0.04)	(0.04)

(d) Non-Wage Income

	All	<25K	25K-50K	50K-75K	75K-100K	100K-200K	>200K
Δ Royalties	1.11***	-0.09**	0.01	-0.01	-0.06	-0.10	1.36***
	(0.30)	(0.03)	(0.01)	(0.01)	(0.04)	(0.13)	(0.29)

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered by county are in parentheses. All regressions are based on the years 2010 to 2014 and include state by year fixed effects and control variables related to drilling and mining earnings.

For Online Publication: Empirical Appendix

Table A1: Royalty Income (2010) and Past Income Levels and Growth (1990-2005)

	Mean Total Income, 1990-2005		Δ Total Income, 1990-2005	
Royalties, 2010	0.01		0.10	
	(0.08)		(0.09)	
Local Royalties, 2010		-0.21		0.19
		(0.12)		(0.14)
Absentee Royalties, 2010		0.52		-0.12
		(0.34)		(0.24)
R-squared	0.26	0.26	0.13	0.13
N	2,980	2,980	2,980	2,980

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered by county are in parentheses. All regressions include state fixed effects.

Table A2: Instrumental Variable Estimates: Royalties, Income, and Spatial Spillovers

	Total	Wage	Non-Wage
Δ Royalties	1.25**	0.25*	1.00*
	(0.45)	(0.11)	(0.40)
Mining Earnings Shock	0.01	0.02*	-0.02
	(0.09)	(0.01)	(0.09)
Drilling Shock	9.21	4.89***	4.31
	(7.83)	(1.26)	(8.50)
Neighbor Royalties	0.45	0.23*	0.22
	(0.32)	(0.09)	(0.27)
Neighbor Mine. Earnings Shock	0.28	0.13**	0.15
	(0.18)	(0.04)	(0.16)
Neighbor Drilling Shock	2.72	11.72	-9.00
	(30.50)	(6.01)	(26.99)
N	11920	11920	11920

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered by county are in parentheses. All regressions include state by year fixed effects. *Drilling Shock* is in wells per 1,000 people. All other variables are in dollars per capita. The F-statistic is 15.2 for the excluded instrument for own royalties and 35.0 for neighboring royalties.

Derivation of the Instrument for Quantity-Driven Royalty Growth

We define the quantity-driven change in royalties as the product of the lagged level of royalties received by county residents multiplied by the percentage change in oil and gas production under leases held by county residents:

$$\Delta Royalties\_Q_{it} = Royalties_{it-1} \times \%\Delta Q_{it}, \tag{A1}$$

The production growth rate ($\%\Delta Q_{it}$) can be estimated by recognizing that the percentage change in royalties is the product of one plus the percentage change in production and one plus the percentage change in price.

$$\%\Delta Q_{it} = \frac{\%\Delta Royalties_{it} + 1}{\%\Delta P_t + 1} - 1. \tag{A2}$$

We observe the percentage change in royalty income, which is the numerator. For the denominator, the percentage change in energy prices, we use changes in national prices as done for the royalty shock instrument described in the text.

Table A3: Persistence in Royalty Income Growth

	OLS Δ Royalties	IV Δ Royalties
Δ Royalties, t-1	0.55***	0.26*
	(0.06)	(0.12)
Mining Earnings Shock	0.05	0.03
	(0.03)	(0.02)
Drilling Shock	-0.02	-3.28
	(1.52)	(2.23)
R-squared	0.36	0.20
N	8,940	8,940

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered by county are in parentheses. All regressions include state by year fixed effects and are based on the years 2010 to 2014. *Drilling Shock* is in wells per 1,000 people. All other variables are in dollars per capita. The IV-based estimate is based on the instrument for unanticipated royalties.

Average Effects of Oil and Gas Growth

Table A4: Average O&G Growth Income Effect, Total Income

	(1) Full Sample		(2) Subsample 1		(3) Subsample 2	
OG_Growth_x_1991	-34	(63)	-5	(53)	-50	(72)
OG_Growth_x_1992	-19	(49)	-94	(59)	-136	(76)
OG_Growth_x_1993	15	(54)	-110	(68)	-146	(88)
OG_Growth_x_1994	55	(68)	-92	(79)	-155	(102)
OG_Growth_x_1995	24	(161)	-99	(168)	-147	(224)
OG_Growth_x_1996	-100	(178)	-268	(189)	-272	(241)
OG_Growth_x_1997	-214	(241)	-393	(291)	-357	(383)
OG_Growth_x_1998	-246	(216)	-439	(238)	-442	(305)
OG_Growth_x_1999	-216	(228)	-535*	(240)	-652*	(311)
OG_Growth_x_2000	-106	(262)	-360	(280)	-327	(390)
OG_Growth_x_2001	-133	(212)	-231	(231)	-82	(312)
OG_Growth_x_2002	-99	(157)	-179	(188)	-143	(256)
OG_Growth_x_2003	-70	(157)	-122	(189)	53	(254)
OG_Growth_x_2004	-47	(135)	-87	(167)	185	(243)
OG_Growth_x_2005	124	(138)	171	(172)	585*	(244)
OG_Growth_x_2006	319*	(156)	526*	(211)	1241***	(315)
OG_Growth_x_2007	317	(163)	574**	(215)	1354***	(313)
OG_Growth_x_2008	885***	(169)	1436***	(245)	2738***	(374)
OG_Growth_x_2009	543**	(181)	808***	(198)	1516***	(257)
OG_Growth_x_2010	858**	(289)	1464***	(383)	2717***	(479)
OG_Growth_x_2011	1495***	(262)	2440***	(382)	4493***	(580)
OG_Growth_x_2012	1332***	(394)	2463***	(575)	4709***	(849)
OG_Growth_x_2013	1430***	(332)	2516***	(494)	4894***	(756)
OG_Growth_x_2014	1792***	(361)	3119***	(539)	5892***	(850)
R-squared	0.44		0.44		0.44	
N	74,500		69,325		66,275	

Note: The number of Oil and Gas Growth counties in the Full Sample, Subsample 1 and Subsample 2 are 455, 248, and 126. Growth counties are defined as having an increase in the combined quantity of oil and gas production from 2000 to 2014. Subsample 1 excludes Growth counties where the increase in oil and gas production was less than $25 million (with production valued at a constant price of $50 per barrel of oil equivalent). Subsample 2 excludes Growth counties where the increase was less than $250 million.

Table A5: Average O&G Growth Income Effect, Wage Income

	(1) Full Sample		(2) Subsample 1		(3) Subsample 2	
OG_Growth_x_1991	-17	(22)	-14	(29)	-39	(39)
OG_Growth_x_1992	-37	(27)	-87*	(36)	-136**	(48)
OG_Growth_x_1993	-55	(30)	-128**	(40)	-166**	(54)
OG_Growth_x_1994	-39	(35)	-111*	(47)	-162**	(62)
OG_Growth_x_1995	-48	(115)	-128	(115)	-162	(147)
OG_Growth_x_1996	-94	(123)	-192	(125)	-206	(157)
OG_Growth_x_1997	-101	(127)	-182	(136)	-163	(177)
OG_Growth_x_1998	-149	(138)	-261	(142)	-273	(185)
OG_Growth_x_1999	-171	(148)	-319*	(153)	-342	(200)
OG_Growth_x_2000	-129	(165)	-284	(170)	-263	(226)
OG_Growth_x_2001	-113	(150)	-168	(159)	-58	(211)
OG_Growth_x_2002	-82	(112)	-130	(131)	-78	(180)
OG_Growth_x_2003	-89	(111)	-106	(134)	18	(180)
OG_Growth_x_2004	-50	(86)	-101	(104)	114	(151)
OG_Growth_x_2005	40	(88)	36	(106)	300*	(148)
OG_Growth_x_2006	95	(88)	157	(110)	495**	(154)
OG_Growth_x_2007	125	(94)	244*	(118)	675***	(169)
OG_Growth_x_2008	261**	(97)	473***	(129)	1004***	(189)
OG_Growth_x_2009	145	(120)	264*	(130)	626***	(169)
OG_Growth_x_2010	241	(135)	459**	(149)	974***	(199)
OG_Growth_x_2011	448***	(121)	783***	(160)	1508***	(233)
OG_Growth_x_2012	481***	(134)	857***	(178)	1640***	(261)
OG_Growth_x_2013	500***	(136)	889***	(185)	1711***	(273)
OG_Growth_x_2014	566***	(144)	992***	(197)	1875***	(292)
R-squared	0.44		0.44		0.43	
N	74,500		69,325		66,275	

Note: The number of Oil and Gas Growth counties in the Full Sample, Subsample 1 and Subsample 2 are 455, 248, and 126. Growth counties are defined as having an increase in the combined quantity of oil and gas production from 2000 to 2014. Subsample 1 excludes Growth counties where the increase in oil and gas production was less than $25 million (with production valued at a constant price of $50 per barrel of oil equivalent). Subsample 2 excludes Growth counties where the increase was less than $250 million.

Table A6: Average O&G Growth Income Effect, Non-Wage Income

	(1) Full Sample		(2) Subsample 1		(3) Subsample 2	
OG_Growth_x_1991	-17	(59)	9	(41)	-11	(55)
OG_Growth_x_1992	18	(39)	-7	(41)	0	(52)
OG_Growth_x_1993	70	(42)	18	(49)	19	(62)
OG_Growth_x_1994	94	(56)	19	(59)	7	(78)
OG_Growth_x_1995	72	(66)	29	(81)	15	(116)
OG_Growth_x_1996	-6	(77)	-76	(92)	-66	(123)
OG_Growth_x_1997	-113	(161)	-211	(214)	-194	(278)
OG_Growth_x_1998	-97	(105)	-178	(132)	-169	(166)
OG_Growth_x_1999	-45	(103)	-215	(118)	-309*	(148)
OG_Growth_x_2000	22	(124)	-76	(143)	-64	(212)
OG_Growth_x_2001	-21	(85)	-63	(104)	-24	(142)
OG_Growth_x_2002	-17	(75)	-49	(94)	-64	(127)
OG_Growth_x_2003	18	(80)	-16	(100)	35	(138)
OG_Growth_x_2004	3	(79)	14	(100)	71	(138)
OG_Growth_x_2005	85	(82)	135	(107)	284	(147)
OG_Growth_x_2006	224*	(102)	369**	(142)	746***	(213)
OG_Growth_x_2007	192	(102)	329*	(138)	680***	(198)
OG_Growth_x_2008	625***	(108)	964***	(162)	1735***	(257)
OG_Growth_x_2009	398***	(89)	544***	(107)	890***	(149)
OG_Growth_x_2010	617**	(210)	1005**	(310)	1743***	(370)
OG_Growth_x_2011	1048***	(179)	1658***	(271)	2985***	(423)
OG_Growth_x_2012	851**	(319)	1607***	(472)	3069***	(691)
OG_Growth_x_2013	930***	(245)	1627***	(378)	3183***	(593)
OG_Growth_x_2014	1226***	(270)	2127***	(416)	4016***	(687)
R-squared	0.33		0.33		0.34	
N	74,500		69,325		66,275	

Note: The number of Oil and Gas Growth counties in the Full Sample, Subsample 1 and Subsample 2 are 455, 248, and 126. Growth counties are defined as having an increase in the combined quantity of oil and gas production from 2000 to 2014. Subsample 1 excludes Growth counties where the increase in oil and gas production was less than $25 million (with production valued at a constant price of $50 per barrel of oil equivalent). Subsample 2 excludes Growth counties where the increase was less than $250 million.

Data Appendix

Basic Construction

Private data provider DrillingInfo supplied data on oil and gas leases across 17 U.S. states.[11] The states are Arkansas, California, Colorado, Kansas, Louisiana, Michigan, Mississippi, Montana, New Mexico, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, Utah, West Virginia, and Wyoming. Of the other producing states, Alaska is the only major producer excluded. Although some producing minerals in Alaska are privately-owned, a majority are controlled by the state and federal government. Producing states omitted for lack of leasing data include Illinois, Indiana, and Kentucky. We exclude all offshore production. For counties with no private leasing data, we assign a state-average royalty rate and assume that all royalties are paid locally.

Mineral leases are effectively option contracts, and in some cases the option expires before production can begin. Cases in which we identified repeated leases of the same parcel led us to drop previous leases and focus on the most recent effective lease. We also excluded secondary transactions between oil and gas operators recorded as leases rather than assignments. These transactions were identified by text matching.

Another concern about leasing data is that multiple leases may be required to lease acreage with fractionated mineral ownership. Because we acre-weighted our observed leases, we used legal descriptions to select only one lease if several different owners signed leases to the same mineral property that were effective simultaneously.

Publicly-Owned Minerals

In many states oil and gas production occurs on minerals owned by either the state or federal government. The share of overall production obtained from these publicly-owned minerals varies substantially from state to state. In order to accurately account for production and royalties from privately-owned minerals, we must first account for the publicly-owned share. To that end, we obtain information on oil and gas production and royalty revenues from both federal and state-owned minerals for key states.

Federal production is tracked by the Office of Natural Resource Revenue (ONRR), and aggregated to the county-year level by the U.S. Extractive Industries Transparency Initiative.[12]

For state-owned minerals, we collected information from each individual state that owns acreage leased for oil and gas development. Each state keeps records of production volumes and lease royalty revenues. We solicited royalty information for state-owned mineral production in thirteen states; four of our states with leasing data do not have state-owned mineral leasing programs: Kansas, Ohio, Pennsylvania, and West Virginia. These states are not members of the Western State Lands Commissioners Association, which is a clearinghouse for information about management of state land assets. We were able to obtain some information on state-owned mineral production for California, Colorado, Louisiana, Michigan,

[11] `http://drillinginfo.com`

[12] Available at: `https://useiti.doi.gov/downloads/federal-production/`, with data construction notes at: `https://github.com/18F/doi-extractives-data/wiki/Data-Catalog#federal-production`.

Montana, New Mexico, North Dakota, Oklahoma, Texas, Utah, and Wyoming. The data that we were able to collect were a mix of physical production and revenue aggregates. The following sections detail the data procedures we used for each state.

California

Approximately 95% of oil and gas production in the State of California falls under the jurisdiction of the California State Lands Commission (CSLC). A portion of production and royalty revenues arise from State School Lands. These numbers are reported by the CSLC in annual state reports. Revenues obtained from the State School Lands are directed to the California State Teachers Retirement Fund.[13] Revenues from the remaining mineral resources under the jurisdiction of the CSLC contribute to the state's General Fund; production and royalty revenue numbers for these resources, separated between offshore and onshore production, are provided by the CSLC Senior Mineral Resources Engineer. The onshore portion of General Fund minerals is combined with School Lands resources to obtain an aggregate measure of production from state-owned minerals in California.

Colorado

Colorado data was obtained from the State Land Board Department of Natural Resources for years 2011–2015.[14] Prior to that time period, older databases are not accessible and the information cannot be aggregated. The department's Mineral Auditor provided the state royalty share of production. The royalty share was then multiplied by the average royalty rate to back out the total production of oil and gas from state minerals.

Louisiana

The Louisiana Department of Natural Resources makes State oil and gas production data available on their website.[15] Annual state share of production is obtained for every year back to 1967 for both oil and gas. Multiplication of the state share of production by the average royalty rate yields an estimate of total production from state minerals. Mineral royalty totals are also made available by the state DNR as far back as 1960 and require no manipulation.[16]

Michigan

Precise production volumes and royalty revenues for Michigan's state-owned oil and gas production could not be obtained and must be estimated. The Revenue Verification Unit Supervisor for the State Department of Natural Resources supplied the state royalty share of production through 2013. We divided the state royalty share of production by the average royalty rate of one-sixth to obtain estimates of production volumes from state-owned minerals. Royalty revenue estimates were obtained by multiplying the state shares of oil and gas production by their respective annual average prices.

[13] http://www.statetrustlands.org/state-by-state/california.html
[14] http://trustlands.state.co.us/Pages/SLB.aspx
[15] http://dnr.louisiana.gov/index.cfm?md=navigation&tmp=iframe&pnid=0&nid=336
[16] http://dnr.louisiana.gov/index.cfm?md=pagebuilder&tmp=home&pid=212&pnid=122&nid=127

Montana

The Department of Natural Resources and Conservation Trust Land Management Division for the State of Montana makes available Fiscal Year Annual Reports prepared by the Minerals Management Bureau. The Annual Reports note production and revenue information for all leases managed by the Bureau. This includes information on oil and natural gas production and royalty revenues obtained from State lands.[17] We utilize oil and gas production volumes in addition to royalty revenues from State-owned minerals in Montana.

New Mexico

Production and royalty revenues from state-owned minerals in New Mexico are overseen by the State Lands Office. The department publishes annual reports that include data on oil and gas production and royalty revenue for the year. The three most recent years' reports are made available on the department's website.[18] We obtain production data for the remaining years of interest from the Oil and Gas Unit Manager and royalty revenue information from the Royalty Management Division's CPA.

North Dakota

The North Dakota Department of Trust Lands oversees oil and gas production on state-owned minerals.[19] Production volume data for 2007–2014 was provided by the department's Land and Minerals Professional. The Department's Revenue Compliance Director supplied royalty revenue information for years 2010–2014.

Oklahoma

State-owned lands in Oklahoma are overseen by the Commissioner of the Land Office.[20] We obtained information about aggregate annual production of oil and natural gas from the Director of the Minerals Management Division. We also received information about the the value of royalties received.

Texas

Oil and gas production from state-owned minerals in Texas is managed by two entities: the Permanent University Fund (PUF) lands and the General Land Office (GLO). PUF lands production data is provided by the University of Texas System University Lands' Associate Landman.[21] We obtained GLO production data from the Energy Resources Mineral Leasing Contact at the General Lands Office.[22] We aggregated PUF and GLO data and constructed aggregate measures of oil and gas production and royalty revenues from state-owned minerals.

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[17] Montana Department of Natural Resources and Conservation Minerals Management Bureau Annual Reports, 2004–2014.

[18] `http://www.nmstatelands.org/Reports.aspx`

[19] `https://land.nd.gov/`

[20] `https://clo.ok.gov/`

[21] `http://www.utlands.utsystem.edu/`

[22] `http://www.glo.texas.gov/`

Condensate, oil, and gas production volumes were obtained for years 1990–2014 while royalty revenues from oil and gas are limited to 2000–2014.

Utah

The State of Utah School and Institutional Trust Lands Administrations tracks oil and gas royalty revenues from state-owned minerals but does not track production volumes. County-level production for oil and gas from state lands were obtained from the Administrative Services & Policy Coordinator for the Utah Division of Oil, Gas & Mining[23] for 2000–2014.

Wyoming

The Office of State Lands and Investments manages leases and royalties for production from minerals owned by the state of Wyoming. The Royalty Compliance Supervisor provided annual totals for royalty revenues from oil, natural gas, and condensate.[24] The Wyoming Oil and Gas Conservation Commission collects oil and gas production numbers and reports production volumes on their website.[25] We obtained oil and gas production volumes by year for 2000–2014.

[23] http://www.oilgas.ogm.utah.gov
[24] http://lands.wyo.gov/
[25] http://wogcc.state.wy.us/