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Jason P. Brown, Timothy Fitzgerald, and Jeremy G. Weber

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Asset Ownership, Windfalls, and Income: Evidence from Oil and Gas Royalties*

Jason P. Brown[1], Timothy Fitzgerald[2], and Jeremy G. Weber[3]

[1]Federal Reserve Bank of Kansas City
[2]Texas Tech University
[3]University of Pittsburgh

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Abstract

How does local versus absentee ownership of natural resources–and their associated income–shape the relationship between extraction and local income? Theory and empirics on natural resources and the broader economy have focused heavily on labor markets, largely ignoring the economic implications of payments to resource owners. We study how local ownership of oil and gas rights shapes the local income effects of extraction. For the average U.S. county that experienced an increase in oil and gas production from 2000 to 2013, increased royalty income and its associated economic stimulus accounted for more than two-thirds of the total income effect from extraction in 2013. Looking at gross royalty income in particular, which we derive from more than 2.2 million leases across the continental United States, we estimate that each dollar in royalty income led to an extra $0.52 in non-royalty income, largely reflecting greater wage income in the service sector. Overall, a U.S. county with complete local ownership of the subsurface captured 29 cents more of each dollar in production than a county with absentee ownership. For a shale county with the median production in 2013, this would translate to an extra $1,098 per capita, or 5.3 percent of total income.

Keywords: resource ownership; oil and gas; royalties; shale; income growth

JEL Classification Numbers: D23, R11, Q32, Q33

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"I went down to the slue to shoot one [a gopher], but just as I cut loose, that little varmint skedaddled, and oil come a oozin' outa that slue just like sorghum out of a leaky hog trough. That's how I made my fortune." - Jed Clampett, *The Beverly Hillbillies*

1 Introduction

How does local versus absentee ownership of natural resources – and its associated income – shape the relationship between extraction and local income? Resource owners can experience financial windfalls caused by new extraction technologies or demand shocks that cause prices to spike (Kilian, 2009). If accruing to local residents, the windfalls can plausibly stimulate local consumer demand or entrepreneurship. If resources are owned by non-residents, such spillovers likely occur outside the local economy. The seminal theoretical work linking a booming resource sector to the broader economy focuses on workers moving across sectors and expenditure of additional income from higher wages (Corden and Neary, 1982). The theory is silent on ownership and how the windfall created by the booming resource sector propagates through the economy. Moreover, empirical research on how extractive booms affect resource-rich areas, which has boomed in recent years, has overwhelming focused on labor markets, with almost no studies explicitly considering payments to resource owners (Fleming et al., 2015).

The recent boom in oil and gas drilling in shale formations provides a unique opportunity to examine the local income implications of resource ownership and the associated financial windfalls. Innovation in extraction methods made it economical to exploit vast endowments of oil and gas trapped in shale, with the six major formations generating nearly $40 billion in gross royalties for U.S. private mineral owners in 2014 alone (Brown et al., 2016). Using the shale boom in the United States, we estimate for the average shale county how much of the total increase in income stems from receiving and spending royalties. To do so, we estimate the total income effect for the average shale county and, separately, how royalties received by county residents affect income in the broader local economy. In addition to quantifying the royalty-induced income effect, this income multiplier permits establishing how variation in local ownership can drive variation in the income effects from extraction.

The empirics on royalties is based on data from more than 2.2 million private oil and gas leases. The leases, which provide the address of the resource owner, allow us to estimate royalties paid to county residents from production within the county, as well as production from elsewhere in the continental United States. To isolate the effect of unanticipated royalty payments due to a resource boom, we use an instrumental variable approach based on annual variation in royalty income caused by oil price shocks.

For the average county experiencing a production increase over the study period, royalty income and its multiplier effect accounted for more than two-thirds of the total increase in per capita income between 2000 and 2013. Using estimates of royalty income for the 2010-2013 period, we find that each dollar in unanticipated royalty income led to $1.52 increase in total income, which largely reflects greater wage income in the service sector. Overall, a U.S. county with complete local ownership of the subsurface captures 29 cents more of each dollar in production than a county with absentee ownership. Assuming the production of the median shale county in 2013, this translates into $1,098 per capita, or 5.3 percent of total income. The estimates help explain why the effects of resource extraction may vary substantially across regions based on historical patterns of ownership.

2 Literature

2.1 Income and Wealth Shocks: Individual Responses and Broader Effects

A broad economics and finance literature has considered the responses of individuals, households, and entrepreneurs to income and wealth shocks. A central question in this literature is how consumption changes with income and wealth. Some have used abrupt changes in income taxes to measure the effect of income shocks on consumption (Shapiro and Slemrod, 2003, 2009). Others have analyzed lotteries, inheritances, and shocks to real estate markets. Our brief review of the literature reveals that such shocks can affect behavior in diverse ways such as reducing labor market participation, increasing entrepreneurship, and encouraging consumption and borrowing.

Looking at lottery windfalls, Imbens et al. (2001) find that winners saved about 16 percent of their prize and reduced their labor market participation—as evidenced by lower labor earnings. Kuhn et al. (2011) find that lottery winners in the Netherlands buy more cars and other durables. Hankins et al. (2011) find that for financially distressed people, winning a lottery only postponed bankruptcy. Moreover, large winners and small winners who filed for bankruptcy five years after winning had similar net assets and unsecured debt.

Considering the effects of inheritances, Holtz-Eakin et al. (1994) find that conditional on becoming an entrepreneur, greater inheritances lead to greater capital investment in the business. Likewise, Blanchflower and Oswald (1998) find that receipt of an inheritance or gift increases the probability of self-employment while Andersen and Nielsen (2012) find that unexpected inheritances increase business survival rates.

A large literature explores how wealth changes caused by housing market shocks affect consumption, borrowing, and entrepreneurship. Campbell and Cocco (2007) interact changes in regional housing prices with a variable indicating whether the household owns or rents its home to study the effects of wealth shocks on consumption, finding that older homeowners increase their consumption in response to greater wealth. Hurst and Lusardi (2004), Disney and Gathergood (2009), Fairlie and Krashinsky (2012) exploit changes in housing values to estimate the link between wealth and entry into entrepreneurship. The first two studies find little relationship, while the third, which uses a geographically-specific measure of housing prices, found a positive effect of housing appreciation on self-employment. Mian and Sufi (2011) find that positive shocks to home equity caused households to increasing borrowing for both consumption and home improvements, finding that the average homeowner extracts 25 to 30 cents of every dollar increase in home equity. Similarly, Weber and Key (2015) examine the increase in farm real estate values caused by the biofuel boom and find that each dollar in paper wealth led younger farmers to increase real-estate-secured borrowing by 48 cents.

The above literature focuses on responses to wealth or income shocks, not their broader implications for the economy in which they occur. Rajan and Ramcharan (2015) is one study that traces the effects of a wealth shock (combined with credit availability) on local land prices around the time of the shock and decades afterwards. Gilje et al. (2016) studies the behavior of windfall recipients who deposit money in branch banks, the subsequent increase in lending capacity, and export of liquidity to non-boom areas in the form of mortgage lending where banks had branches.

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 federally-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).

Though research on resource booms has overwhelmingly focused on labor markets (Marchand and Weber, 2016), a growing literature suggests that effects related to resource ownership may be important. Brown et al. (2016) use leasing data from across the United States to show that royalty rates and the extent of local ownership vary substantially across the country. They also estimate royalty income from the major shale formations, reporting that six formations generated $39 billion in gross production royalties in 2014. Feyrer et al. (2015) estimates the non-wage income effect in an analysis of the full income effect of shale development. Analyzing IRS Statistics of Income data, they find that each million dollars in production generated $66,000 in wage income and $61,000 in non-wage income within the county where production occurred. That wages accounted for only half of the local income effect from extraction is striking given the extensive focus of extraction on labor markets (as evidenced by the review by Marchand and Weber (2016)). The result also seems to hold in an individual state: looking at changes in rental and royalty income in Pennsylvania counties, Hardy and Kelsey (2015) find evidence that the royalty income effect exceeds other income effects.

Other research shows evidence of the economic implications of royalty payments. Using cross-sectional data on U.S. farms, Weber et al. (2013) find that $1 in royalty income per acre is associated with $2.50 increase in land values. Similarly, Weber and Hitaj (2015) look at farms on the Pennsylvania-New York border before and after widespread shale development and find that shale development caused a 48 percent increase in farm real estate values, an effect likely explained by the capitalization of expected flows of royalty payments. Also looking at the Pennsylvania-New York Border, Boslett et al. (2016) estimate how the state of New York's moratorium on hydraulic fracturing changed economic expectations and consequently housing values. Their theoretical model highlights financial amenities from royalty payments as a primary reason why the moratorium might have a negative effect on housing values. Their empirical analysis, which is based on housing transactions close to the border, indicate that the moratorium decreased housing values in New York relative to Pennsylvania by 23 percent. Although their data did not permit isolating the effect of foregone royalty payments, the results fit with those of Weber and Hitaj (2015), which looked at farm real estate values in the same counties.

3 Economic Framework

Consider a local economy – a small open economy within a larger national economy – with an endowment of a natural resource in the spirit of Allcott and Keniston (2014). Examples might be oil deposits or particularly fertile agricultural land. A shock such as an innovation (e.g., hydraulic fracturing) or change in policy (e.g., the Renewable Fuel Standard) causes a sharp increase in the demand for the resource and therefore the quantity of the resource supplied. Our focus here and in the empirical analysis is on the income of local residents of the economy, meaning individuals who resided in the small open economy prior to the shock.

Assume that residents earn income from selling labor and from renting out assets, which we will call royalties. The total income increase from greater resource demand – and therefore greater extraction – will stem from a direct wage effect and its multiplier effect, and a direct royalty effect and its multiplier effect. The direct wage effect is from extraction causing an increase in labor demand, which will increase the wage rate as long as firms do not face a perfectly elastic labor supply curve. The local spending of additional wage income will in turn have its own effect on labor demand, reinforcing the initial wage increase.

At the same time, greater resource demand will increase payments to resource owners and asset prices. Some owners may decide to sell their assets at the new higher price or to rent out the asset at a higher rental rate. In either case, resource owners experience a positive income shock. To the extent that owners live in the local economy, some of the greater resource income will likely be spent locally, thereby increasing labor demand in the same manner as increased spending of additional wage income.

The contribution of royalties to the total income effect for local residents depends heavily on the extent that resources are locally owned and on the use of greater royalty income by resource owners. Ownership of the resource by non-residents is conceptually equivalent to the local economy being a colony controlled by distant powers, with all rents leaving the local economy. If, instead, some or all of the resource is owned by residents, the greater resource income enters the household budget where it is saved or consumed. Resource owners could use their windfall to consume more leisure by working less or buying goods from outside the local economy. Both uses will have little, if any, effect on the rest of the local economy. Spending on local goods and services would, in contrast, create additional income through increased labor demand and wages.

If owners instead save and invest some of their windfalls, the savings can generate additional capital income. If invested outside the local economy, as long as the investment generates a return, it will increase the flow of income to residents. Resource owners may also actively invest some windfalls locally, perhaps because of higher returns because of lower transaction and monitoring costs. Building and renting out a commercial property, for example, would have lower transaction and monitoring costs if made near the investor's residence. Alternatively, some resource owners may have faced credit constraints prior to receiving the windfall, in which case the windfall allows them to start or expand a business. To the extent that some of this local investment would not have happened in absence of windfalls to local resource owners, it will increase local labor demand relative to the case where no windfalls accrue locally.

4 Empirical Approach

4.1 The Local Income Effect of Shale Development

We first estimate the total per capita income effect for the average shale county. Estimating (1) reveals how the difference in average income between shale and non-shale counties evolved year by year as shown by:

$$Y_{it} = \gamma_i + \theta_{st} + \sum \beta_t (Shale_i \times Year_t) + \varepsilon_{it}, \tag{1}$$

where γ_i is a county fixed effect and θ_{st} is a state-year fixed effect.

The binary shale variable $Shale$ equals one if the combined quantity of oil and gas production in the county increased from 2000 to 2013 according to data reported by DrillingInfo (described in the next section). We label these counties as shale counties because the vast majority of them (87 percent) are in or adjacent to shale formations according to the Energy Information Administration's 2011 delineation of shale boundaries (Figure 1).

The technological breakthroughs that made drilling in shale profitable only emerged after 2000 and propagated unevenly. Because growth in production in the 2000s occurred primarily in shale and other low-permeability formations, the binary shale variable is credibly exogenous to county-specific shocks (other than those related to shale development) and should result in economically similar prior trends for shale and non-shale counties. To assess prior trends, which are necessary for identification of the average income effect from shale development, we estimate (1) for the 1990–2013 period. The magnitude and statistical significance of the interaction between the shale variable and the dummy variables for 1990–1999 will reveal any differences in trends prior to widespread drilling in shale.

We also decompose the total income effect into changes in wage and non-wage income. Even though non-wage income includes royalty income, the decomposition cannot reveal the role of royalties in the total income effect. Non-wage income includes income other than royalties, but perhaps more importantly, some of the increases in wage income may stem from the spending of royalty income. Estimating the role of royalties requires an estimate of the growth in royalty income in particular as well as its multiplier effect on local income.

4.2 Estimating the Effects of Royalty Income

To estimate how royalty income affects income in the broader economy, we use a first-differenced model where the change in income is regressed on the change in gross royalty income:

$$\Delta Y_{it} = \theta_{st} + \lambda \Delta Royalties_{it} + \varepsilon_{it}, \tag{2}$$

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 continental 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.

Some of the change in gross royalty income is likely anticipated by owners, especially those driven by predictable changes in production from an aging well. To isolate the effect of unanticipated changes in royalties, we use an instrumental variable approach that exploits variation in royalty income driven by oil price changes alone.[1] Let initial royalty income be defined as the product of the acre-weighted mean royalty rate on acreage owned by residents of county i anywhere in the continental U.S., the gross production from that acreage, and the mean output price in year t:

$$Royalties_{it} = r_i Q_{it} P_t \tag{3}$$

A reasonable prediction for the change in royalty income from year $t-1$ to t is:

$$\Delta \widehat{Royalties}_{it} = r_i Q_{it-1}(P_t - P_{t-1}), \tag{4}$$

[1] We use the change in oil prices to predict the change in all royalty payments even though some payments come from natural gas production. It turns out that this does not result in a weak instrument (see Table 2). This in part reflects the increasing importance of natural gas liquids in the value of unconventional natural gas. The prices of these liquids are more correlated with oil than with gas (0.52 vs. 0.1).

which can be re-written as

$$\Delta \widehat{Royalties}_{it} = Royalties_{it-1} \frac{P_t - P_{t-1}}{P_{t-1}}. \tag{5}$$

Equation (5) motivates a first-stage regression of the form

$$\Delta Royalties_{it} = \theta_{st} + \alpha \left(Royalties_{it-1} \times \% \Delta P_t \right) + \varepsilon_{it}. \tag{6}$$

In addition to isolating unanticipated changes in royalties, the instrumental variable approach addresses attenuation bias caused by measurement error in royalty income. Our calculation of royalty income, which the following section explains, provides a credible but imperfect estimate. For example, we can calculate the acre-weighted royalty rate on acreage owned by county residents but do not have data to calculate a production-weighted royalty rate. The royalty rate applied to the average dollar of production may be higher or lower than the royalty rate for the average acre.

A threat to the validity of the instrument—the predicted change in royalties—is a correlation between it and local drilling, which will have its own effect on local income through employment, thereby creating a correlation between the instrument and the error term in (2). The correlation between the predicted change in royalties and local drilling is because the predicted change depends in part on the lagged quantity of production occurring 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 high energy prices. The geographic coincidence of conventional and unconventional formations increases these concerns.

To address this potential threat to the instrument's validity, we control for measures of the change in mining earnings and the number of wells drilled, both normalized by lagged population. For both drilling measures, we control for the contemporaneous change, the change in the prior year, and the average contemporaneous change in counties contiguous to county i (using a queen contiguity matrix). Combined, the six control variables should provide a robust accounting of any relationship between local incomes and the drilling industry.

5 Data

5.1 Lease Data

We obtained information about individual mineral leases across the United States from private data provider DrillingInfo. We processed the data to focus on private mineral ownership in 17 major producing states: Arkansas, California, Colorado, Kansas, Louisiana, Michigan, Mississippi, Montana, New Mexico, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, Utah, West Virginia, and Wyoming.[2] We excluded all leases of federal, state, and local government-owned minerals, leaving only leases of privately-owned minerals. Each observed lease contains important details about contractual terms, including lessor, location, date signed, and the royalty rate. Importantly, the leases also include information on the address of the mineral owner.

We exclude duplicate leases, those appearing to be less than arm's length, and those between known oil and gas operators. In cases where fractionated mineral interests resulted in multiple leases for a single parcel, we weighted each fractionated interest according to equal ownership shares. More detail on the data construction is included in the data appendix.

5.2 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 the years 2000 to 2013. Economically important production occurs on Federal and state estates, with royalties paid to respective government coffers. To

[2] We exclude all offshore production. Of other producing states, Alaska is the only major producer excluded. Although some producing minerals in Alaska are privately-owned, a majority are controlled by state and federal governments. Producing states omitted for lack of leasing data include Illinois, Indiana, and Kentucky.

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—the data appendix details the procedures that we used.

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. We extend the EIA series, which stopped in 2010, by regressing state-level wellhead prices on the U.S. average wellhead price and state fixed effects using data from 1970 to 2010. The coefficients from the model, which accounted for 93 percent of the variation in prices over the period, were applied to the U.S. average wellhead price to construct state-level wellhead prices after 2010. The approach assumes that the relationship between state-level wellhead prices and the national average wellhead price remained constant after 2010.

5.3 Estimating Royalty Income to County Residents

Treating each county as a distinct leasing market, we calculate acre-weighted mean royalty rates for every pair of producing and receiving counties that we observe. This allows for the possibility of different royalty rates for local and absentee owners. The county-specific mean royalty rate governing payments from acreage in producing county c to residents in the receiving county r is calculated according to,

$$\sum_{i \in c,\, j \in r} \left(\frac{acres_{i,j}}{\sum\limits_{i \in c,\, j \in r} acres_{i,j}} \times Rate_i \right) = \overline{Rate_{r(c)}}. \tag{7}$$

These county-specific mean royalty rates can be aggregated on an acre-weighed basis to calculate a county-wide mean royalty rate, along the lines used in Brown et al. (2016). Another related statistic, which we use in the discussion of the empirical results, is the percent of observed acreage of each producing county that is owned by local residents. This share varies between 0 to 100 percent.

The value of production in county c payable to county r in year t is calculated as:

$$\sum_{r \in R} \sum_{c \in C} \left(\frac{acres_{r(c)}}{\sum_{i \in c} acres_i} \times \overline{Rate_{r(c)}} \right) \times value_c = Royalties_{r(c)}, \tag{8}$$

for each observed combination of c and r.

Having calculated the royalties from every county to every other county according to equation (8), the flow of royalties to residents of a particular county r in year t is given by:

$$Royalties_r = \sum_{c \in C} Royalties_{r(c)}. \tag{9}$$

where counties $c \in C$ are all producing counties and $r = c$ corresponds to locally-retained royalties. This calculation is made for each year t. The estimate is an upper bound on the royalties paid to royalty owners because well operators often deduct transportation allowances and other post-production costs from gross royalties.

Our dataset of leases is extensive but not exhaustive. We have data on private leasing markets in 575 counties. Combined, these counties accounted for 82 percent of onshore oil and gas production in 2013 according to the DrillingInfo production data. For counties with no private leasing data, we assign a state-average royalty rate and assume that all royalties are paid locally.

One county in Texas' Eagle Ford Shale, Karnes County, had an increase of royalty income per capita several times larger than any other county (more than $60,000 in one year). We exclude Karnes County in the regression analysis of royalty income multipliers.

5.4 Income and Wage Data

We use the county-level Internal Revenue Service Statistics of Income data (IRS-SOI), which are based on individual tax returns and assigned to counties based on the addresses in the returns.[3] We use adjusted gross income (AGI) as our measure of total income, which is then broken into income from wages and salaries and non-wage income, defined as AGI less wage and salary income. Because the data are assigned to county of residence, the wage income may better indicate where income may be consumed or saved than wage data based on location of work. One limitation of the IRS-SOI data is that wages and salaries are not broken out by industry. To look at and control for wages in the mining sector we use data from the Bureau of Labor Statistics Quarterly Census of Employment and Wages (QCEW).[4] Annual county population estimates, which are used to put variables on a per capita basis, are from the U.S. Census Bureau.[5]

6 Descriptive Statistics

Table 1 provides descriptive statistics for sample counties for the years 2010–2013, with all variables except the shale and metro indicator normalized by lagged population or, in the case of wells drilled, by lagged population divided by 1,000. All monetary variables are converted to 2010 dollars. We focus on the years 2010 to 2013 for estimation of gross royalty income multipliers because the majority of leasing occurred prior to 2010; for 90 percent of counties, the average year of signing was before 2010. The focus on later years limits the extent that we use a lease signed in 2011, for example, to inform the flow of royalties in 2010.

Over the period the average county saw an annual increase in gross royalty income of $62 per person, which is almost double the average increase in mining earnings. This average increase in gross royalty income represented about 9 percent of the average increase in total income as measured by reported Adjusted Gross Income (AGI). Looking at particular percentiles reveals that royalty income is quite skewed: the median county only saw a $2 per capita increase, while the counties at the 90th and 95th percentiles saw increases of $74 and $204 per person, respectively.

[3] County-level SOI data are available at: `https://www.irs.gov/uac/soi-tax-stats-county-data`.

[4] `http://www.bls.gov/data/`

[5] `https://www.census.gov/popest/`

Growth in drilling was even more concentrated than growth in royalty income. The county at the 90th percentile for drilling growth had an increase less than one tenth of a well per 1,000 persons while the county at the 95th percentile had an increase of 0.4 wells well per thousand persons.

Both the IRS-SOI and QCEW wage income measures show increases in wages over the study period, but the IRS-SOI measure is about 60 percent larger than the QCEW measure. This likely reflects the more comprehensive nature of the IRS measure. For example, QCEW does not cover the self-employed, military, railroad, and certain farm, domestic, and non-profit workers. Another difference between the two series is that the QCEW wage data have a standard deviation one-third larger than that of the IRS-SOI data. The greater annual variability is likely because people change their county of employment more often than their county of residence.

7 Results

7.1 The Average Shale Income Effect

Figure 2 depicts the $\hat{\beta}_t$ coefficients from (1) across three dependent variables: total income, wage income, non-wage income.[6] Shale and non-shale counties experienced similar income trends during the 1990s and early 2000s for all three measures.[7] Economically large differences in income between shale and non-shale counties only emerged after 2005, corresponding to widespread shale development. By 2013, residents of shale counties had per capita incomes \$2,144 higher than those in non-shale counties, a 10 percent increase over the average county income in 2000. Breaking total income into its components reveals that

[6]See appendix Tables A1–A3 for coefficients and standard errors.

[7]The slight decline in income in shale counties observed in the mid parentheses correspond to an oil price decline, with prices declining from 1996 to 1998 and then rebounding from 1998 to 2001. This fits data showing that shale counties, as we define them, had economically important conventional oil and gas development before the emergence of shale technology: in 2000 shale counties produced on average \$88 million in oil and gas compared to the \$31 million for non-shale counties.

two-thirds of the total income effect came from growth in non-wage income. The large contribution of non-wage income was not unique to 2013: from 2010 to 2013, non-wage income accounted for between 65 and 69 percent of the difference in total income between shale and non-shale counties.

The shale county definition only requires that a county have an increase in oil and gas production over the 2000 to 2013 period. To see how the results change with different thresholds of production growth, we re-estimate the coefficients in (1) after dropping counties whose change in production was positive but less than \$25 million and then again after dropping those whose increase was less than \$250 million. As expected, the income effects increase. For the two subsamples, the total income effect in 2013 increased to \$3,650 and then to \$6,705 (Table A1). As before, non-wage income accounts for about two-thirds of the total income increase.

As mentioned earlier, breaking total income into wage and non-wage income does not indicate the share of the total income effect accounted for by royalties. Non-wage income includes royalty income but also income from rental properties, proprietorships, and partnerships. Moreover, local expenditure of royalty income may in fact account for some of the increase in wage income. This link is the focus of the next section.

7.2 The Multiplier Effect of Royalty Income

We establish the relevance of our instrumental variable – the predicted change in royalty income from oil price changes alone – by estimating (6) with and without control variables. The control variables are based on the change in mining earnings and the number of wells drilled, both normalized by lagged population. For both mining earnings and wells drilled, we control for the contemporaneous change, the change in the prior year, and the average contemporaneous change in counties contiguous to a given county. Because the subsequent analysis estimates multipliers separately for shale and non-shale counties as well as metropolitan and non-metropolitan counties, we also provide first-stage results for these subsamples.

Table 2 shows that when only controlling for state-year fixed effects, a \$1 increase in predicted royalty income led to \$0.97 greater royalty income; when adding control variables, the coefficient is \$0.88. The coefficient is roughly similar when splitting counties out by shale status or metro status. The F-statistic of the excluded instrument (predicted royalties) is 89 with additional control variables, indicating sufficient instrument strength to avoid concerns about weak-instrument bias. For the subsamples, the F-statistic is always above 40.

Table 3 shows the results of estimating (2) with and without controls for drilling and mining earnings and for total adjusted gross income and its wage and non-wage components. In all cases, controlling for various drilling and mining earnings variables reduces the multiplier estimate. For example, \$1 in gross royalty income is associated with \$1.78 in total adjusted gross income when only including state-year fixed effects and \$1.52 when including control variables. Because of their greater credibility, we focus on the estimates that hold drilling and mining earnings constant.

Properly interpreting the estimated multipliers requires assumptions about differences between gross and net royalty income. Because well operators deduct various costs from payments to royalty owners, royalty owners would receive and report on their taxes less than a \$1 in net royalty income for each \$1 in gross royalties. Ignoring such deductions results in a conservative estimate of the multiplier effect of royalty income. For example, if each \$1 in gross royalties leads to \$0.90 in net royalty income, then the coefficient of \$1.52 indicates that \$0.62 in non-royalty income was created in the local economy (= 0.52+0.10). To discuss the results, we take this conservative approach and assume that \$1 in gross royalties leads to \$1 in net royalties.

The estimated income effect of \$1.52 indicates that each \$1 in gross royalty income received by county residents generates \$0.52 elsewhere in the local economy such that it enters the income of people filing taxes in that county. The multiplier is consistent with other local income multipliers in the literature; for example, Suárez Serrato and Wingender

(2015) find each dollar of government spending generates and additional \$0.7 to \$1 of local income.

Breaking total AGI into its wage and non-wage components shows that each \$1 in gross royalties leads to \$0.39 in additional wage income and \$0.13 in non-wage, non-royalty income. The estimates indicate that a large part of the multiplier effect of royalty income 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 others who work and reside in the county. The \$0.13 in additional non-wage income, which is only marginally statistically significant, would stem from the spending of royalty income in the local economy in ways that increase business or partnership income. Additionally, if royalties are saved and invested they would also generate additional non-wage income for county residents.

By comparison, the OLS multiplier estimates, which are shown in Table A4, are dramatically smaller than the IV estimates. The difference is expected. Royalty owners should have little response to anticipated changes in royalty income. In addition, substantial measurement error in royalty income would attenuate the coefficient towards zero.

Tables 4a–4c show the total, wage, and non-wage multipliers for counties split by shale and metro status. The estimated total income multipliers vary from 1.07 to 1.94, with the variation driven by the non-wage multiplier, which ranges from 0.60 to 1.65. It is less precisely estimated than the wage multiplier, which is expected because non-wage income includes gains and losses from business or capital investments, which will vary substantially more than annual wage income.

The wage multipliers, in contrast, are similar across subsamples, only ranging from \$0.28 (shale counties) to \$0.54 (metro counties) (Table 4b). The larger wage multiplier in metro counties is plausible because royalty recipients likely spend more of their windfalls in areas offering more local goods and services.

As noted in the description of the sample, the distribution of royalty income is very skewed. To test the robustness of our multiplier estimate, we re-estimate the total income multiplier but dropping the top 0.5, 1.0, 1.5, and 2.0 percent of counties for the change in royalty income from 2010 to 2013. The estimates are quite stable. The multiplier based on the full sample is 1.52; after cutting the top 2.0 percent of counties, the multiplier is 1.69 (Table A5).

7.3 Royalty-Wage Multiplier Effects By Industry

The IRS-SOI data do not allow identification of the industries where the wage income effect is accruing. We therefore look at the effect of royalty income on labor earnings as reported in the QCEW. Looking at wage effects by sector is one way to check the plausibility of our results: if the wage-multiplier estimates reflect a true causal effect of local spending of royalty income, then most of the effect should appear in the service sector. The service sector is more local than, say, manufacturing, which is tradable and typically sells to broader markets. We examine three sectors: services, construction, and manufacturing. We exclude mining because we control for the change in mining earnings in the regression.

Table 5 shows estimates for the full sample and then by the shale and metro county subsamples. Overall, the QCEW data give point estimates of the royalty-wage multiplier smaller than that of the IRS-SOI. The QCEW data also yield less precise estimates, such that the wage multiplier is never statistically significant at the 10 percent level. This is consistent with the descriptive statistics showing greater variability in the QCEW measure of wages than in the IRS-SOI measure, a likely artifact of greater year-to-year variation in where people work than where they reside.

Despite the imprecisions of the QCEW estimates, the estimated multipliers across sectors suggest that essentially all of the increase in wage income occurs in the service sector (see Table 5b). Wages in the construction and manufacturing sectors show essentially no change. Moreover, these near-zero effects are also relatively precisely estimated, with standard errors of 0.04 for construction and 0.02 for manufacturing.

The lack of a construction effect suggests that the drilling and mining control variables are accounting for any link between royalties, drilling, and earnings. The construction sector is one sector where studies of drilling activity have found large multiplier effects. Fetzer (2014) finds that drilling-driven expansions in mining earnings caused the largest earnings increases in the construction sector, with each $1 in mining earnings causing a $0.38 increase in construction earnings.

Similarly, the lack of a manufacturing effect suggests that our empirical approach is not undermined by confounding factors related to broad economic trends. Because most manufacturing firms serve broader regional markets, greater incomes to local residents should have little effect on sales and earnings of local manufacturing firms. This is consistent with our findings: for the full sample and the four subsamples, the estimated multiplier is never larger than 0.04, with a standard error that is also never larger than 0.04.

8 Resource Ownership and Local Incomes

The average shale income effect increased by $1,081 from 2010 to 2013, of which $735 came from increases in non-wage income (Figure 2a, Tables A1–A3). Over the same period, royalty income increased by $1,031 more in shale counties if considering the full sample and $507 if excluding the top five royalty income counties, suggesting that most, if not all, of the non-wage income increase was from royalty income. Using a royalty income increase of $507 from 2010 to 2013, the royalty income multiplier of $1.52 predicts a total income increase of $770, or 71 percent of the total income effect. This is a conservative estimate because of the exclusion of royalty outliers.

We further consider the role of local resource ownership by explicitly considering variation in the percent of minerals owned by county residents. The percentage varies enormously, ranging from 0 to 100 percent, with the median county having 24 percent of the acreage locally owned (Table 6). At the sample production-weighted mean royalty rate of 19 percent, some counties will receive no royalty income while others receive $0.19 for each $1 of oil and gas production. Our estimate that each \$1 in royalties generates \$1.52 in total income implies counties with complete local ownership capture \$0.29 ($= 0.19 \times 1 \times 1.52$) in income for each \$1 in local production through gross production royalties alone. Counties with no local ownership, in contrast, would not experience this income effect, though incomes would likely rise through other channels such as greater labor demand. Instead, the royalties are paid into other local economies, where they can have a multiplier effect.

The median shale county had \$3,785 in production per capita in 2013. Assuming complete local ownership, this implies a royalty-related income effect of \$1,098 per person, which is 5.3 percent of median total income for shale counties. Thus, if production were held constant at its 2013 level, the median shale county would have an annual income 5.3 percent higher if it had complete local ownership than if it had no local ownership. If the county had the median local ownership share (24 percent), royalties would increase income by \$263 per capita, a 1.3 percent increase.

The significance of local resource ownership is striking considering the money at stake for the average county. In 2013, total royalty income for the average county–using our estimated income multiplier of 1.52–was nearly \$22 million (Figure 3). The cumulative total for the roughly 3,000 counties in our sample was \$64 billion, roughly 0.4 percent of U.S gross domestic product in 2013. If at least some royalty income is spent outside of the county of the recipient, then our multiplier serves as a lower-bound estimate due to potential leakages.

Resource ownership may play a large economic role for resources other than oil and gas. With reasonably competitive land markets, for example, shocks to agricultural prices should generate large windfalls for land owners, who may or may not live near the land they own. This fits the findings of Weber et al. (2014) who find that each price-driven \$1 increase in agricultural revenues generated \$0.64 in local income, of which 36 percent went to nonfarmers owning farm assets such as land.

9 Conclusion

This study documents the role of resource ownership in shaping the local income effects of extraction. Put simply, it matters whether resources are locally or absentee owned. This key institutional dimension has not been considered in the literature surrounding the economic impacts of unconventional oil and gas development or natural resources in general. The receipt and spending of royalty income accounted for more than two-thirds of the total income effect for the average shale county. In 2013 the median shale county would have 5.3 percent higher per capita income if local residents instead of absentee owners had exclusive rights to the subsurface.

The large role of royalty income in the local income effects of extraction indicates that the overwhelming emphasis on labor markets in prior research may overstate the channel's relative economic importance. It also shows that an important part of the increase in labor earnings stems from the spending of royalty income as opposed to increases in labor demand from the drilling industry.Moreover, the dispersion in local ownership shares across U.S. counties provides a clear reason for the short- and long-term effects of natural resource booms to vary across time and region.

While our study documents the importance of resource ownership, the findings raise additional questions. How much royalty income is actually saved or spent, and over what time frame? Are royalties generally used to expand businesses and cancel debts, or to finance increased consumption? What are the long-term effects of royalties on wealth accumulation and therefore income? These questions are beyond the scope of the current analysis, but are fruitful areas of future research.

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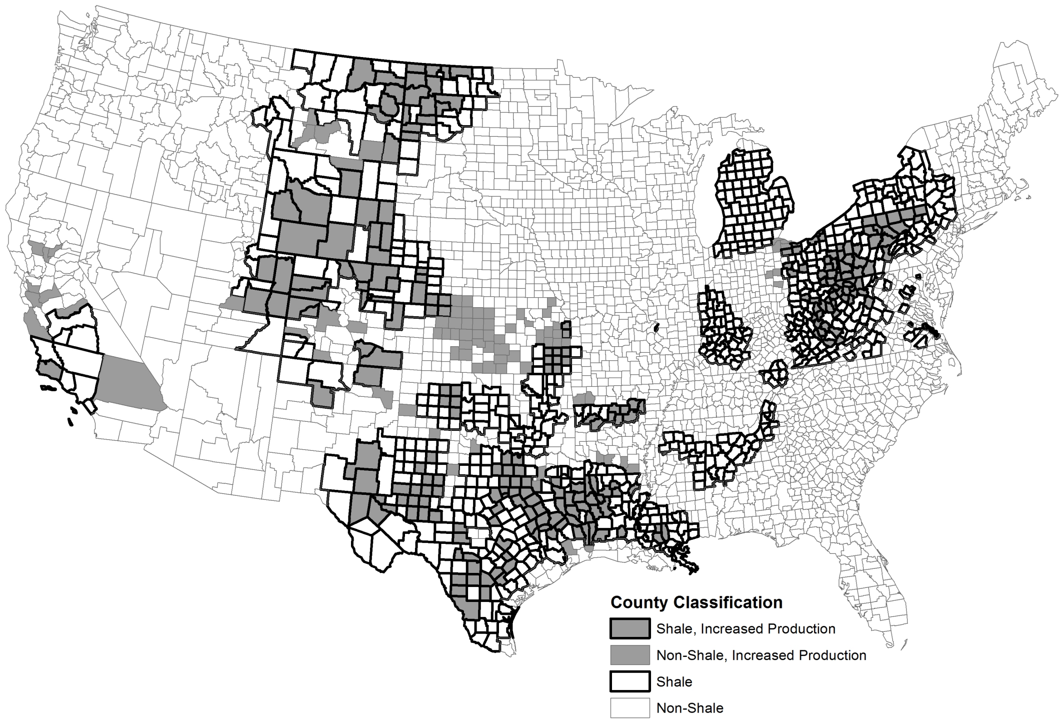
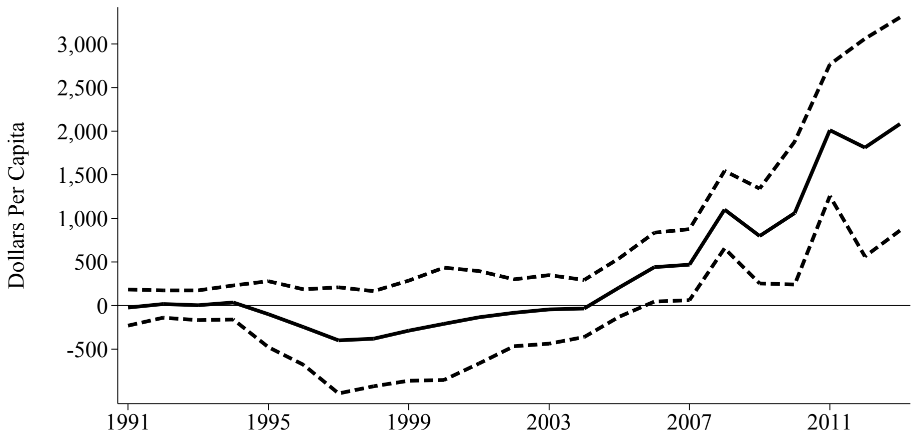
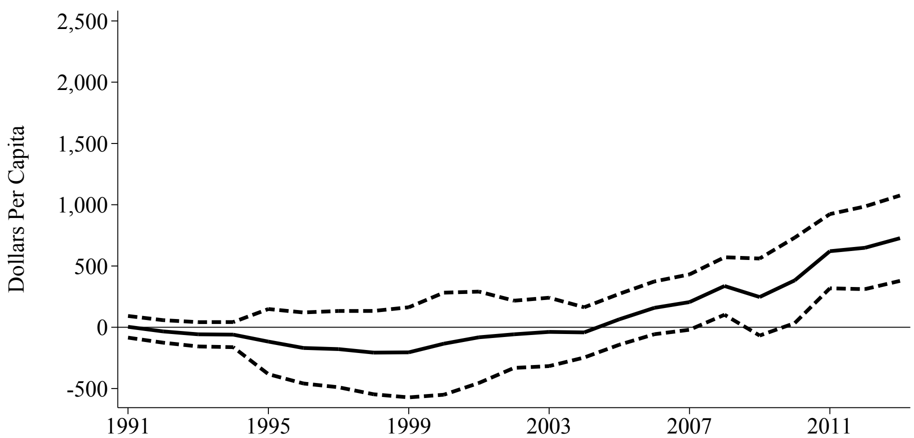


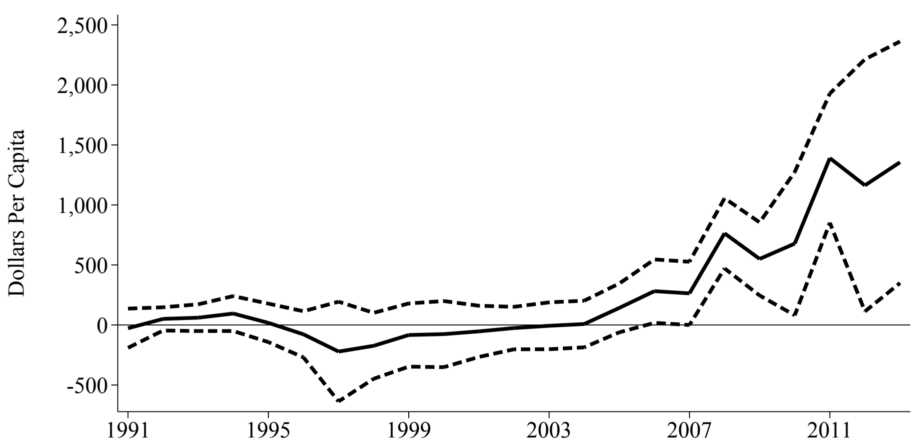
Figure 1: Defining Shale vs. Non-Shale Counties



(a) Total Adjusted Gross Income



(b) Wage Income



(c) Non-Wage Income

Note: The solid line depicts the $\hat{\beta}_t$ coefficients estimated in (1) using data from 1990–2013. The dashed lines represent 95 percent confidence intervals.

Figure 2: Difference in Per Capita Income of Shale vs. Non-Shale Counties

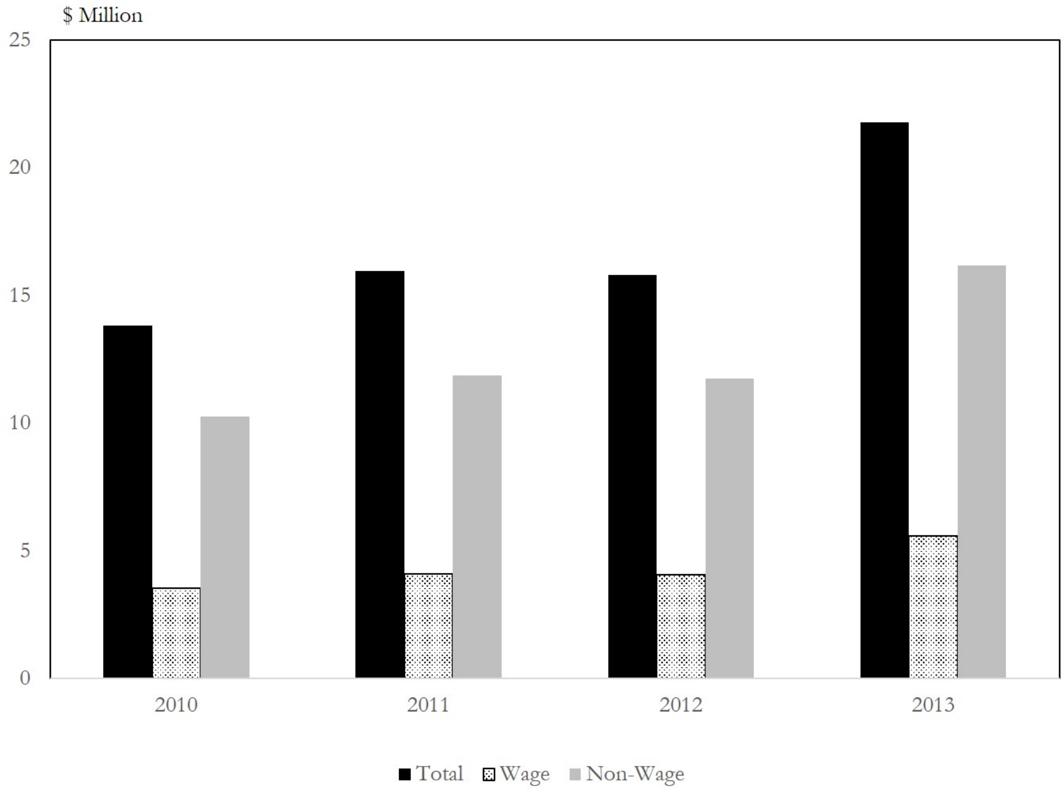


Figure 3: Average County Income from Royalties, 2010–2013

Table 1: Sample Descriptive Statistics, 2010-2013

	Mean	SD	P50	P75	P90	P95
Δ Royalties	62.2	777.0	1.7	9.7	74.1	204.0
Δ Mining Earnings	37.4	567.8	0.0	0.0	45.9	207.1
Δ Wells Drilled (per 1,000 people)	0.1	5.5	0.0	0.0	0.0	0.4
Shale County (0/1)	0.1	0.3	0.0	0.0	1.0	1.0
Metro County (0/1)	0.3	0.5	0.0	1.0	1.0	1.0
Δ Adjusted Gross Income (AGI)	698.7	3,155.8	386.9	1,204.7	2,382.8	3,536.5
Δ Wage Income	224.4	738.8	137.5	409.9	792.7	1,161.7
Δ Non-wage Income	474.3	2,873.4	270.3	855.2	1,771.0	2,708.3
Δ Wage Income-QCEW	142.4	1,004.2	68.8	289.0	634.3	1,027.5
Δ Service Earnings-QCEW	85.5	2,197.9	32.8	156.2	338.8	529.5
Δ Construction Earnings-QCEW	-0.5	317.0	0.0	32.8	104.2	219.5
Δ Manufacturing Earnings-QCEW	22.2	291.6	2.6	73.9	201.3	315.9
N	11828					

Note: All variables except the shale and metro indicator variables are normalized by the lag of county population. Wells drilled is per 1000 persons.

Table 2: First Stage Regressions: Changes in Royalty Income Predicted by Variation in Oil Prices

	All	All	Shale	Non-shale	Metro	Non-metro
Δ Predicted Royalties	0.97***	0.88***	1.06***	0.74***	1.22***	0.84***
	(0.10)	(0.09)	(0.16)	(0.09)	(0.19)	(0.09)
Δ Mining Earnings		0.06	0.06	0.07	0.31	0.03
		(0.03)	(0.05)	(0.04)	(0.25)	(0.02)
Δ Mining Earnings, t-1		-0.00	0.04*	-0.00	-0.03	-0.00
		(0.00)	(0.02)	(0.00)	(0.02)	(0.00)
Δ Mining Earnings, Adj. Counties		0.13***	0.19**	0.08*	0.28*	0.12***
		(0.03)	(0.07)	(0.03)	(0.13)	(0.04)
Δ Wells Drilled		0.41	-2.16	11.67	-19.27***	4.62
		(4.69)	(5.01)	(7.75)	(3.10)	(5.05)
Δ Wells Drilled, t-1		-6.34	-7.71	-4.56	-10.20	-4.79
		(3.55)	(5.20)	(2.87)	(9.35)	(2.85)
Δ Wells Drilled, Adj. Counties		-1.37	-4.12	2.31	-16.70	-0.14
		(2.01)	(2.89)	(2.72)	(10.99)	(1.57)
R-squared	0.14	0.17	0.15	0.19	0.41	0.16
N	11,824	11,824	1,312	10,512	4,080	7,744

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. Shale counties are as defined in the text – counties overlying a shale formation and that had an increase in the number of active wells over the 2000–2013 period. Metropolitan counties are based on the Office of Management and Budget classifications based on the 2000 Census. For the results in columns 1-6, the F-statistic on predicted royalties is 89, 101, 44, 61, 40, and 82.

Table 3: Instrumental Variable Estimates: Royalties and Wage and Non-Wage Income

	Total AGI		Wage		Non-Wage	
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Royalties	1.78***	1.52**	0.46***	0.39***	1.32**	1.13*
	(0.51)	(0.52)	(0.10)	(0.10)	(0.46)	(0.47)
Δ Mining Earnings		0.89		0.11**		0.78
		(0.48)		(0.04)		(0.49)
Δ Mining Earnings, t-1		-0.01		-0.01		-0.00
		(0.02)		(0.00)		(0.02)
Δ Mining Earnings, Adj. Counties		0.24		0.24***		-0.00
		(0.23)		(0.04)		(0.21)
Δ Wells Drilled		18.77		-1.09		19.87
		(11.25)		(2.34)		(10.18)
Δ Wells Drilled, t-1		3.20		1.74		1.46
		(6.20)		(1.38)		(5.77)
Δ Wells Drilled, Adj. Counties		25.14		5.31***		19.83
		(26.62)		(1.32)		(26.14)
N	11824	11824	11824	11824	11824	11824

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. Shale counties are as defined in the text – counties with an increase from 2000 to 2013 in the combined quantity of oil and gas produced. Metropolitan counties are based on the Office of Management and Budget classifications based on the Census.

Table 4: Royalty Multiplier Estimates Across County Metro and Shale Status

(a) Total Adjusted Gross Income

	Shale	Non-Shale	Metro	Non-Metro
Δ Royalties	1.94***	1.07	1.82**	1.56**
	(0.51)	(0.79)	(0.56)	(0.60)

(b) Wage Income

	Shale	Non-Shale	Metro	Non-Metro
Δ Royalties	0.28**	0.46**	0.54**	0.41***
	(0.10)	(0.18)	(0.18)	(0.12)
N	1312	10512	4080	7744

(c) Non-Wage Income

	Shale	Non-Shale	Metro	Non-Metro
Δ Royalties	1.65***	0.60	1.27**	1.15*
	(0.46)	(0.69)	(0.43)	(0.55)

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered by county are in parentheses. AGI stands for Adjusted Gross Income. Non-wage income is calculated as Total AGI less wage Wage Income. All regressions include state by year fixed effects and control variables related to drilling and mining earnings. Shale counties are as defined in the text – counties with an increase from 2000 to 2013 in the combined quantity of oil and gas produced. Metropolitan counties are based on the Office of Management and Budget classifications based on the 2000 Census.

Table 5: Royalty-Wage Multiplier Estimates By Sector

(a) Total Wage Income

	All	Shale	Non-Shale	Metro	Non-Metro
Δ Royalties	0.25	0.04	0.36	0.10	0.23
	(0.17)	(0.12)	(0.38)	(0.28)	(0.19)

(b) Service Sector Wage Income

	All	Shale	Non-Shale	Metro	Non-Metro
Δ Royalties	0.19	0.10	0.13	-0.04	0.16
	(0.16)	(0.10)	(0.39)	(0.18)	(0.18)

(c) Construction Sector Wage Income

	(1)	(2)	(3)	(4)	(5)
	All	Shale	Non-Shale	Metro	Non-Metro
Δ Royalties	-0.04	-0.10	0.04	-0.08	-0.03
	(0.05)	(0.08)	(0.05)	(0.06)	(0.06)

(d) Manufacturing Sector Wage Income

	All	Shale	Non-Shale	Metro	Non-Metro
Δ Royalties	0.01	-0.01	0.04	-0.00	0.02
	(0.02)	(0.02)	(0.04)	(0.04)	(0.03)
N	11824	1312	10512	4080	7744

Note: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust standard errors clustered by county are in parenthesis. All regressions include state by year fixed effects and control variables related to drilling and mining earnings. Shale counties are as defined in the text – counties with an increase from 2000 to 2013 in the combined quantity of oil and gas produced. Metropolitan counties are based on the Office of Management and Budget classifications based on the 2000 Census.

Table 6: The Role of Ownership in the Local Capture of Income from Production

		Local Royalty-Driven Income Effect of $1 in Production	
Ownership Percentile	Local Ownership Share	Direct Effect (=Royalty Rate × Ownership Share)	Total Effect (=Direct Effect × 1.52)
1	0	0	0
5	0.02	0.00	0.00
25	0.14	0.03	0.04
50	0.24	0.05	0.07
75	0.39	0.07	0.11
95	0.74	0.14	0.21
99	0.91	0.17	0.26
Maximum	1	0.19	0.29

Note: The production-weighted average royalty rate for counties for which we have leasing data is 0.19. Only counties for which leasing data are available are used in calculating the percentiles for the Local Ownership Share. The multiplier used to calculate the total income effect is that estimated using the full sample, which is 1.52.

Appendix: Additional Empirical Results

Average Shale Income Effects Over Time

Table A1: Average Shale Income Effect, Total Income

	(1) Full Sample		(2) Subsample 1		(3) Subsample 2	
Shale × 1991	-25	(105)	104	(128)	256	(235)
Shale × 1992	15	(80)	-21	(117)	130	(202)
Shale × 1993	3	(87)	-80	(122)	91	(206)
Shale × 1994	34	(99)	-76	(124)	87	(199)
Shale × 1995	-101	(193)	-189	(187)	-145	(254)
Shale × 1996	-256	(221)	-404	(218)	-329	(295)
Shale × 1997	-410	(311)	-649	(331)	-496	(436)
Shale × 1998	-380	(278)	-588*	(278)	-443	(364)
Shale × 1999	-297	(292)	-635*	(274)	-603	(361)
Shale × 2000	-220	(328)	-426	(290)	-278	(392)
Shale × 2001	-145	(270)	-212	(262)	95	(366)
Shale × 2002	-91	(196)	-129	(220)	79	(308)
Shale × 2003	-53	(200)	4	(240)	418	(356)
Shale × 2004	-40	(167)	-54	(199)	376	(288)
Shale × 2005	199	(171)	275	(208)	949**	(291)
Shale × 2006	430*	(201)	723**	(258)	1707***	(389)
Shale × 2007	457*	(208)	807**	(267)	1902***	(398)
Shale × 2008	1088***	(227)	1802***	(320)	3536***	(491)
Shale × 2009	789**	(277)	1230***	(332)	2210***	(512)
Shale × 2010	1063*	(417)	1845***	(523)	3500***	(801)
Shale × 2011	2018***	(384)	3226***	(566)	5523***	(935)
Shale × 2012	1854**	(637)	3297***	(943)	5927***	(1559)
Shale × 2013	2144***	(624)	3650***	(975)	6705***	(1710)
R-squared	0.42		0.42		0.42	
N	70,992		67,464		65,280	

Note: The number of shale counties in the Full Sample, Subsample 1 and Subsample 2 are 328, 181, and 90. Shale counties are defined as having an increase in the combined quantity of oil and gas production from 2000 to 2013. Subsample 1 excludes Shale 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 Shale counties where the increase was less than $250 million.

Table A2: Average Shale Income Effect, Wage Income

	(1) Full Sample		(2) Subsample 1		(3) Subsample 2	
Shale × 1991	4	(45)	33	(69)	82	(124)
Shale × 1992	-33	(47)	-52	(70)	-23	(122)
Shale × 1993	-57	(50)	-93	(75)	-44	(127)
Shale × 1994	-59	(52)	-89	(75)	-59	(124)
Shale × 1995	-117	(135)	-155	(129)	-202	(179)
Shale × 1996	-174	(148)	-246	(141)	-272	(194)
Shale × 1997	-183	(159)	-284	(148)	-253	(198)
Shale × 1998	-204	(173)	-325*	(158)	-314	(211)
Shale × 1999	-209	(187)	-377*	(169)	-387	(224)
Shale × 2000	-139	(212)	-315	(186)	-264	(256)
Shale × 2001	-87	(190)	-141	(178)	33	(245)
Shale × 2002	-62	(140)	-96	(155)	24	(222)
Shale × 2003	-42	(142)	-23	(166)	195	(246)
Shale × 2004	-43	(104)	-63	(126)	164	(186)
Shale × 2005	61	(106)	101	(125)	416*	(176)
Shale × 2006	153	(110)	256	(136)	683***	(199)
Shale × 2007	200	(115)	359*	(143)	861***	(210)
Shale × 2008	330**	(120)	591***	(155)	1198***	(234)
Shale × 2009	241	(160)	407*	(164)	748***	(204)
Shale × 2010	377*	(178)	655***	(191)	1225***	(261)
Shale × 2011	617***	(154)	1038***	(200)	1810***	(307)
Shale × 2012	646***	(172)	1095***	(226)	1952***	(349)
Shale × 2013	723***	(177)	1204***	(237)	2142***	(367)
R-squared	0.43		0.43		0.43	
N	70,992		67,464		65,280	

Note: The number of shale counties in the Full Sample, Subsample 1 and Subsample 2 are 328, 181, and 90. Shale counties are defined as having an increase in the combined quantity of oil and gas production from 2000 to 2013. Subsample 1 excludes Shale 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 Shale counties where the increase was less than $250 million.

Table A3: Average Shale Income Effect, Non-Wage Income Income

	(1)		(2)		(3)	
	Full Sample		Subsample 1		Subsample 2	
Shale × 1991	-28	(83)	71	(72)	174	(125)
Shale × 1992	49	(49)	31	(62)	153	(96)
Shale × 1993	60	(57)	14	(68)	135	(102)
Shale × 1994	93	(74)	12	(77)	146	(111)
Shale × 1995	16	(82)	-34	(92)	57	(121)
Shale × 1996	-82	(98)	-159	(111)	-57	(147)
Shale × 1997	-227	(213)	-364	(251)	-243	(327)
Shale × 1998	-177	(140)	-263	(165)	-129	(210)
Shale × 1999	-88	(134)	-258	(142)	-216	(184)
Shale × 2000	-81	(140)	-111	(139)	-13	(184)
Shale × 2001	-58	(109)	-72	(123)	62	(171)
Shale × 2002	-29	(90)	-34	(107)	54	(144)
Shale × 2003	-11	(100)	27	(127)	222	(185)
Shale × 2004	4	(99)	10	(118)	212	(164)
Shale × 2005	138	(104)	173	(129)	533**	(178)
Shale × 2006	277*	(135)	468**	(174)	1024***	(260)
Shale × 2007	257	(134)	448*	(174)	1041***	(257)
Shale × 2008	758***	(149)	1211***	(215)	2338***	(340)
Shale × 2009	548***	(155)	823***	(216)	1462***	(368)
Shale × 2010	686*	(304)	1189**	(400)	2274***	(623)
Shale × 2011	1401***	(274)	2188***	(416)	3713***	(701)
Shale × 2012	1208*	(536)	2202**	(801)	3974**	(1323)
Shale × 2013	1421**	(515)	2446**	(824)	4564**	(1472)
R-squared	0.30		0.30		0.30	
N	70,992		67,464		65,280	

Note: The number of shale counties in the Full Sample, Subsample 1 and Subsample 2 are 328, 181, and 90. Shale counties are defined as having an increase in the combined quantity of oil and gas production from 2000 to 2013. Subsample 1 excludes Shale 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 Shale counties where the increase was less than $250 million.

OLS Estimates of Royalty Income Multiplier

Table A4: OLS Estimates: Royalties and Wage and Non-Wage Income

	Total AGI		Wage		Non-Wage	
	(1)	(2)	(3)	(4)	(5)	(6)
Δ Royalties	0.49***	0.31*	0.11***	0.07*	0.38**	0.24
	(0.13)	(0.15)	(0.03)	(0.03)	(0.13)	(0.15)
Δ Mining Earnings		0.97*		0.13***		0.84
		(0.49)		(0.04)		(0.49)
Δ Mining Earnings, t-1		-0.01		-0.01*		-0.00
		(0.02)		(0.00)		(0.02)
Δ Mining Earnings, Adj. Counties		0.45*		0.30***		0.15
		(0.21)		(0.04)		(0.19)
Δ Wells Drilled		19.54		-0.89		20.43*
		(10.27)		(2.42)		(9.32)
Δ Wells Drilled, t-1		-6.00		-0.70		-5.30
		(5.88)		(0.63)		(5.68)
Δ Wells Drilled, Adj. Counties		24.21		5.06***		19.15
		(26.79)		(1.26)		(26.37)
N	11824	11824	11824	11824	11824	11824

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. Shale counties are as defined in the text – counties with an increase from 2000 to 2013 in the combined quantity of oil and gas produced. Metropolitan counties are based on the Office of Management and Budget classifications based on the 2000 Census.

Robustness to Excluding High Royalty Growth Counties

Table A5: Robustness of Multiplier Estimates to Dropping High Royalty Growth Counties

	Excluding Counties in the Top __ Percent for Royalty Growth				
	0 %	0.5 %	1.0 %	1.5 %	2.0 %
Δ Royalties	1.52**	1.70*	1.50	2.29**	1.69*
	(0.52)	(0.78)	(0.84)	(0.79)	(0.76)
Δ Mining Earnings	0.89	1.00	0.95	0.98	0.40***
	(0.48)	(0.53)	(0.53)	(0.56)	(0.12)
Δ Mining Earnings, t-1	-0.01	-0.01	-0.01	-0.01	-0.00
	(0.02)	(0.02)	(0.02)	(0.02)	(0.01)
Δ Mining Earnings, Adj. Counties	0.24	0.29	0.38	0.29	0.50*
	(0.23)	(0.24)	(0.24)	(0.26)	(0.20)
Δ Wells Drilled	18.77	13.57	1.50	0.97	29.97*
	(11.25)	(23.91)	(15.71)	(18.76)	(13.14)
Δ Wells Drilled, t-1	3.20	2.68	-0.12	0.27	-4.51
	(6.20)	(2.91)	(2.16)	(2.70)	(8.02)
Δ Wells Drilled, Adj. Counties	25.14	25.68	-0.61	-7.63	-1.97
	(26.62)	(27.60)	(7.97)	(7.83)	(4.53)
N	11824	11768	11708	11648	11588

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. For four trimmed regressions, the first stage F-statistic on the instrument is 113, 46, 27, and 18.

Appendix: Data Construction and Notes

Basic Construction

Private data provider DrillingInfo supplied data on oil and gas leases across the United States.[8] We processed this data to focus on private mineral ownership in 17 states: Arkansas, California, Colorado, Kansas, Louisiana, Michigan, Missouri, Montana, New Mexico, North Dakota, Ohio, Oklahoma, Pennsylvania, Texas, Utah, West Virginia, and Wyoming. Each observed lease contains important details about contractual terms, including location, year of effect, length of primary term, royalty rate, and in some select cases, bonus payment. Importantly, the observations also include information on the address of the mineral owner, which allows computation of our local ownership measures.

Mineral leases are effectively option contracts; 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 recorded as leases rather than assignments. These transactions were identified by text matching.

Another concern about leasing data is that multiple instruments 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 instrument if several different owners signed leases to the same mineral property that were effective simultaneously.

After cleaning to data to include only active primary leases without duplication, we defined the county as a pertinent leasing market. Weighting the different leases we observed by their acreage, we calculated county-level average royalty rates to capture cross-sectional variation in the prevailing royalty rate. We observe the ZIP code of both the grantor (mineral owner) and the grantee, so for each county where we observe leases, we were able to create acre-weighted measures of where royalty flows are due from production in each county. Because ZIP codes are subsets of counties and states, we constructed measures of county-level NPRI (net private royalty interest) for each potential recipient county. Counties can then be aggregated to the state level.

Publicly-Owned Minerals

In many states oil and gas production occurs on minerals owned by either the federal or the state government, or both. The share of overall production obtained from these publicly-owned minerals varies substantially from state to state. In order to properly 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 sampled 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.[9]

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

[9] 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`.

For state-owned minerals, we collected information from each individual state that owns acreage that is 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 sample states 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, Montana, New Mexico, North Dakota, 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.[10] 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 is obtained from the State Land Board Department of Natural Resources for years 2011 and 2012.[11] The department's Mineral Auditor provides the state royalty share of production. The royalty share is 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.[12] 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.[13]

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

Michigan

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. We divide 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 are obtained by multiplying the state shares of oil and gas production by their respective annual average prices.

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.[14] 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.[15] 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.[16] Production volume data for 2007-2012 is provided by the department's Land and Minerals Professional. The department's Revenue Compliance Director supplies royalty revenue information for years 2010-2012.

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.[17] We obtain GLO production data from the Energy Resources Mineral Leasing

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

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

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

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

Contact at the General Lands Office.[18] We aggregate PUF and GLO data and construct aggregate measures of oil and gas production and royalty revenues from state-owned minerals. Condensate, oil, and gas production volumes are obtained for years 1990-2012 while royalty revenues from oil and gas are limited to 2000-2012.

Utah

The State of Utah School and Institutional Trust Lands Administrations tracks oil and gas royalty revenues from state-owned minerals and does not track production volumes. The Utah Division of Oil, Gas & Mining provided county-year production volumes by mineral ownership type.

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.[19] The Wyoming Oil and Gas Conservation Commission collects oil and gas production numbers and reports production volumes on their website.[20] We obtain oil and gas production volumes by year for the window 2000-2014.

Calculation

Private Production

In order to establish royalty flows, aggregate annual production of oil and gas from private minerals was imputed. Aggregate production is the sum of private, state, and federal production. We imputed the production levels on an annual basis, at both state and county levels of aggregation. Because state mineral production was typically reported to us at the state level, we allocated that production across counties. Where we received data disaggregated to the county-year level, we used it.

Private Revenue

To establish gross revenue at the wellhead, we multiplied private mineral production figures for oil and natural gas by annual state-specific wellhead (for natural gas) or first purchase prices (for oil), in states where those series were available from EIA. For states that do not have their own series, we used the U.S. natural gas wellhead prices, and the U.S. First Purchase Price (excluding Alaska North Slope). For states that had their own series, but the series were discontinued for later years, we estimated the average basis differentials between the state wellhead value and benchmark prices (WTI Cushing for oil and Henry Hub for natural gas), and assumed that those basis differentials did not change during later years. This gives an aggregate gross revenue for each state and county in each year.

[18] http://www.glo.texas.gov/
[19] http://lands.wyo.gov/
[20] http://wogcc.state.wy.us/

Royalty Flows

To establish flows of gross royalties between states or counties, the observed-acre-weighted royalty rate was calculated for each producing-receiving pair. Then the receiving location was assigned a weighted share of production from each originating location. These weights necessarily summed to one to provide for the allocation of all production revenues. Once the weights were established, gross revenue from each producing region was allocated into revenue flows. The revenue flows to various counties can then be used to create ratios of received royalties to production at different spatial scales.