HEADWATERS ECONOMICS

Long-term effects of income specialization in oil and gas extraction: the U.S. West, 1980-2011

Published in the Journal of Energy Economics
Haggerty, J., P.H. Gude, M. Delorey, and Rasker, R. 2014. Long-term effects of income specialization in oil and gas extraction: The U.S. West, 1980-2011. Energy Economics 45: 186-195

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Abstract

The purpose of the study is to evaluate the relationships between oil and natural gas specialization and socioeconomic well-being during the period 1980 to 2011 in a large sample of counties within the six major oil- and gas-producing states in the interior U.S. West: Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming. The effects of participation in the early 1980s oil and gas boom and long-term specialization were considered as possible drivers of socioeconomic outcomes. Generalized estimating equations were used to regress 11 measures of economic growth and quality of life on oil and gas specialization while accounting for various confounding factors including degree of access to markets, initial socioeconomic conditions in 1980, and dependence on other economic sectors. Long-term oil and gas specialization is observed to have negative effects on change in per capita income, crime rate, and education rate. Participation in the early 1980s boom was positively associated with change in per capita income; however the positive effect decreases the longer counties

remain specialized in oil and gas. Our findings contribute to a broader public dialogue about the consequences of resource specialization involving oil and natural gas and call into question the assumption that long-term oil and gas development confers economic advantages upon host communities.

1. Introduction

The shale oil and gas boom has introduced a new phase of extractive commodity development to many different parts of the United States. Rapid drilling and related extensive industrial development are underway in parts of Pennsylvania, North Dakota, Texas, Louisiana, Oklahoma, Colorado, and New Mexico, while shale-rich states in regions from the Central Atlantic to the Midwest to the California Coast are anticipating the arrival of local shale booms.

The shale boom has been a source of jobs in a challenging economic period, but oil and gas drilling is not without their challenges for local areas. Residents of areas that host energy development often welcome the immediate employment associated with oil and gas development, and at the same time wonder about long-term tradeoffs related to the risk of negative impacts to local environmental amenities and quality of life, along with the direct economic risks of an eventual bust. Understanding and managing these tradeoffs for long-term community prosperity is a common goal of local government efforts. For example, a county commissioner from the Bakken region in North Dakota said in 2012, "A few years ago, [we] set a goal that Mountrail County would be a better place to live and work as this oil play works itself out over the next 30 years."[1]

In this context, understanding the long-term social and economic impacts of oil and gas development on local economies has tremendous importance. The research described in this paper contributes to the body of literature concerning the influence of oil and gas activities on key measures of local socioeconomic well-being, such as income, education, and crime rates. While resource economists and sociologists have tackled these questions from different angles, results are mixed and inconclusive with regard to long-term outcomes.

This study uses a regional economic lens to address long-term trends. Specifically, our analysis uses a statistical approach to evaluate the relationships between oil and gas specialization and socioeconomic well-being during the period 1980 to 2011 in a large sample of counties within the six major oil- and gas-producing states in the U.S. West: Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming. This geographically contiguous cohort of states has hosted multiple episodes of significant oil and/or natural gas development activities, including high levels of participation in the oil and gas activity buildup during the energy boom of the late 1970s and early 1980s. Taken together, the latest available rankings show that this group of states produces more than 75 percent of crude oil and more than 95 percent of natural gas in the contiguous West (US EIA, 2013).

Our approach makes a concerted effort to control for and better understand the variety of factors that could lead to different experiences with energy development. We acknowledge the demands from econometricians for statistically robust approaches for evaluating differences in economic performance (Moretti 2010). Our approach also responds to mining impact analyses that have emphasized the many contingencies affecting local experiences of energy development (Deller and Scheiber, 2012; Freudenburg and Wilson, 2002; Nord and Luloff, 1993; Wilson, 2004; Jacquet and Kay, n/d).

[1] Commissioner Dave Hynek, quoted in, Oldham, J. 2012. "North Dakota's Oil Boom Strains its Infrastructure." *Bloomberg Businessweek Magazine* Feb. 2, 2012. Accessed online 10/17/2013: http://www.businessweek.com/magazine/north-dakotas-oil-boom-strains-its-infrastructure-02022012.html.

1.1. Conceptual framing and relevant literature

There is a large body of literature addressing the social and economic consequences of specialization in natural resource extraction. Both the rural sociology and resource economics disciplines have made contributions to this area of inquiry through consideration of the economic phenomenon known as the 'resource curse' and, in rural sociology, framings of boom-bust economies and the social disruption model. Regional economists have also recently begun to focus research on this topic (Court, et. al. 2012). Our approach uses a regional economics lens while also building on insights from resource economics and sociology.

As Weber's recent summary of relevant literature in this journal observes, the resource curse—the empirical observation that resource dependence depresses long-term GDP growth relative to diversified economies—is well-established as a feature of many national economies (Frankel, 2012; Freudenburg, 1992; Weber, 2012) and has also been identified at the state and county-level in recent studies of the United States (James and Aadland, 2010; Papyris and Gehrlagh, 2007; Zuo and Schieffer, 2013). At the national scale, the conceptual model focuses primarily on two related dynamics: 1) the tendency for specialization in commodities to undermine the competitiveness of non-commodity export sectors and 2) the influence of institutions on the degree of lost competitiveness and in mitigating other issues such as income disparity and political conflict. However, whether some version of a resource curse phenomenon has in the past been associated with or may still apply to oil and gas extraction at local scales in the United States, and if so, what might drive it, remain open questions.

Four recent econometric studies fail to find evidence of the resource curse in county-level economic indicators oil and gas development. Three are studies of the recent natural gas boom. Only one considers a longer-term perspective. Weber (2012) examines the relationship between natural gas production and county-level measures of economic performance in Colorado, Texas, and Wyoming during the natural gas boom of the 2000-2008 period. The study found that while natural gas production led to gains in employment and income, recent input-output based modeling efforts have significantly overestimated the number of jobs that can be attributed to shale gas production. Similar findings resulted in Weber's second study of 362 non-metro counties in Oklahoma, Texas, Louisiana, and Arkansas during the period 2000-2010 as well as Brown's inquiry into 647 non-metro counties in Oklahoma, Texas, Louisiana, Arkansas, New Mexico, Colorado and Wyoming for the period 2000-2011. In the two latter studies, both Weber and Brown fail to find evidence of a crowding out effect in terms of the relationship between mining employment and other sectors including manufacturing. The only observable concern in terms of socioeconomic performance is Weber's discovery of some evidence unequal distribution of the income benefits associated with the shale boom in his Colorado, Texas, and Wyoming 2000-2008 sample (Weber, 2012: 1586).

Michaels' (2011) study of oil-abundant counties in the U.S. South over the period 1890-1990 estimates the relationship between oil abundance (in terms of geologically proven reserves) and a variety of county-level economic metrics. This study finds a positive relationship between oil abundance and income, and between oil abundance and manufacturing density. Michaels argues that this is evidence of an agglomeration benefit to manufacturing industries associated with the presence of strong labor productivity, itself an offshoot of oil-related high per capita income levels. He also finds evidence of beneficial impacts of oil abundance on the presence of critical infrastructure such as airports. His study suggests some of the conditions under which fossil fuel abundance can be beneficial to regional development. A major feature of the region he studies (the oil-rich southern states) is the concentration of both extraction and refining activities there, a situation that could explain encourage the agglomeration effects he notes. In the American West, infrastructure is dispersed, and many oil and gas products are exported out of the region unrefined. Furthermore, manufacturing has had at best a minor role in economic growth trajectories in the non-metro U.S. West for the period 1980-2011. These differences suggest at minimum, the value of an inquiry unique to the Western region and a time period covering two major boom-bust cycles.

Standing in contrast to the recent regional econometric studies of the resource curse is the large body of sociological literature documenting negative socioeconomic effects as a result of specialization on resource extraction (see Peluso et. al. 1992). However, most energy-focused analyses are detailed case studies of particular places and times., there were few detailed studies of energy industries and they yielded mixed results. Considering the period 1969-1985, Weber, Castle, and Shriver (1987) found energy-related mining had positive impacts on employment growth and earnings, while metal mining had negative impacts. Nord and Luloff's 1993 study suggested that the West did not show declines in employment and income as significant as other U.S. regions experienced in the energy bust of the 1980s. Black et al. (2005) considered the impact of the 1970s-1980s coal boom-bust cycle in the Appalachian coal region and observed that rapid job growth during the period exceeded losses during the bust, suggesting a net positive outcome. However, the study also found that any improvements in poverty rates associated with the boom were lost during the bust. The latter finding reinforces other studies of Appalachia that suggest that coal mining has lessened rather than improved total quality of life, particularly when health and educational metrics are considered (cf. Hendryx, 2011).

When Freudenburg and Wilson (2002) reviewed 301 quantitative studies about the socioeconomic performance of mining (including but not limited to coal and oil and gas extraction) areas as compared to non-mining areas in the United States, they concluded that available research did "not support the widespread expectation that mining can be expected to increase the prosperity of isolated rural communities" (ibid., 571). They noted evidence in the literature that economic problems in mining communities become increasingly pronounced over time, exacerbated by the volatility of commodity prices, the potential for cost-price squeeze, and "flickering," or the periodic shut-downs in operations due to prices fluctuating below operations costs.

Our research approach is informed not only by studies on the impacts of resource specialization on economic performance, but also by sociological studies on impacts of oil and gas activities on metrics of social well-being, such as educational attainment and crime rates (Krannich et al., 1985; Krannich and Luloff, 1991). In this literature, the boomtown social disruption model has influenced interpretations of energy booms since it first emerged in the late 1970s (Gilmore, 1976; for summaries see Jacquet, 2009 and Jacquet and Kay, n.d.). One concern about the social disruption literature is the challenge of putting the many observable negative boom impacts into longer-term context due to the failure to collect data before and after the boom. Brown's repeat surveys in Delta, Utah, a major coal-mining area, suggested that a boom-bust-recovery cycle characterized social dynamics, at least in regard to community satisfaction and social integration in Delta (Brown et al., 2005).

Taken together, the existing literature suggests that the long-term community effects of specialization in oil and gas development merit further attention. The importance of considering time periods that include both boom and bust cycles cannot be overstated. As described below, our methods go to some effort to explore the interaction between boom and bust cycles, long-term specialization, and socioeconomic outcomes. We submit that further empirical evaluations of basic performance metrics are necessary to assess the presence or absence of discernible effects of energy specialization on economic performance before analysts can begin to even consider questions about causation. Similarly, understanding long-term social impacts is limited to a small number of studies. For these reasons, our analysis focuses on basic testable hypotheses about the possible outcomes of oil and gas development at the local scale suggested but yet not established by the literature for the U.S. West. Our hypotheses are:

1) Greater specialization in oil and gas over the long term leads to diminished economic performance.
2) A significant presence of oil and gas extractive activities is associated with diminished performance in other metrics of local well-being, such as crime rates, health, and education.

The data and methods described below address these hypotheses empirically for a large sample of counties in six states. The sample, timeframe, and statistical approach allow us to evaluate the unique influence of oil and gas specialization on local economies.

2. Data and Methods

The study focused on counties within the six major oil- and gas-producing states in the U.S. West, excluding those counties for which historic data on income from oil and gas extraction was not available. The counties studied included 207 of the 258 counties in the following western states: Colorado, Montana, New Mexico, North Dakota, Utah, and Wyoming. Counties offer the best scale of analysis because they are the smallest geographic unit for which long-term data on a variety of economic and social metrics are available. The county sample included some with no reliance on oil and gas development, others where oil and gas production has been the dominant economic sector, and others where oil and gas development has occurred within a diverse economy.

2. 1 Oil and gas influence (explanatory variables)

The statistical analyses in this study focused on determining whether or not the level of influence of oil and gas extraction on income has been associated with increases or decreases in county socioeconomic well-being. We defined two oil and gas explanatory variables using data from the Bureau of Economic Analysis' Regional Economic Information System (REIS) (U.S. Department of Commerce, 2012). A "Boom" variable was defined as the average percent of income from oil and gas during 1980, 1981, and 1982 (Figure 1). A "Duration" variable was calculated as the count of years, from 1980 to 2011, in which the percent of personal income from oil and gas extraction in an individual county exceeded the annual average for the sample counties (i.e., a count of years in which the location quotient value is greater than one) (Figure 2). A "Volatility" variable, calculated as the standard deviation in the annual percent of income from oil and gas extraction from 1980 to 2011, was considered but dropped due to its high correlation with the boom variable. The definitions we employed for the oil and gas explanatory variables were carefully selected to avoid the use of arbitrary thresholds or groupings that can result in a loss of information and/or biased results.

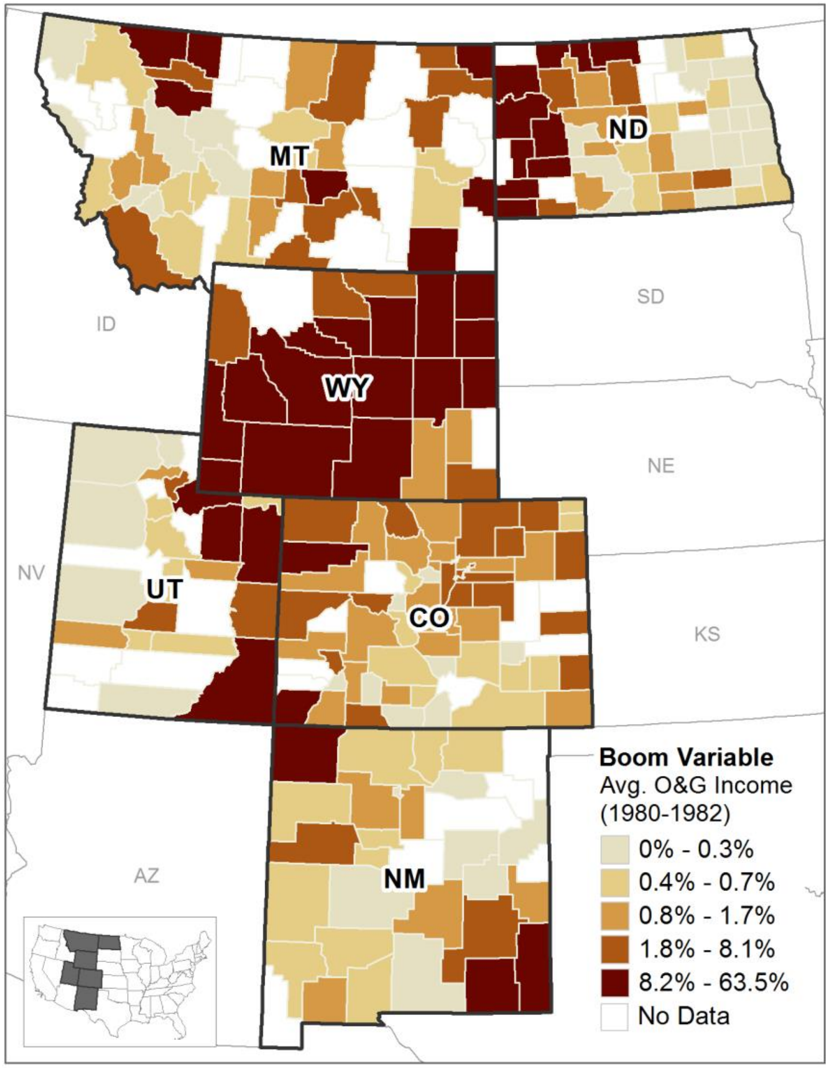

FIGURE 1. The “Boom” oil and gas extraction explanatory variable was calculated as the average percent of personal income from oil and gas extraction from 1980 to 1982.

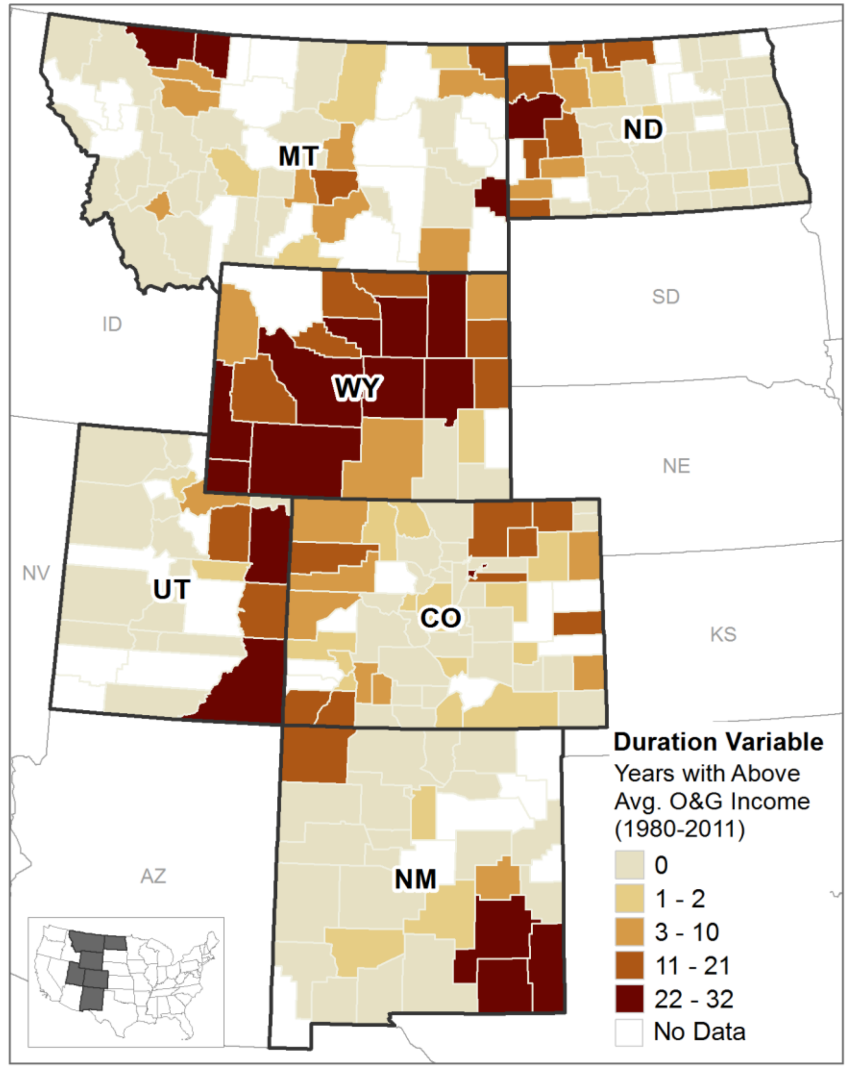

FIGURE 2. The “Duration” oil and gas extraction explanatory variable was calculated as the count of years, from 1980 to 2011, in which the percent of personal income from oil and gas extraction was above the annual average for the sample counties.

For the “Boom” variable, the period 1980-1982 was selected because it contained the highest share of personal income from oil and gas for each of the six study states (Figure 3). The data were obtained from REIS Table CA05, Linecodes 230 (oil and gas extraction income) and 10 (total personal income). Counties for which no oil and gas extraction income data were disclosed by REIS during 1980-1982 were excluded from the analysis.[2]

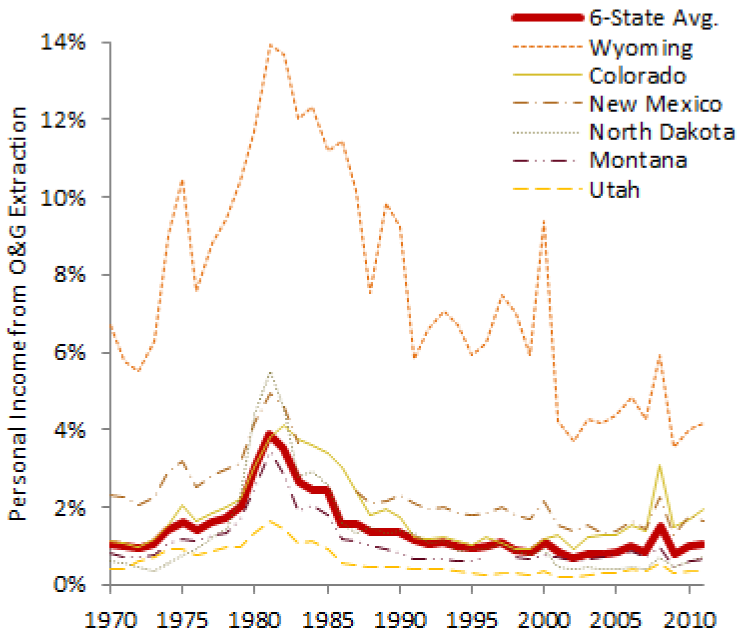

FIGURE 3. The “Boom” variable was defined as the average percent of personal income from oil and gas extraction from 1980 to 1982 because this period contains the highest share of income from oil and gas for each of the six energy-developing states in the West.

The “Duration” oil and gas extraction explanatory variable was calculated as the count of years, from 1980 to 2011, in which the percent of personal income from oil and gas extraction was above the annual average for the sample counties. For example, if County X had five percent of personal income from oil and gas extraction in 1980, and the average percent of personal income from oil and gas extraction for the sample counties in 1980 was two percent, County X was assigned a “1”. The value of “Duration” for County X was calculated by summing the binary values over the 32-year period, such that the possible values of “Duration” range from zero to 32. The data were obtained from REIS Table CA05, Linecodes 230 (oil and gas extraction income) and 10 (total personal income) for

[2] There are two main situations in which REIS withholds personal income from oil and gas extraction: (1) When a small enough number of oil and gas extraction firms exist so that reporting county oil and gas income totals could be equivalent to reporting data for the firms themselves, which violates privacy laws; and (2) When a similar situation has occurred in another industry, and oil and gas income has been withheld randomly so that the income of the firms in question cannot be deduced by subtracting all reported income from total personal income. In the case of oil and gas extraction, an exploratory comparison with county-level production data in Montana shows that the lack of reported data appear to be distributed relatively evenly across quartiles of production. The non-disclosed data are unlikely to have biased the results in a predictable way since counties with little to high amounts of oil and gas activity are adequately represented in the sample. That REIS introduces a random element to non-disclosures also makes it unlikely that the exclusion of counties for which data were not reported biased the results.

1980 through 2000. The data for 2001 through 2011 were obtained from REIS Table CA05n, Linecodes 201 (oil and gas extraction income) and 10 (total personal income). Beyond those counties for which insufficient data were available for calculating the "Boom" variable, no additional counties were dropped from the study due to non-disclosed data affecting the "Duration" variable.

We selected these explanatory variables rather than production-related variables since our objective was to represent degrees of local economic influence of oil and gas. The data source for both explanatory variables was REIS which reports income by place of work. Higher levels of personal income from oil and gas extraction are synonymous with higher levels of influence of oil and gas activity in the local economy.

2.2 Socioeconomic measures (response variables)

Eleven variables were identified as being representative of overall county socioeconomic well-being (Table 1). For all 11 variables, we analyzed either the change from 1980 to 2011 (2011 being the latest year for which the data were available), or the average characteristic during this period. The data source for the five traditional economic growth measures is REIS. Sources for responses related to quality of life include the U.S. Census Bureau's American Community Survey, the Decennial Census, the Bureau of Labor Statistics' Local Area Unemployment Statistics, and the Federal Bureau of Investigation's Uniform Crime Reports. We used the consumer price index to adjust all dollar amounts to 2012 dollars prior to making other calculations.

Per capita income (PCI), average earnings per job, total employment, and total income were obtained from REIS Table CA30, Linecodes 110, 290, 240, and 10, respectively. Investment income was obtained from REIS Tables CA05 and CA05n, Linecode 46 (dividends, interest, and rent). These variables were represented as the change from 1980 to 2011. Crime rate (Federal Bureau of Investigation, 2012) and unemployment rate (U.S. Department of Labor, 2013) were averaged across the 1980-2011 period because data gaps and changes in methods make change over time calculations problematic for these variables. For example, the U.S. Bureau of Labor Statistics does not consider their pre-1990 estimates of unemployment rates to be comparable to the 1990 and forward estimates due to changes in methodology. College education, poverty, rent >35% of household income, and Gini coefficient for 2011 were obtained from the American Community Survey (ACS) (U.S. Department of Commerce, 2012). These values result from a five-year survey, and are representative of average characteristics during 2007-2011. These data were used as a proxy for present-year conditions because five-year ACS estimates tend to report higher accuracy for rural areas, making them ideal for cross-geography comparisons. For 1980 data, we obtained variables from the Decennial Census of Population and Housing (U.S. Department of Commerce, 1980). Gross rent >35% of household income was used to represent housing affordability and the Gini coefficient was used to represent income distribution. Education was used as a measure of the quality of human resources and the potential for economic development since many high-wage occupations such as engineering, architecture, finance, and health care require college-educated workers.

Table 1. Variables used to determine whether specialization in oil and gas is associated with increased or decreased county socioeconomic measures within the six major oil- and gas-producing states in the U.S. West. Variable types are as follows: E = Explanatory, R-T = Response - Traditional Economic Growth Measure, R-Q = Response - Quality of Life Measure, C = Confounder.

Variable	Average	Std. Dev.	Type	Source
Boom: Avg. % of Income from O&G (1980-1982)	5.3%	9.5%	E	REIS*
Duration: Count of Years in which Income from O&G was Above Avg. (1980-2011)	5.3	8.8	E	REIS*
Change in Per Capita Income (2011 minus 1980)	$18,017	$12,989	R-T	REIS*
Change in Avg. Earnings Per Job (2011 minus 1980)	$8,610	$16,578	R-T	REIS*
Change in Total Employment (2011 / 1980)	1.8	1.5	R-T	REIS*
Change in Total Income (2011 / 1980)	$2.3	$1.7	R-T	REIS*
Change in Per Capita Investment Income (2011 minus 1980)	$8.9	$51.8	R-T	REIS*
Unemployment Rate, Count of years in which UNR was > National Avg. (1980-2011)	8.0	8.9	R-Q	BLS**
Change in % of Adults with College Education (2011^ minus 1980)	8.2%	4.7%	R-Q	ACS***
Change in % of Individuals in Poverty (2011^ minus 1980)	-1.0%	5.9%	R-Q	ACS***
Change in % of Renter-Occupied Units With Gross Rent >35% of Household Income (2011^ minus 1980)	6.6%	10.6%	R-Q	ACS***
Change in Income Distribution (Gini Coefficient) (2011^ minus 1980)	0.07	0.04	R-Q	ACS***
Avg. Violent and Property Crimes per 1000 People (1980-2011)	13.7	8.6	R-Q	FBI
State	na	na	C	US CB
Per Capita Income (1980)	$23,530	$6,484	C	REIS*
Avg. Earnings Per Job (1980)	$32,390	$12,191	C	REIS*
Total Employment (1980)	17574.6	48749.6	C	REIS*
Total Income (1980)	$897,881	$2,309,748	C	REIS*
Per Capita Investment Income (1980)	$6.7	$8.4	C	REIS*
Unemployment Rate (1980)	5.8	3.2	C	BLS**
% of Adults with College Education (1980)	15.2%	6.9%	C	ACS***
% of Individuals in Poverty (1980)	14.6%	6.8%	C	ACS***
% of Renter-Occupied Units With Gross Rent >35% of Household Income (1980)	25.3%	7.6%	C	ACS***
Income Distribution (Gini -Lower is better) (1980)	0.36	0.04	C	ACS***
Violent and Property Crimes per 1000 People (1980)	33.1	24.1	C	FBI

Avg. % of Income in Farming (1980-2011)	9.8%	24.1%	C	REIS*
Avg. % of Income in Timber (1980-2011)	0.6%	1.9%	C	REIS*
Avg. % of Income in Other Mining (1980-2011)	1.3%	3.4%	C	REIS*
% of Basin that is Private Land	27.8%	37.3%	C	US EIA
Mean Std. Dev. Elevation	230	164	C	US GS
% of Housing Units that are Seasonally Occupied	12.0%	13.2%	C	ACS***
Avg. Airport Travel Time	198	86	C	Rasker et al. (2009)

* US Department of Commerce (2012). Bureau of Economic Analysis, Regional Economic Information System

** U.S. Department of Labor (2013). Bureau of Labor Statistics, Local Area Unemployment Statistics

*** U.S. Department of Commerce (2012). Census Bureau, American Community Survey Office

^ ACS data calculated using annual surveys conducted during 2007-2011 and are representative of average characteristics during this period.

2.3 Confounding variables

Nineteen variables were identified as possibly confounding associations between the oil and gas explanatory variables and the socioeconomic response variables (Table 1). The state was included as a confounding variable since state policies can affect the socioeconomic outcomes of oil and gas development. Values in 1980 for all 11 responses were also included as confounding variables since growth factors are not independent of initial conditions. Five variables were used to represent the presence of natural amenities, and dependence on timber, agriculture, and other mining activities. These factors result in predictable socioeconomic outcomes that may affect or obscure outcomes related to oil and gas extraction. Access to major airports also has a demonstrated effect on differential economic performance in rural areas in the U.S. West (Rasker et al., 2009) and was represented as the mean drive time to the nearest major airport, calculated following the methods of Rasker et al. (ibid.). Finally, the percent of the oil and gas basin, a geographic information systems layer obtained from the US Energy Information Administration, that intersects private land was used as a proxy for the potential for private landowners to derive income from oil and gas royalties. Socioeconomic outcomes of oil and gas extraction may differ depending on whether the resource is primarily on public or private land. These variables were controlled for to improve our ability to detect a true association between the oil and gas extraction variables and the socioeconomic response variables.

2.4 Statistical analyses

All statistical analyses were performed using R version 3.0.1. Principal components analysis (PCA), a variable reduction procedure, was used to reduce the number of quantitative confounding variables (i.e., excluding state) into a smaller number of principal components (sometimes called “artificial” variables) that account for most of the variance in our confounding variables. The principal components that explained a cumulative 85% of the variability in the complete set of quantitative confounding variables were included in the analysis. Variable reduction was used since we had a large number of confounding variables and models with large numbers of explanatory variables generally yield less precise coefficient estimates. Since we wanted to control for the effects of the confounders, but were not interested in interpreting their specific effects, PCA was used to lower the number of variables and, therefore increase the precision of the coefficient estimates for the explanatory variables of interest (“Boom” and “Duration”).

The matrix of socioeconomic variables was vectorized, and this vector of socioeconomic variables was regressed on the set of confounding variables and oil and gas variables using generalized estimating equations (GEE) (Liang & Zeger, 1986) assuming a normal distribution. GEE is a semiparametric estimation method that is an attractive alternative to likelihood-based solutions to generalized, mixed-effects models when the within-subject (in our case, the within-county) correlation structure does not need to be estimated. GEEs have consistent and asymptotically normal solutions, even with misspecification of the correlation structure. The working covariance structure accounted for the correlation among variables from the same county and heteroskedasticity among the different socioeconomic variables. Oil and gas variables were standardized prior to performing the regression. Standard diagnostics were performed to ensure that distributional assumptions were reasonable and that model residuals exhibited no unusual patterns.

The regression equation used is:

$$\begin{aligned} y_{ij} = \beta_0 &+ (\boldsymbol{Z\lambda})_{\boldsymbol{ij}} + (\boldsymbol{X_{econ}\beta_{econ}})_{\boldsymbol{ij}} + \beta_{boom}X_{boom(ij)} + \beta_{dur}X_{dur(ij)} + (\boldsymbol{X_{econ}\beta_{econ*boom}})_{\boldsymbol{ij}}X_{boom(ij)} \\ &+ (\boldsymbol{X_{econ}\beta_{econ*dur}})_{\boldsymbol{ij}}X_{dur(ij)} + \beta_{boom*dur}X_{boom(ij)}X_{dur(ij)} \\ &+ (\boldsymbol{X_{econ}\beta_{econ*boom*dur}})_{\boldsymbol{ij}}X_{boom(ij)}X_{dur(ij)} + \alpha_i + \epsilon_{ij}, \end{aligned}$$

where y_{ij} is the *jth* economic indicator observed in county *i*; $\boldsymbol{Z}$ is a matrix of principal components; $\boldsymbol{\lambda}$ is a vector of coefficients for the principal components; $\boldsymbol{X_{econ}}$ is a matrix of indicator functions specifying which economic variable y_{ij} represents; $(\boldsymbol{X_{econ}\beta_{econ*boom}})_{\boldsymbol{ij}}X_{boom(ij)}$ represents the 2-way interaction between the economic variable indicator and the Boom variable; $(\boldsymbol{X_{econ}\beta_{econ*dur}})_{\boldsymbol{ij}}X_{dur(ij)}$ represents the 2-way interaction between the economic variable indicator and the Duration variable; $(\boldsymbol{X_{econ}\beta_{econ*boom*dur}})_{\boldsymbol{ij}}X_{boom(ij)}X_{dur(ij)}$ represents the 3-way interaction between the economic variable indicator, the Boom variable, and the Duration variable; $\boldsymbol{\alpha}$ is a 0-mean vector of random effects for counties with a block-diagonal working covariance structure; and the ϵ_{ij}'s are independent, normally distributed random error terms.

3. Results

Of the 207 counties included in this analysis, most have seen little oil and gas development: 99 counties (48% of the sample) had less than one percent income from oil and gas extraction during 1980-82 (boom) and less than or equal to one year in which the percent of income from oil and gas was above the annual average (Duration). The distribution of counties relative to both Boom and duration variables is shown in Figure 4. Only 11 counties within the sample had Boom values greater than 20 percent and duration values greater than 20 years: Rio Blanco County, CO; Fallon County, MT; Musselshell County, MT; Lea County, NM; McKenzie County, ND; Williams County, ND; Uintah County, UT; Johnson County, WY; Natrona County, WY; Uinta County, WY; and Weston County, WY. Of these counties, Natrona County is classified by the Census Bureau as a metropolitan statistical area; Uinta County (WY), Uintah County (UT), Williams County, and Lea County are classified as micropolitan statistical areas; and the remaining counties are classified as rural.

3.1 Statistical analyses

The information contained in the 18 quantitative confounding variables was reducible to eight principal components. The eight components preserve 86% of the variability of the original eighteen variables. Regression involving the set of confounding variables used the first eight principal components of the quantitative confounding variables.

To aid with the description and interpretation of the results in this section, we will refer to specific levels of Boom and Duration that correspond to the quintile breakpoints. When divided into quintiles based on the Boom variable, the sample is grouped as follows: 0 to 0.3 percent, 0.3001 to 0.7 percent, 0.7001 to 1.7 percent, 1.7001 to 8.1 percent, and 8.1001 to 63.5 percent. The breakpoints between these groups are: 0.3, 0.7, 1.7, and 8.1 percent. When divided into quintiles based on the Duration variable, the sample is grouped as follows: 0 years, 0.0001 to 2 years, 2.0001 to 10 years, 10.0001 to 21 years, and 21.0001 to 32 years. The quintile breakpoints for Duration are therefore: 0, 2, 10, and 21 years.

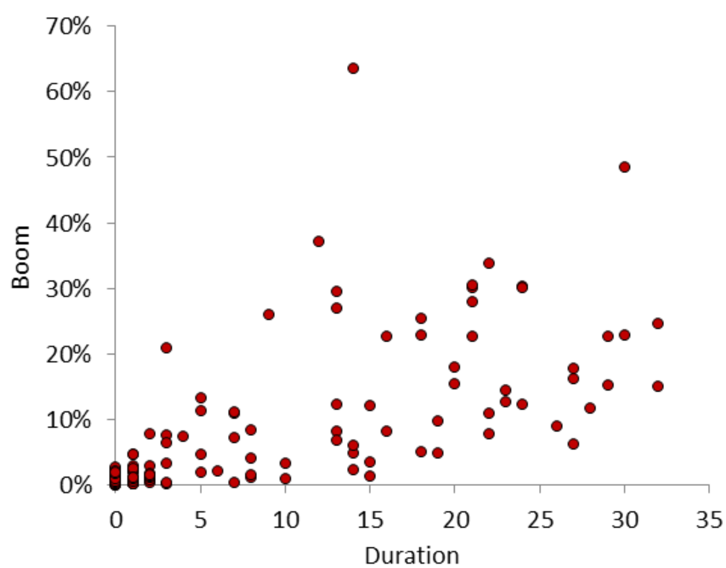

FIGURE 4. The sample counties are shown in a scatterplot of the "Boom" variable, the average percent of personal income from oil and gas during 1980-82, versus the "Duration" variable, the count of years from 1980 to 2011 in which the percent of personal income from oil & gas was above the annual average within the sample.

The interaction between Duration and Boom is statistically significant (p=0.04). Therefore, the change in any socioeconomic variable associated with an increase in Duration varies with the level of Boom, and vice-versa. Examples of these relationships, shown for levels of Boom and Duration corresponding to their quintile breakpoints, can be seen in Table 2. Due to the space required to report estimates and standard errors for models involving interactions, we show results only for the three responses for which "Boom" and "Duration" were significant predictors.

Three of the socioeconomic variables were found to be statistically associated with the duration of oil and gas development: change in per capita income, average violent and property crimes per 1,000 people, and change in percent of adults with a college education (Table 2a). The magnitude of the association depends upon the percent of income a county derived from oil and gas during the 1980-82 boom. In the following paragraphs, we describe scenarios to help with the interpretation of Table 2. The values described as expected outcomes reflect 95 percent confidence intervals.

To interpret the first confidence interval ("-$6070 to 1700") in Table 2a, consider an example of two counties, similar in every way with the exception of the number of years that income from oil and gas was above average. Imagine that both counties had low participation during the 1980-82 boom (0.3 percent of income from oil and gas), however the duration of above average income from oil and gas was 10 years longer in one of the counties. We would expect change in per capita income (1980 to 2011) in the county with 10 years longer duration to be anywhere from $6,070 lower to $1,700 higher. This estimated effect overlaps zero and is therefore not significant.

Now, consider another scenario to illustrate the interpretation of the significant confidence interval ("-$7000 to -340") in the same column of Table 2a. Imagine two counties, similar in every way, both with a high boom income of 8.1 percent. The only difference between these hypothetical counties is that the duration of above average income from oil and gas was 10 years longer in one of the counties. We would expect change in per capita income (1980 to 2011) in the county with 10 years longer duration to be $340 to $7,000 lower than in the otherwise identical county.

These results suggest that for counties where oil and gas initially contributes a low share of income, longer-term specialization in oil and gas has little effect on change per capita income. On the other hand, for counties with higher initial shares of income from oil and gas, longer-term oil and gas specialization has a negative effect on change in per capita income.

Similar scenarios can be applied to the crime rate and education variables in the second and third columns of Table 2a, respectively, to see that the effect of longer-term specialization in oil and gas depends upon a county's initial income from oil and gas. The results indicate that the average number of violent and property crimes per 1,000 people increases with increased length of specialization in oil and gas but increases at a faster rate for counties whose boom income was higher. Also, we find that among counties with high levels of boom income, growth in the percent of college-educated adults decreases with increasing duration.

Two of the socioeconomic variables were found to be statistically associated with the percent of income a county derived from oil and gas during the 1980-82 boom: change in per capita income and average violent and property crimes per 1000 people (Table 2b). The magnitude of these associations depends upon the duration of above average income from oil and gas.

Similar scenarios can be used to interpret Table 2b. To interpret the first confidence interval ("$374 to 2594") in Table 2a, consider two counties, neither of which had above average oil and gas income in any year. Imagine that one county has a boom income 1.7 percent higher, but that the two counties are otherwise identical. We would expect change in per capita income in the county with 1.7 percent higher boom income to be $374 to $2,594 higher.

Table 2. Estimated relationships at selected intervals (quintile breakpoints) of "Boom" and "Duration" are reported for the three responses for which "Boom" and "Duration" were significant predictors. The results are presented this way since the significant interaction (p=0.04) between "Boom" and "Duration" indicates that "Boom" has a different effect on the socioeconomic responses depending on the values of "Duration", and vice versa. The reported ranges represent 95% confidence intervals, and those that do not overlap zero are shown in bold red. As an example, one can infer from column 1 of table 2a that a significant negative relationship exists between "Duration" and "Change in Per Capita Income", but only at higher levels of "Boom". Since reporting the effects of interactions requires more data, to save space, we present neither non-significant results nor the effects of the confounders, which are modeled as principal components.

2a) Estimated effects of "Duration" at four levels of "Boom"

	Change in Per Capita Income (2011 minus 1980)	Average Violent and Property Crimes per 1000 People (1980 through 2011)	Change in Percent of Adults with College Education (2011* minus 1980)
Effect of 10 years additional Duration at Boom level 0.3%	-$6070 to 1700	**0.2 to 5.3**	-2.5 to 0.3%
Effect of 10 years additional Duration at Boom level 0.7%	-$6080 to 1570	**0.2 to 5.3**	-2.4 to 0.2%
Effect of 10 years additional Duration at Boom level 1.7%	-$6110 to 1220	**0.4 to 5.2**	-2.4 to 0.1%
Effect of 10 years additional Duration at Boom level 8.1%	**-$7000 to -340**	**1.2 to 5.6**	**-2.6 to -0.2%**

2b) Estimated effects of "Boom" at four levels of "Duration"

	Change in Per Capita Income (2011 minus 1980)	Average Violent and Property Crimes per 1000 People (1980 through 2011)	Change in Percent of Adults with College Education (2011* minus 1980)
Effect of 1.7% additional Boom at Duration level 0	**$374 to 2594**	-1.46 to 0.01	-0.2 to 0.5%
Effect of 1.7% additional Boom at Duration level 2	**$401 to 2434**	**-1.36 to -0.03**	-0.2 to 0.5%
Effect of 1.7% additional Boom at Duration level 10	**$457 to 1858**	**-1.04 to -0.12**	-0.1 to 0.4%
Effect of 1.7% additional Boom at Duration level 21	**$151 to 1448**	-0.85 to 0.02	-0.1 to 0.3%

*ACS data calculated using annual surveys conducted during 2007-2011; representative of average characteristics during this period.

Now, consider another scenario to illustrate the interpretation of another confidence interval ("$151 to $1448") in the same column of Table 2b. Imagine two counties that both experienced 21 years in which the percent of their incomes from oil and gas was above average. If one of the counties had 1.7 percent higher boom income, we could expect change in per capita income in that county to be $151 to $1,448 higher.

This suggests that for counties that do not receive a large part of their incomes from oil and gas over the long-term, an increased initial reliance on oil and gas is associated with higher increases in per capita income than for counties receiving large parts of their incomes, long-term, from oil and gas. A short-lived surge of energy development appears to deliver better income benefits as an isolated event, rather than a continuous focus on energy development.

The preceding examples can be applied to the crime rate and education variables in Table 2b as well, although the 95 percent confidence intervals overlap zero for both short- and long-term values of duration. For counties with medium-term oil and gas specialization, a negative relationship emerges between crime rate and initial participation during the 1980-82 boom. It is possible that this relationship is spurious since there is not a clear explanation of why this relationship would exist for only medium-term specialization, and the result is inconsistent with other studies on the topic.

4. Discussion

4.1 Summary of results

Looking at counties within the leading oil- and gas-producing states of the U.S. West over a thirty-year period, the statistical analysis described in this paper shows a meaningful relationship between participation in the early 1980s oil and gas boom, long-term specialization (relative to the cohort average) in oil and gas, and several socioeconomic measures. We found evidence for an interaction between participation in the boom and long-term specialization in oil and gas, indicating that the change in any socioeconomic variable due to an increase in long-term specialization varies with the level of participation in the boom, and vice-versa. For example, the negative effects of long-term oil and gas specialization on change in per capita income, crime rate, and education rate are only significant for counties with high levels of participation in the early 1980s boom. Similarly, the positive effect of participation in the early 1980s boom on change in per capita income decreases the longer counties remain specialized on oil and gas.

The following findings contribute to current knowledge regarding two hypotheses about local economic and social well-being and energy resource specialization:

1) Greater specialization in oil and gas over the long term leads to diminished economic performance.

We find evidence that oil and gas specialization is related to long-term income effects. For counties with high participation during the 1980-82 boom, per capita income over the period 1980-2011 decreases with longer above average income from oil and gas. The magnitude of this relationship is substantial, decreasing per capita income by as much as $7,000 for a county with high participation in the boom and long-term specialization (greater than 10 years) versus a hypothetical identical county with only one year of specialization in oil and gas. Similarly, we find that the shorter time a county has experienced above average levels of income from oil and gas, for increasing participation during the oil and gas 1980-82 boom, the higher the county's growth in per capita income. This suggests that continued exposure to above average levels of oil and gas activity lowers per capita income growth, such that initial income gains erode and may eventually become negative.

Two things are important about these results. First, these findings support the theory that a resource curse is operating with regard to income and oil and gas specialization in local communities in the six energy-producing states in the U.S. West. Second, these findings are consistent with other research that shows diminished socioeconomic benefit of resource extraction at the local level over time (Michaels, 2011). Possible explanations for the diminished benefit range from factors endogenous to the industry, such as increasing reliance on a nonlocal workforce and changing wage structures, to the shifting broader economy and the diminishing role of energy production in it. The scope of this analysis is limited to a search for evidence of an effect; further inquiry will be needed to probe mechanisms of the effect.

2) Growth in the oil and gas sector is associated with diminished performance in other metrics of local well-being, such as crime rates, health, and education.

In addition to income effects, we find evidence that oil and gas specialization is related to long-term trends in crime and education rates. The longer a county has been specialized on oil and gas, the higher the county's crime rate. The magnitude of this relationship is modest, increasing the crime rate by up to 50 violent and property crimes for a county with a population of 20,000, high initial participation in the boom (greater than 8% of income from oil and gas), and long-term specialization (greater than 10 years) versus a hypothetical similar county with only one year of above average income from oil and gas. The positive relationship that we find between duration of oil and gas specialization and crime rates for counties is not surprising in that crime and related increases in demand for police services are consistently associated with energy booms in both popular and academic literature (Berger and Beckmann, 2010; Jacquet et al., n/d). But ours is the first study to isolate a relationship between oil and gas and reported violent and property crime rates over a timespan encompassing multiple cycles of energy development.

Finally, we find that for counties with high participation during the 1980-82 boom (greater than 8% of income from oil and gas), the percent of adults with a college education decreases the longer the county stays specialized on oil and gas. The magnitude of this relationship is severe, with as many as 2.5 percent fewer adults with college degrees in a county with high participation in the boom and consistent, long term specialization (greater than 10 years) versus a hypothetical identical county with only one year of specialization in oil and gas. The education effect may be a predictable outcome of specialization in a workforce that traditionally has had low education requirements, but it does raise questions about the competitiveness of the local economy during periods when the energy development sector is not active. Does the place fail to attract educated workers because of weak development in other economic sectors? This is again, a mechanistic relationship outside of the scope of our study, but one that merits further exploration.

4.2 Limitations and Future Considerations

Interpreting statistical results requires caution and reason. As with all observational studies, causality cannot be proved. The linear relationships found between oil and gas specialization and socioeconomic performance hold within the range of data within our sample, and have not been validated outside of this range. Importantly, the range of oil and gas specialization within which one can make reasonable comparisons is conditional on the value of the other variables in the model. For example, one might be tempted to compare two hypothetical counties with 50 percent of income from oil and gas during the early 1980s boom, one with 30 years of specialization to another with 5 years of specialization, and draw conclusions regarding socioeconomic impacts. This extrapolation would not be reasonable since there are no counties within our sample with these characteristics. Table 2 should be referred to carefully to understand the range of data in the oil and gas response variables over which comparisons between counties can be made.

This study measured the effect of oil and gas specialization on socioeconomic performance during three recent decades, 1980 to 2011. Although more complex statistical methods would be required, a longitudinal study that considers inter-annual variability during this period would be informative. Further study could also be done using alternative measures of socioeconomic performance. For example, it would be useful to measure the effects of oil and gas specialization on factors such as average earnings per job, the rate of uninsured individuals, health care costs, drinking water safety, and access to recreational facilities. These variables were considered, but not collected due to the challenges in collecting historical data.

It would also be interesting to assess long-term socioeconomic performance in areas with varying levels of oil and gas activity using alternative measures of specialization. For example, oil and gas employment or production could be used as measures of oil and gas activity. In the case of both employment and income data, all existing sources share the problem of non-disclosures, and it is not possible to know the exact effect on the accuracy of study results. In recent work, Weber (2013) has focused on measures of production, pointing out that dependence on oil and gas should be studied as a consequence of resource extraction, not assumed as a measure of the industry. Although challenging to obtain, reliable data tracking production values at a county level for a multi-decadal analysis could yield valuable insights. Moving forward, regional and resource economists will gain insights from studies that measure resource dependence in a variety of ways. There continues to be space for discussion and debate about viable options (for example, see Deller, S. C. and A. Schreiber, 2012 and Weber, 2014 for examples of differing approaches).

From an analytical standpoint, the small number of places that have experience with consistent, long-lasting and intensive energy development (in the sense of being a large share of local income) poses some challenges. We did not find statistically significant relationships between oil and gas specialization and socioeconomic well-being for the roughly 10 percent of counties with the highest values in oil and gas specialization. For analyzing specialization exceeding 20 years or 20 percent of income from oil and gas during the early 1980s boom, the sample was either too small, too heterogeneous, or both. The economic lessons of places with extensive specialization in oil and gas development are probably best learned through detailed case studies. In fact, these detailed case studies are likely to lead to the best preliminary models of how the resource curse and social disruption phenomena function and interact (or not) in both the near and the long term.

Lastly, the data on community well-being that are available for evaluation in a statistical model such as the one described in this paper leave out a number of important measures of well-being, including environmental quality, social cohesiveness, and local government fiscal health and functionality to name just a few. These metrics should be included in any holistic consideration of local costs and benefits of energy development.

4. Conclusions

This study of the relationship between oil and gas activities and local socioeconomic well-being during three recent decades can inform policy debates in energy-producing areas. It also contributes to broader public dialogue about the consequences of resource specialization involving oil and natural gas.

Our findings call into question the understandable, but mistaken assumption that long-term oil and gas development is a clear economic advantage for host communities. Our study does not question the idea that oil and gas activity can have a strong immediate positive impact on employment and income, but it does suggest there are negative effects when oil and gas extraction plays a major role in a local economy for a long-period of time. The income benefits of oil and gas activity are largest in the 1980-1982 boom environment and trend negative with even a modest level of continued involvement in oil and gas. In contrast, negative impacts of increased crime and decreased educational attainment increase with the duration of above average influence of oil and gas on local economies.

The long time period we investigate, and the effects we observe, are significant in the era of unconventional oil and gas. Due to the challenges of extracting oil and natural gas from shale rocks, the nature of production is shifting to more intensive development, greater in short- and long-term intensity. On the one hand, this suggests a longer, more consistent presence of extractive industry workers and the services they demand in energy-focused areas. However, industry trends increasingly focus on an offshore model in which workers maintain a permanent residency in a hub area and enter into oil and gas development areas on a temporary basis. The implications of this for local income and employment statistics merit consideration. It may be that the nature of development forces us to rethink ideas about the presence of extraction and economic dependence as Weber has suggested (Weber 2013). Continued analysis, particularly focusing on economic cycles of expansion and contraction will be helpful in furthering this line of inquiry. Our analysis also suggests there is value in developing a geographic understanding of where employment and income benefits from unconventional shale development actually accrue; a national econometric analysis could be helpful here.

This study offers evidence of the limited geographic and temporal scale of energy "booms" in the U.S. West. Only a small number of counties have experienced energy development at a scale that other studies have used as a threshold of specialization. This is a reminder of the degree to which the economy of the West has changed over time, relegating energy development to a smaller and smaller share of overall activity over the past four decades in all but a handful of places. This diversification is a positive development from the perspective of long-term economic well-being and the ability to weather boom-bust cycles.

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