A Decade of Natural Gas Development: The Makings of a Resource Curse?

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Abstract: Many studies find that areas more dependent on natural resources grow more slowly – a relationship known as the resource curse. For counties in the south-central U.S., I find little evidence of an emerging curse from greater natural gas production during the 2000s. Increases in population mitigated a rise in average compensation and crowding out of the non-mining sector. Each gas-related mining job created a little more than two jobs, indicating a neutral effect on resource dependence as measured by employment. Furthermore, changes in the adult population by education level reveal that greater production did not lead to a less educated population.

JEL Codes: Q32, Q33, O13

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1. Introduction

In the 2000s natural gas production from shale formations increased tenfold in the U.S. and growth in production is expected to continue in what The Economist magazine and others have called the ‘shale gas revolution’ (Economist Intelligence Unit, 2011). According to the U.S. Energy Information Administration, “The production of natural gas from shale formations has rejuvenated the natural gas industry in the United States” (EIA, 2011). The industry has expanded drilling in a broad swath of the country, from Pennsylvania to Texas to Wyoming.

A large cross-country literature documents how economies based on natural resources grow more slowly than other economies in what is broadly known as the resource curse (Sachs and Warner, 2001; Auty, 2001; Van der Ploeg, 2011). Similar within-country evidence has also emerged. Papyrakis and Gerlagh (2007) find that U.S. states with a greater dependence on natural resources (measured by the share of output accounted for by the natural resource sector) grew slower than other states. James and Aadland (2011) find the same for U.S. counties. In contrast – at least at first glance, Weber (2012) finds that greater natural gas production increased employment and income in counties in three Western states. Over his study period, participation in a natural gas boom added 1,780 jobs and 69 million dollars in wage and salary income to the average county.

The findings of Weber (2012), however, do not necessarily indicate that the resource curse does not or will not apply where the shale gas industry has expanded. Industry growth may create more jobs and earnings in the broader economy than in the mining sector. Alternatively, if workers are unwilling to move to areas with development, the growth may cause wages to appreciate and crowd out other sectors with a higher growth potential. Similarly, the industry could have few linkages to the non-mining economy. The increase in employment in the counties in Weber (2012) may therefore have occurred primarily or even entirely in the mining sector and increase dependence on mining in terms of employment. If the empirical finding in the literature reflects a true causal effect, the counties who experienced short-term employment gains will grow more slowly in the long run.

To test if the shale gas industry created conditions symptomatic of the resource curse, I study how local labor markets responded to a decade of natural gas development in the south-central U.S. The four-state study region of Texas, Louisiana, Arkansas, and Oklahoma accounted for two-thirds of the increase in onshore natural gas production in the U.S. from 2000 to 2010. Accounting for spatial spillovers and the potential endogeneity of the intensity of extraction, I look for evidence of higher compensation, a growing dependence on the mining sector, and declines in the educational attainment of the adult population.

For nonmetropolitan counties in the region, I find little evidence of an emerging resource curse from natural gas production. Increases in population in gas producing counties prevented a large increase in average compensation and severe crowding out of manufacturing. Each gas-related mining job added 2.3 jobs total jobs in the county where production occurred, indicating that natural gas development had a largely neutral effect on resource dependence as measured by employment. Furthermore, the change in the adult population with different education levels indicates that extraction did not lead to a less educated workforce.

2. The boom in natural gas drilling

2.1 Cost-reducing technology meets higher natural gas prices

The growth in natural gas production stems from higher energy prices and the refinement of two complementary technologies, hydraulic fracturing and horizontal drilling. The technologies permit extraction of gas trapped in hard rock formations like shale, broadly known as unconventional gas. Hydraulic fracturing involves injecting a mix of chemicals and water deep into the ground to open fissures in rock. Fracturing is not new, having been first used commercially in Texas and Oklahoma in 1949 (Montgomery and Smith, 2010). Innovation in drilling horizontally has occurred more recently and partly reflects earlier public investments in research. Spurred by high energy prices in the late 1970s and 1980s and concerned about domestic supplies, the U.S. government funded research on extracting gas from hard rock formations. The research has been recognized as having lowered the cost of drilling horizontal wells capable of drawing gas over a large area (King, 2010; National Energy Technology Laboratory, 2011). As costs fell, the productivity advantage of horizontal wells encouraged their use (EIA, 1993).

In the 1990s, several companies experimented with combining hydraulic fracturing with horizontal drilling in the Barnett Shale in Texas (National Energy Technology Laboratory, 2011). The combination and application of technologies occurred in spite of wellhead gas prices in the 1990s that averaged just $1.92 per thousand cubic feet.[1] Prices increased markedly in the 2000s, averaging $5.19 over the decade, which accelerated hydraulic fracturing and horizontal in Texas and elsewhere.

2.2 Drilling hotspots and state policy responses

Companies have used fracking and horizontal drilling to exploit previously untapped gas reservoirs in Colorado, Wyoming, the south central U.S, and more recently in Pennsylvania and

Ohio. The Barnett Shale in Texas has been the most exploited shale gas reservoir, but production from formations in Arkansas and Louisiana also spiked during the decade. In 2010, Texas, Louisiana, Arkansas, and Oklahoma accounted for more than half of onshore natural gas production in the U.S. As mentioned in the introduction, the states accounted for two-thirds of the growth in U.S. onshore production from 2000 to 2010 (Table 1). Of the four states, Arkansas saw the largest percent increase – a more than four-fold increase – while Texas had the largest absolute increase.

States have much discretion over taxing and regulating gas extraction, and policies vary markedly. Major producing states (e.g., Texas, Wyoming, Colorado, Louisiana, Oklahoma) permit hydraulic fracturing but apply a severance tax on gas extracted. Comparatively, Pennsylvania permits fracturing but in lieu of a severance tax it started applying an impact fee on wells in 2012. Nearby New York has had a moratorium on fracking since December of 2010 (Hoye, 2010).

Table 1

3. Natural gas development: the makings of a resource curse?

Prior studies have described various channels through which greater resource dependence may lower long-term economic growth. Van der Ploeg (2011) describes several of them, including that natural resource windfall lead to deindustrialization; encourage rent seeking, corruption, and conflict; reduce savings rates; and cause governments to overspend. Supposing that at least one of the causal channels described in the literature applies to local economies in the U.S. (as the results from James and Aadland (2011) suggest), one sign of the making of a resource curses is growing economic dependence on natural resources. It may seem odd to question the link between resource extraction and resource dependence. Closer scrutiny suggests that like much in applied empirical work the link should not be taken for granted.

The natural gas industry may have strong linkages with the non-mining sector (which I use as synonymous for the non-natural resource sector) and consequently create more jobs and earnings in the non-mining sector than in the mining sector. Hirshman (1956) and Watkins (1966) long ago emphasized linkages to other industries and sectors as central to an industry's potential to create broad-based economic growth. Model-based estimates from a study by IHS Global Insight suggest that the shale-gas industry had higher employment multipliers than finance and construction (IHS Global Insight, 2011). The study cites the industry's intensive use of capital and its strong linkages to the construction, fabricated metals, and chemical sectors.

Aside from direct production linkages with the non-mining sector, natural gas extraction may have large consumption linkages that broadly stimulate economic activity. Employees in the shale-gas sector reportedly earn more than $23 dollars an hour (IHS Global Insight, 2011). Gas development also generates substantial payments to landowners with mineral rights. Landowners provide access to natural gas through leases with drilling companies that often specify a one-time lease payment and a royalty based on production. A survey of firms drilling in the Haynesville shale in Louisiana revealed that they spent $1.2 billion in lease and royalty payments in 2009 (L.C. Scotts and Associates, 2009). A survey of landowners in two counties in Pennsylvania showed that they consumed roughly 10 percent of the payments received in 2009 (Kelsey, Shields, Ladlee, and Ward, 2011). Spent at the same rate, the more than a billion dollars in lease and royalty payments to landowners in the Haynesville Shale alone would have increased consumer spending by 100 million dollars.

The prospect that greater extraction may not increase economic dependence on natural resources as measured by a share of employment (or other outcomes) raises the question of whether such measures accurately capture resource dependence. An engineering firm that surveys land for clients in the natural gas industry may depend on the industry but its employees are part of non-mining employment. Still such firms often have services and products sold to non-mining clients. Growth in the gas industry may help them expand, gain economies of scale, and compete more broadly. A fall in natural gas prices will likely have less effect on these firms than on those directly involved in drilling. For example, a masonry business that pours well concrete for drilling pads can shift to residential projects in slow times.

The intuition that growth in resource extraction increases an area’s dependence on natural resources may nonetheless hold. For one, the natural gas industry may have weaker linkages than what has been reported. Looking at the 1970s coal boom in Appalachia, Black et al. (2005) find that each coal mining job created only a quarter of a local sector job and no traded sector jobs. A flurry of drilling and royalty payments could also crowd out other sectors. Increased demand from the booming natural gas sector may raise prices for apartments and dining out (nontradable goods and services) but not for shoes (tradable), whose price is set by the world market. Furthermore, wage appreciation caused by greater demand for labor erodes the competitiveness of the nonbooming tradable good sector (Corden and Neary, 1982). On the national level, greater exports by a booming natural resource sector may also cause the exchange rate to appreciate, thereby lowering the competitiveness of other exporters. This appears to have happened in Canada where currency appreciation from energy production eroded the competitiveness of manufacturing (Beine, Bos, and Coulombe, 2012).

3.1 Natural gas development and education

Another sign of the making of a resource curse is a decline in human capital, which is often cited a cause of higher long-term growth. Papyrakis and Gerlagh (2007) summarize several channels through which resource dependency may lower long-run growth through effects on education. One channel is that nonwage income from resource extraction discourages people from developing skills that earn them higher wages. With windfalls like royalty payments in pocket, a person places less value on the extra consumption that higher wages would enable. Another channel is that resource industries may have value education less; the greater share of the economy accounted for by natural resources, the lower the returns to education.

Both channels involve changes in incentives to invest in education. For areas experiencing an abrupt increase in drilling, changes in the stock of skills and abilities in the local population probably come from people coming and going. Suppose that resource extraction increases the demand for low or semi-skilled workers – think people with a commercial driver's license. The wage differential between high and low skilled jobs declines and the influx of lower skilled workers increases housing costs. More skilled workers – the creative class of scientists, engineers, and artists likely to spur innovation and growth (Florida, 2002) – may move, or if they did not live there in the first place, they may be less likely to come.

On a related note, the environmental risks and costs of resource extraction may discourage more educated people from locating to gas producing areas. The environmental Kuznets curve implies that as incomes increase, people demand more environmental amenities. There is some evidence that unconventional gas drilling affects newborn health and lowers the values of homes that rely on well water (Muehlenbachs, Spiller, and Timmins, 2012; Hill, 2012).

4. Sample counties

The analysis focuses on the 362 nonmetropolitan counties in Arkansas, Louisiana, Oklahoma, and Texas. Using nonmetropolitan counties creates a more homogenous sample and substantially decreases the skewness of the variables of interest. Reducing skewness avoids the need for a nonlinear transformation of the data, allowing for an easily interpretable estimation of the jobs or compensation associated with a given scale of gas extraction. Furthermore, more than 80 percent of the counties in the top quintile for the change in gas production were non-metro counties.

Employment, compensation, and total population come from the Regional Economic Accounts of the Bureau of Economic Analysis.[2] For 2000, data on the number of people in the county with different levels of education come from the Census Bureau Census of Population; for the end-period population by education level, I use the 2007-2011 average from the American Community Survey. The website of the Energy Information Administration provides GIS data on unconventional gas formations (shale, sandstone or "tight", and coalbed formations). Data on gas production by county by year come from state organizations involved in monitoring oil and gas development.[3]

In 2000 the average county produced 15.6 billion cubic feet of gas, and over the next nine years production increased by 6.8 billion cubic feet. The median county, however, produced less than a billion cubic feet in 2000 and saw no growth in the ensuing years. The innovation in drilling technology and higher prices in the 2000s should have primarily affected counties with unconventional gas. To illustrate the link between unconventional gas formations and growth in production, I divide sample counties into three groups based on the percent of the county covering an unconventional gas formation. The sample contains 138 non-gas counties, defined as having no unconventional gas formations; 82 fringe counties, where 0.1 to 49.9 percent of the county covers an unconventional gas formation; and 142 gas counties, where 50 percent or more covers a formation. The appendix has a map of counties shaded by group.

Figure 1 shows the average production of gas in billions of cubic feet from 1995 to 2010 for the three groups. In the late 1990s, gas counties consistently produced more gas than the other two groups, but production for all groups was flat until the early 2000s when it increased dramatically in gas counties, was steady in fringe counties, and fell slightly in non-gas counties. From 2003 to 2010, average production in gas counties increased by roughly 20 billion cubic feet.

5. Empirical approach

The first set of outcomes studied includes average compensation defined as wage and salary earnings per wage and salary job, population, manufacturing employment, and to put the other outcomes in perspective, total employment. I look at changes over the 2000 to 2010 period (the period of development) relative to the change in the prior five years. Thus, the dependent variable is defined as “change in *Y*, 2010-2000” minus “change in *Y*, 2000-1995”. The key independent variable – the change in natural gas production in billions of cubic feet – is defined similarly. Subtracting the change in the pre-development period accounts for any trends uniquely affecting counties that were to experience gas development. Furthermore, converting the data into a cross section of differenced variables permits using the percent of a county covering an unconventional gas reservoir, which is time-invariant, as an instrument for the change in gas production.

Studies of extractive booms have repeatedly speculated that their labor market effects likely extend beyond the localities where extraction occurs (Black et al., 2005; Michaels, 2010; Weber, 2012). If natural gas extraction creates the conditions for a resource curse in the county of production, it may create similar conditions in neighboring counties. In a similar vein, a prolonged resource boom in one area could cause the booming area to draw capital and labor from peripheral areas, which creates and perpetuates geographic disparities in economic growth (Myrdal, 1957).

A common approach to modeling local spillovers is to include spatially lagged variables as regressors. The lag is created by multiplying a spatial weights matrix with the variable to be lagged, which for each county gives the weighted average of neighboring counties. The Spatial Durbin model is common in the literature and includes a spatially lagged dependent variable (Wy) and spatially lagged covariates (WX) and is estimated by maximum likelihood (Anselin, 1988). The spatial autoregressive model is another approach and consists of including Wy instrumented by lagged covariates (WX) (Kelejian and Prucha, 1999).

Recent work, however, shows that the Durbin model and the spatial autoregressive model lead to a similar reduced form equation involving X and WX that only differs in how many spatial lags it includes–the neighbors, the neighbors of the neighbors, and so forth (Pinkse and Slade, 2010; Gibbons and Overman, 2012). Furthermore, compared to the peer effects literature, the spatial econometrics literature has given little heed to the reflection problem highlighted by Manski's 1993 seminal paper on peer or neighborhood effects. A county's outcomes may move with the average outcome of neighboring counties for reasons other than spillovers of economic activity. Gibbons and Overman (2012) recommend that applied empirical work on spatial relationships focus less on parsing out the effects of *Wy* from *WX* and more on identifying causal responses to changes in a spatially lagged covariate of interest.

I therefore include in the empirical model the average change in natural gas production of a county's contiguous neighbors. The model also includes several control variables and their spatially lagged versions (averages of the county's contiguous neighbors):

$$(1)\ \Delta Y_{00-10,95-00} = \theta(\Delta Gas_{00-10,95-00}) + \rho W(\Delta Gas_{00-10,95-00}) + X_{94}\beta + W(X_{94}^{s}\beta^{s}) + \varepsilon$$

where *W* is the spatial weights matrix that permits calculating the average of contiguous counties and *X* includes the control variables. Because spatial spillovers decline with distance, using contiguous counties provides a good opportunity for a statistically precise estimate of the spillover. The *X* used to calculate spatial lags includes metropolitan counties and counties that share a commuting zone with a sample county, even if they are outside of all of the four states. [4]

Included in *X* are income per capita, population density, and the percent of total employment accounted for by the mining, construction, manufacturing, and agricultural sectors. I also include the county's driving distance (in driving time using the existing roads) to the nearest city of 100,000 and state dummy variables to control for state-specific growth trends. The X^{s} vector includes the same variables as the *X* vector except for the state dummies and the driving distance variable, which already reflects spatial relationships. All continuous control variables correspond to 1994 except the driving distance variable.

5.1 Estimation and identification

Growth in the value of gas production and its spatial lag may be correlated with omitted variables that affect labor market outcomes. Gas companies may drill more in economically depressed areas where they can lease land for less. The Center for Business and Economic Research (2008) found that prior to an expansion in drilling, counties in the Fayetteville Shale in Arkansas had lower growth in wages per employee than the state as a whole. This is consistent with Weber (2012) who finds higher employment and income effects from a gas boom when using instrumental variables than when using OLS. Similar to Weber, I address endogeneity bias by using the location of unconventional gas reservoirs and its spatial lag to instrument for the growth in the value of gas production and its spatial lag.[1] The instruments are correlated with growth in gas production because unconventional gas accounted for most production growth in the region. They are also likely to be uncorrelated with the outcomes of interest. Without drilling there is no apparent reason why gas trapped two miles underground and once thought to be infeasible to extract should be correlated with labor market outcomes on the surface.

Regressions with $\Delta\, Gas_{00-10,95-00}$ and its spatial lag as the dependent variable reveal a strong correlation between *Percent Gas* and growth in natural gas production (Table 2). Compared with counties with no unconventional gas formations (*Percent Gas* = 0), counties completely covering such a formation (*Percent Gas* = 1) saw gas production increase by 34 billion cubic feet from 2000 to 2010 relative to the prior five years. The coefficient for the spatial lag is similar, at 29 billion cubic feet.

Angrist and Pischke (2009, p.218) explain how to test for an instrument's strength to ensure that each endogenous regressor has at least one unique, excluded instrument sufficiently correlated with the regressor to ensure identification. The key is to test the strength of the

[1] To avoid giving a small neighboring county the same weight as a large county in calculating the spatial lag of *Percent Gas*, I calculate the total area of contiguous counties and the total area covering unconventional gas formations separately. The spatial lag variable *W*(Percent gas)* is the division of these two areas.

correlation between the excluded instrument and the regressor that it's instrumenting for after partialing out variation captured by other covariates, the instrumented value of other endogenous regressors, and other excluded instruments. I use the Angrist and Pischke approach to calculate the F-statistic for the relationship between *Percent gas* and $\Delta\ Gas_{00-10,95-00}$ and between the spatial lags of both variables. The F-statistic for the relevance of *Percent gas* and *W*(Percent gas)* is 15.8 and 17.1 indicating sufficient instrument strength to avoid concerns about weak instrument bias (Stock and Yogo, 2005).

With the same number of excluded instruments and endogenous regressors, GMM estimation reverts to traditional Two Stage Least Squares, which I use to estimate equation (1). The standard errors reflect a robust covariance matrix that allows for arbitrary heteroskedasticity.

5.2 Production and local economic effects: A lagged relationship?

Much of the local economic effects of natural gas development are thought to occur when companies drill wells and lay pipelines. Because production starts immediately after the well is fracked and declines exponentially afterwards, there should be a strong correlation between employment related to drilling activity and growth in production. But if production lags drilling by a year or more, potentially because wells are not immediately fracked after they are drilled, then production in one year may be most correlated with employment in the prior year. I therefore estimate the total employment effect using 2010 as the end point for the change in gas production but using 2009 and then 2008 and so forth for the end point for employment. I find that the total employment effect is largest when the same end year is used for employment and production. As the end point for the change in employment is move backward the estimated employment effect declines (appendix Table A.1).

6. Findings

6.1 Production and employment, compensation, and population

To place the compensation and population effects of greater gas production in context, I first estimate the change in total employment. I find that each billion cubic feet in gas production created 18.5 total jobs and 12.4 wage and salary jobs in the county of production (Table 3). The coefficient on the change in gas production in neighboring counties suggests that gas production in neighboring counties had little effect on employment in the county in question. The point estimate of the coefficient is small and statistically insignificant in both cases and for wage and salary employment it is even negative.

An increase in population accompanied the increase in employment, with each billion cubic feet of gas attracting 25 people. Each job therefore drew 1.3 persons. This does not mean that unemployment increased; each job would have drawn several people if each worker brought several non-working dependents. That the population effect is only slightly larger than the employment effect is consistent with anecdotal evidence that natural gas drilling relies heavily on young, transient workers who do not have families or do not move them to drilling locations. Similar to the prior results, there is no evidence that a boom in gas production in contiguous counties affected population, although it may have attracted as many people as it caused to move.

The increase in employment and population accompanied a statistically weak increase in average compensation, that is, wage and salary disbursements per wage and salary job. Each billion cubic feet in gas led to an increase in $30 per job per year. For the county at the 90th percent for the change in gas production (a change of 22 billion cubic feet), production would have increased compensation by about $660 dollars or 2.4 percent of average compensation in 1994. Interestingly, the coefficient on the spatial lag implies that gas production in neighboring counties caused a decline in compensation per job. This is counter-intuitive since an increase in compensation in one county would presumably draw labor from nearby, causing employers to have to pay more to retain workers. From the employment results, we know that there was no systematically positive spatial employment or population spillover. Still, the composition of the population may have changed, with higher skilled workers moving to production areas and lower skilled workers moving to the peripheral area with lower housing costs. The type of jobs may have also changed in neighboring counties, with part-time jobs in convenience stores replacing full-time manufacturing jobs.

Of all sectors, natural gas extraction is most likely to crowd affect manufacturing – the classic tradable sector whose input prices may increase without a corresponding increase in output prices. Unfortunately, manufacturing employment in the BEA data is suppressed in at least one year for a quarter of sample counties. As a rough imputation method, I give all suppressed counties the lowest observed manufacturing employment in the state and estimate the model with and without counties with an imputed value. The trimmed sample yields a small and statistically insignificant coefficient on $\Delta\, Gas_{00-10,95-00}$; the full sample gives a negative but also small and statistically insignificant coefficient. The coefficient on the spatial lag is imprecisely estimated in both cases. While the changing composition of jobs may still explain the negative compensation spillover effect, it does not appear to be from a decline in manufacturing.

6.2 The employment multiplier from natural-gas-related mining jobs

Next, I estimate the total number of jobs created by each gas-related mining job by estimating

$$(2) \qquad \Delta\, Total\ Emp_{00-10,95-00} = \theta\big(\Delta\, Mining_{00-10,95-00}\big) + \rho W\big(\Delta\, Mining_{00-10,95-00}\big) + X_{94}\delta + W(X_{94}^{s}\delta^{s}) + \varepsilon$$

Similar to the previous model, I instrument the change in mining employment with the percent of the county covering an unconventional gas formation. As shown in Table 3, the instrument is strongly correlated with growth in natural gas production and for good reasons. Using it as an instrument for the change in mining employment therefore isolates the change linked to natural gas development. A preliminary regression (not shown) reveals that the instrument is correlated with the change in mining employment, though not as strong as the correlation with the change in production – the F-statistic on *Percent Gas* is 8.8.

As with manufacturing employment, mining employment is suppressed for many counties and a similar imputation is done. The counties where the imputation may affect the results are the 43 percent of counties that were suppressed in one or two but not all periods, in which case the change in mining employment will be measured with error. (If they were suppressed in all periods, the change in mining employment would be zero and they would not contribute to identification). Error in measuring a variable will attenuate coefficient estimates to zero and inflate standard errors. Assuming classical measurement error, however, such bias is addressed by instrumenting for the imprecisely measured variable.

At least in terms of employment, the estimated multiplier of 2.3 (s.e. of 0.9) implies that greater natural gas extraction will not increase a county's dependence on mining. Each natural-gas-related mining job creates 2.3 total jobs in the county economy, one mining job and 1.3 non-mining jobs. This is in line with Weinstein and Partridge (2011) who studied the total employment effect from Marcellus Shale development in Pennsylvania and argued that each mining job likely creates one additional job in the economy. At the same time, it's possible that the multiplier may be lower in other regions. The study region's long-standing natural gas industry and pioneering of fracking and horizontal drilling implies that its supply chain is the most developed of any region in the U.S. Its employment multiplier most likely provides an upper bound estimate for other regions.

Even though the multiplier suggests that extraction has a robust effect on the non-mining economy, it also implies that several Input-Output studies of natural gas development have overstated the industry's employment effect – a conclusion consistent with Weber (2012). Referenced by President Obama in the 2012 State of the Union Address, the study by IHS Global Insight implies that in 2010 each mining job associated with the industry supported 10 total jobs. Other studies projecting employment impacts have implied similar multipliers (Perryman Group, 2008; L.C. Scotts and Associates, 2009; Kelsey et al, 2009; Considine et al., 2011).

6.3 Educational attainment in the adult population

To see if greater gas extraction potentially jeopardizes long-run growth by leading to a less skilled labor force, I look at changes in the adult population (age 25 and older) with an educational attainment of less than a high school; only high school; some college; and college or more. The change is between 2000, which is based on the Census of Population, and the 2007-2011 average value based on the American Community Survey, which has insufficient coverage for a reliable county estimate in one year. The model estimated is

$$(3) \qquad \Delta\, Adult\ Pop_{00-07,11}^{educ=j} = \eta(\Delta\, Gas_{00-10}) + \lambda W(\Delta\, Gas_{00-10}) + X_{94}\pi + W(X_{94}^{s}\pi^{s}) + \varepsilon$$

Incorporating 1990 data on population by educational attainment would permit another differencing analogous to that of the previous two models but natural gas production data does not go back to 1990 for all states. Despite the lack of differencing the effect of extraction on the adult population is consistent with the prior estimate for total population: each billion cubic feet of gas attracted slightly more than 21 people ages 25 and older, compared with 25 people in the general population (Table 5).

Gas production had, if anything, a small negative effect on the number of adults with less than a high school education. This is notable because in 2000 this group accounted for 30 percent of the adult population in the average county (see Table 2). In contrast, each billion cubic feet of gas increased added 11.5 people with only a high school education to the adult population. The high school educated adult population accounted for more than half of the total change even though it accounted for just 34 percent of the adult population in the average county. The point estimate for the change in adults with some college and those with college indicates the each group's share of the increase is in line with their share of the adult population.

The estimated effects are consistent with what is known about the workforce associated with natural gas extraction – that the majority of laborers are low or semi-skilled. It worth highlighting that even though the total adult population increased, the point estimate for the number of people with less than a high school education is negative. One interpretation is that higher rents may have encouraged lower income, less educated adults to move or to not come if they were considering it. On the other end of the education spectrum, greater extraction did not cause higher educated workers, broadly understood as those with a college education or more, to move or to stay away at a rate higher than counties with little or no gas production.

7. Conclusion

Natural gas drilling will likely expand in many areas United States in coming years. The common empirical finding of lower economic growth in areas with greater dependence on natural resources raises the possibility that drilling will undermine the long-term economic prospects of a growing swath of the country. For the south-central U.S., a decade of natural gas expansion appears to have not generated the conditions associated with the resource curse – a finding consistent with Michaels' 2009 study which showed that oil abundance promoted long-term growth in the 20th century in the same region. Any crowding out is sufficiently small that the estimated employment multiplier associated with gas-related mining employment is more than two, implying that extraction has not systematically increased the dependence of local economies on mining for employment. Furthermore, greater extraction did not erode the human capital stock; it may have even improved it by increasing the semi-skilled population (high school and some college).

At the same time, local labor market effects are only part of the economic consequences of extractive industries. The resource curse may in fact operate through other channels such as destabilizing local and state government revenues and expenditures or creating health and environmental risks that increasingly manifest themselves over time. A nascent empirical literature is beginning to explore the environmental and health consequences of the recent wave of natural gas extraction (Muehlenbachs, Spiller, and Timmins, 2012; Klaiber and

Gopalakrishnan, 2012; Hill, 2012) but the externalized costs, who bears them, and how long they linger are still largely unknown. The wide dispersion of unconventional gas endowments across the U.S. and the world and projections of continued high oil prices imply that these questions will occupy public policy discussions in many places for many years, suggesting high returns to such a research agenda.

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[1] Natural gas prices for states and the U.S. are available at the website of the Energy Information Administration: http://www.eia.gov/dnav/ng/ng_pri_sum_dcu_nus_m.htm

[2] A challenge with the publically available BEA data is the suppression of observations where the small number of establishments creates confidentiality problems. In cases of suppression, I impute the suppressed value using the lowest unsuppressed observation in the sample.

[3] These agencies are the Arkansas Oil and Gas Conservation Commission, the Kansas Geological Survey, the Louisiana Department of Natural Resources, the Mississippi Oil and Gas Board, GO-TECH at the New Mexico Institute of Mining and Technology, the Oklahoma Corporation Commission, and the Texas Railroad Commission. Of the counties outside of the four-state region, there is only evidence of gas production in the counties in Mississippi, New Mexico, and Kansas.

[4] Commuting zones are groupings of counties with relatively integrated labor markets as evidenced by where people live and work. Tolbert and Sizer (1996) describe the creation of commuting zones based on the 1990 Census journey-to-work data, which are the commuting zones used in this study. The average commuting zone in the U.S. (and the study region) contains about four counties.

Tables

Table 1. Onshore natural gas production (billions of cubic feet), 2000-2010

State	2000	2010	Increase	Percent Increase
Arkansas	172	927	755	439%
Louisiana	1,343	2,091	748	56%
Oklahoma	1,613	1,827	214	13%
Texas	5,682	7,565	1,883	33%
Four-state total	8,810	12,410	3,600	41%
U.S. total	18,474	23,960	5,486	30%

Note: The data are from the Energy Information Administration.

Table 2. Sample descriptive statistics (N=362)

Variable	Mean	SD	Median
Gas production (billion cubic feet), 2000	15.60	35.42	0.83
Change in gas production, 2000-2010	6.89	47.32	0.00
Total employment, 1994	8,454	7,386	6,083
Average compensation, 1994	27,054	4,516	26,154
Population, 1994	18,482	15,132	14,277
Per capita income	23,517	4,066	23,135
Population density (people/sq. mile)	22	19	18
Travel Time to Nearest City of 100,000 (min)	1.88	0.81	1.73
Mining share of total earnings, 1994	0.04	0.06	0.02
Construction share of total earnings, 1994	0.04	0.02	0.04
Manufacturing share of total earnings, 1994	0.11	0.10	0.08
Agricultural share of total earnings, 1994	0.03	0.02	0.02
Share of the adult population in 2000 with …			
Less than high school	0.30	0.08	0.29
Some high school	0.34	0.05	0.34
Some college	0.23	0.04	0.23
College or more	0.13	0.04	0.12

Note: Gas production data are from the state-level agencies listed in the endnotes. Employment, income, and compensation data are from the Bureau of Economic Analysis. Population by education level is from the Census Bureau. Monetary figures are in 2010 dollars.

Table 3. Instrument relevance

Variable	ΔGas	W*ΔGas
Percent Gas	34.2***	-1.3
	(8.6)	(3.6)
W(Percent Gas)*	2.7	29.3***
	(8.5)	(7.3)
Controls for state	yes	yes
Other control variables	yes	yes
Spatial lags of control variables	yes	yes
Adjusted R squared	0.079	0.066
Observations	361	361

Notes: Robust standard errors are in parenthesis. The asterisks ***,**,* denote statistical significance at the one, five, and ten percent levels. The spatial weights matrix *W* is row normalized and based on contiguous counties. The control variables include the mean driving distance to a city of 100,000 or more, income per capita, population density of the county, and the percent of total employment accounted for by the mining, construction, manufacturing, and agricultural sectors. The sample includes all non-metro counties in the four states, less one county which was excluded for its extreme change in average compensation, which was negative and four times the magnitude of the next closest observation.

Table 4. Employment, population, and compensation effects of greater natural gas production

Variable	Δ Total Employment	Δ Population	Δ Average Compensation	Δ Manufacturing (1)	Δ Manufacturing (2)
Δ Gas	18.5***	25.2***	30.1*	0.4	-1.2
	(6.4)	(9.1)	(17.8)	(2.6)	(1.7)
W*(Δ Gas)	3.5	-1.5	-65.4**	6.4	6.3
	(10.7)	(13.6)	(32.9)	(5.9)	(7.0)
Controls for state	yes	yes	yes	yes	yes
Other control variables	yes	yes	yes	yes	yes
Spatial lags of control variables	yes	yes	yes	yes	yes
Observations	361	361	361	270	361

Notes: Robust standard errors are in parenthesis. The asterisks ***,**,* denote statistical significance at the one, five, and ten percent levels. The change in employment and natural gas production is the change from 2000 to 2010 less the change from 1995 to 2000. Natural gas is in billions of cubic feet. The spatial weights matrix *W* is row normalized and based on contiguous counties. The sample includes all non-metro counties in the four states, less one county which was excluded for its extreme change in average compensation, which was negative and four times the magnitude of the next closest observation. For the change in manufacturing employment, I look at the change from 2001 to 2010 relative to the change from 1995 to 2000. This is done because 2001 is the first year that the Bureau of Economic Analysis started using the North American Industrial Classification System codes instead of the Standard Industrial Classification System. The first column of manufacturing results excludes counties with suppression in 1995, 2001, or 2010.

Table 5. Natural Gas Production and the Adult Population, By Educational Attainment

Variable	Δ Adult Population	Δ Adult Population: Less than HS	HS Only	Some College	College
Δ Gas	21.6***	-1.3	11.5***	7.9**	3.6
	(7.4)	(2.5)	(4.1)	(3.2)	(2.3)
W*(Δ Gas)	-4.7	4.2	-4.8	2.0	-6.1
	(12.0)	(4.9)	(7.1)	(5.5)	(3.9)
Controls for state	yes	yes	yes	yes	yes
Other control variables	yes	yes	yes	yes	yes
Spatial lags of control variables	yes	yes	yes	yes	yes
Observations	361	361	361	361	361

Notes: Robust standard errors are in parenthesis. The asterisks ***,**,* denote statistical significance at the one, five, and ten percent levels. The change in natural gas production is the change from 2000 to 2010. Natural gas is in billions of cubic feet. The spatial weights matrix *W* is row normalized and based on contiguous counties. The sample includes all non-metro counties in the four states, less one county which was excluded for its extreme change in average compensation, which was negative and four times the magnitude of the next closest observation. For the change in population, the change from the 2000 value from the Census of Population to the 2007-2011 average value from the American Community Survey.

Figures

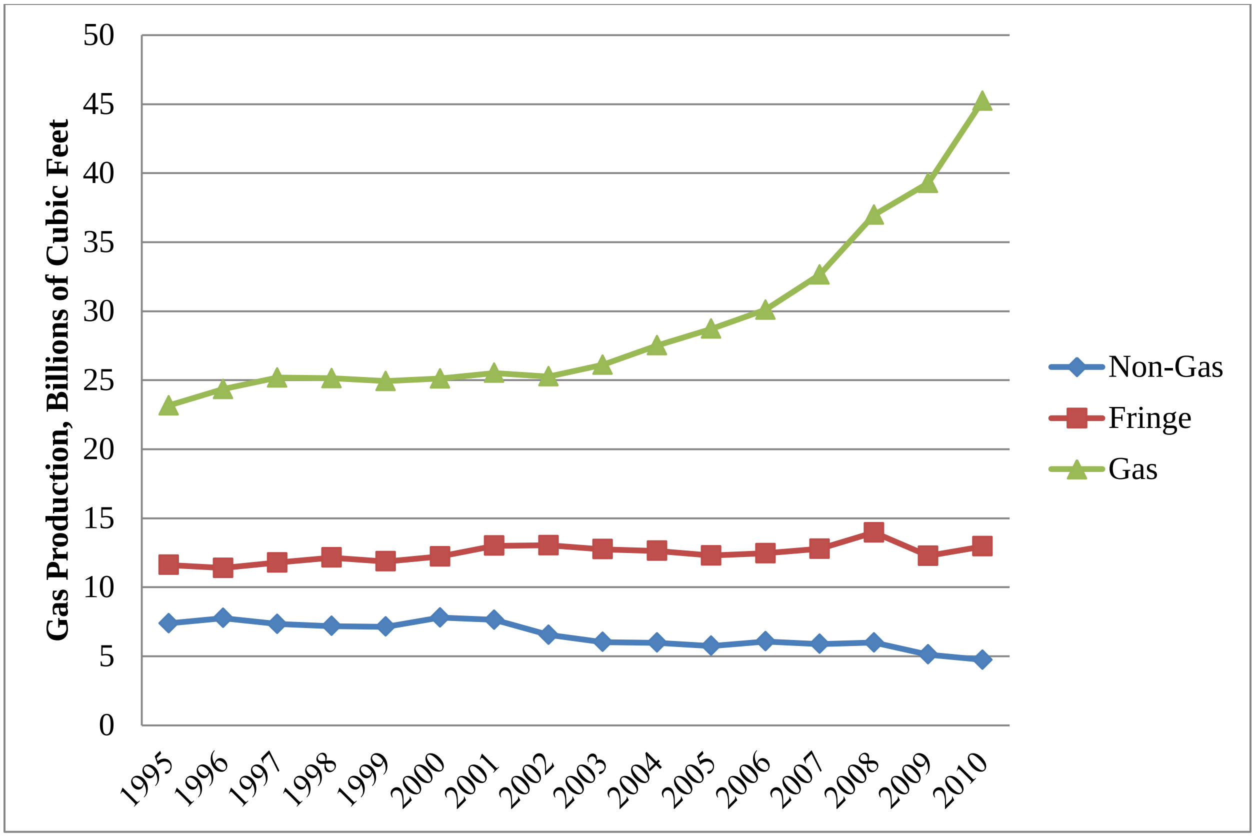

Figure 1: Natural gas production (billions of cubic feet) for non-gas, fringe, and gas counties, 1995-2010

Notes: The sample consists of all non-metro counties in Arkansas, Louisiana, Oklahoma, or Texas. Non-gas counties do not cover any part of an unconventional gas formation; fringe counties have 0.1-49.9 percent of the county covering a formation while gas counties have 50 percent or more of their area covering a formation. Production data are from the Arkansas Oil and Gas Conservation Commission, the Louisiana Department of Natural Resources, the Oklahoma Corporation Commission, and the Texas Railroad Commission

References

Anselin, L., *Spatial Econometrics: Methods and Models* (The Netherlands: Kluwer Academic Publishers, 1988).

Auty, R.M., Introduction and Overview in Auty Ed. "Resource Abundance and Economic Development," (2001)Oxford University Press, Oxford.

Beine, M., Bos, C.S., and S. Coulombe, "Does the Canadian Economy Suffer from Dutch Disease?" *Resource and Energy Economics*, 34:4 (2012), 468-92.

Black, D, T. McKinnsh, and S. Sanders, "The Economic Impact of the Coal Boom and Bust," *The Economic Journal* 115 (2005), 449-76.

Center for Business and Economic Research, "Projecting the Economic Impact of the Fayetteville Shale Play for 2008-2012," University of Arkansas College of Business (2008).

Considine, T., R.Watson, and S. Blumsack, "The Pennsylvania Marcellus Natural Gas Industry: Status, Economic Impacts, and Future Potential," (State College, PA: Penn State University Department of Energy and Mineral Engineering, 2011).

Corden, W.M. and P.J. Neary, "Booming sector and de-industrialization in a small open economy," *Economic Journal* 92 (1982), 825-848.

Economist Intelligence Unit, "Breaking new ground: A special report on global shale gas developments," (November 2011).

Energy Information Administration, "What is shale gas and why is it important?" (August 4, 2011) Available at http://www.eia.gov/energy_in_brief/about_shale_gas.cfm.

_____ "Drilling Sideways – A Review of Horizontal Well Technology and Its Domestic Applications," (Washington, D.C: U.S. Department of Energy, April 1993).

Florida, R., *The Rise of the Creative Class*, Basic Books, New York: NY, 2002.

Gibbons, S. and H. Overman, "Mostly Pointless Spatial Econometrics," *Journal of Regional Science* 52:2 (2012) 172-191.

Hill, E. L. "Unconventional Natural Gas Development and Infant Health: Evidence from Pennsylvania," (2012) Cornell University Applied Economics and Management Working Paper No. 128815.

IHS Global Insight, "The Economic and Employment Contributions of Shale Gas in the United States," (2011) Available at http://anga.us/media/235626/shale-gas-economic-impact-dec-2011.pdf

Hoye, S., "New York governor pauses 'fracking,'" (December 13, 2010) Available at http://www.cnn.com/2010/US/12/13/new.york.fracking.moratorium/index.html

James, A. and D. Aadland, "The Curse of Natural Resources: An Empirical Investigation of U.S. Counties," *Resource and Energy Economics*, 33:2 (2011), 440-53.

Kelejian, H. H. and I. R. Prucha, "A Generalized Moments Estimator for the Autoregressive Parameter in a Spatial Model," *International Economic Review*, 40:2 (1999), 509-533.

Kelsey, T. W., M. Shields, J.R. Ladlee, M. Ward, "Economic Impacts of Marcellus Shale in Pennsylvania: Employment and Income in 2009," (Marcellus Shale Education and Training Center, 2011).

King, G.E., “Thirty Years of Gas Shale Fracturing: What Have We Learned?” Society of Petroleum Engineers Annual Technical Conference, Florence, Italy, 19-22 September, 2010.

Klaiber, H. A. and S. Gopalakrishnan, “The Impact of Shale Exploration on Housing Values in Pennsylvania,” *2012 Annual Meeting, August 12-14, 2012, Seattle, Washington*. No. 124368. Agricultural and Applied Economics Association, 2012.

L.C. Scott and Associates, “Economic Impact of the Haynesville Shale on the Louisiana Economy” (Louisiana: Louisiana Oil and Gas Association, 2010) Available at http://www.loga.la/pdf/Economic%20Impact%20of%20HS.pdf.

Manski, C.F., “Identification of Endogenous Social Effects: The Reflection Problem,” *Review of Economic Studies* 60 (1993), 531-42.

Michaels, G., “The Long Term Consequences of Resource-Based Specialisation,” *The Economic Journal* 121: 551 (2010), 31-57.

Montgomery, C.T., and M.B. Smith, “Hydraulic Fracturing: History of an Enduring Technology,” *Journal of Petroleum Technology* (December, 2010).

Muehlenbachs, L., Spiller, E., and C. Timmins. “Shale Gas Development and Property Values: Differences across Drinking Water Sources,” NBER Working Paper No. w18390 (2012).

Myrdal, G., *Economic Theory and Under-developed Regions*, London: Duckworth, 1957.

National Energy Technology Laboratory “Shale Gas: Applying Technology to Solve America’s Energy Challenges,” (March, 2011) Available at http://www.netl.doe.gov/technologies/oil-gas/publications/brochures/Shale_Gas_March_2011.pdf.

Papyrakis, E. and R. Gerlagh, “Resource Abundance and Economic Growth in the United States,” *European Economic Review*, 51:4 (2007), 1011-39.

Perryman Group, “Drilling for Dollars: An Assessment of the Ongoing and Expanding Economic Impact of Activity in the Barnett Shale on Fort Worth and the Surrounding Area,” (2008) Available at http://www.bseec.org/content/2008-economic-impact-report-released-perryman-group.

Pinkse, J. and M. E. Slade, “The Future of Spatial Econometrics,” *Journal of Regional Science* 50:1 (2010), 103-117.

Stock, J.H., and M. Yogo, “Testing for weak instruments in linear IV regression,” In Donald W. K. Andrews and J.H. Stock (Eds.), *Identification and inference for econometric models: Essays in honor of Thomas Rothenberg* (Cambridge and New York: Cambridge University Press, 2005).

Tolbert, C., and M. Sizer, “U.S. commuting zones and labor market areas: A 1990 update” (Washington, DC: U.S. Department of Agriculture, Economic Research Service, 1996).

Van der Ploeg, F., “Natural Resources: Curse or Blessing?" *Journal of Economic Literature*, 49:2 (2011), 366-420.

Weber, J., “The Effects of a Natural Gas Boom on Employment and Income in Colorado, Texas, and Wyoming,” *Energy Economics* 34: 5 (2012) 1580-1588.

Weinstein, A. L. and Partridge, M.D. “The Economic Value of Shale Natural Gas in Ohio,” Swank Program in Rural-Urban Policy Summary and Report (2010).

Appendix

Table A1: Does natural gas production lag the employment effect from drilling?

	Change in employment ((End Year - 2000)-(2000-1995)), using as a End Year…				
Variable	2010	2009	2008	2007	2006
Δ Gas ((2010-2000)-(2000-1995))	18.5***	15.9***	16.0***	13.1**	10.0**
	(6.4)	(6.0)	(6.1)	(5.4)	(4.6)
W*(Δ Gas)	3.5	3.2	-0.8	-2.3	1.3
	(10.7)	(10.2)	(10.2)	(8.8)	(7.5)
Controls for state	yes	yes	yes	yes	yes
Other control variables	yes	yes	yes	yes	yes
Spatial lags of control variables	yes	yes	yes	yes	yes
Observations	361	361	361	361	361

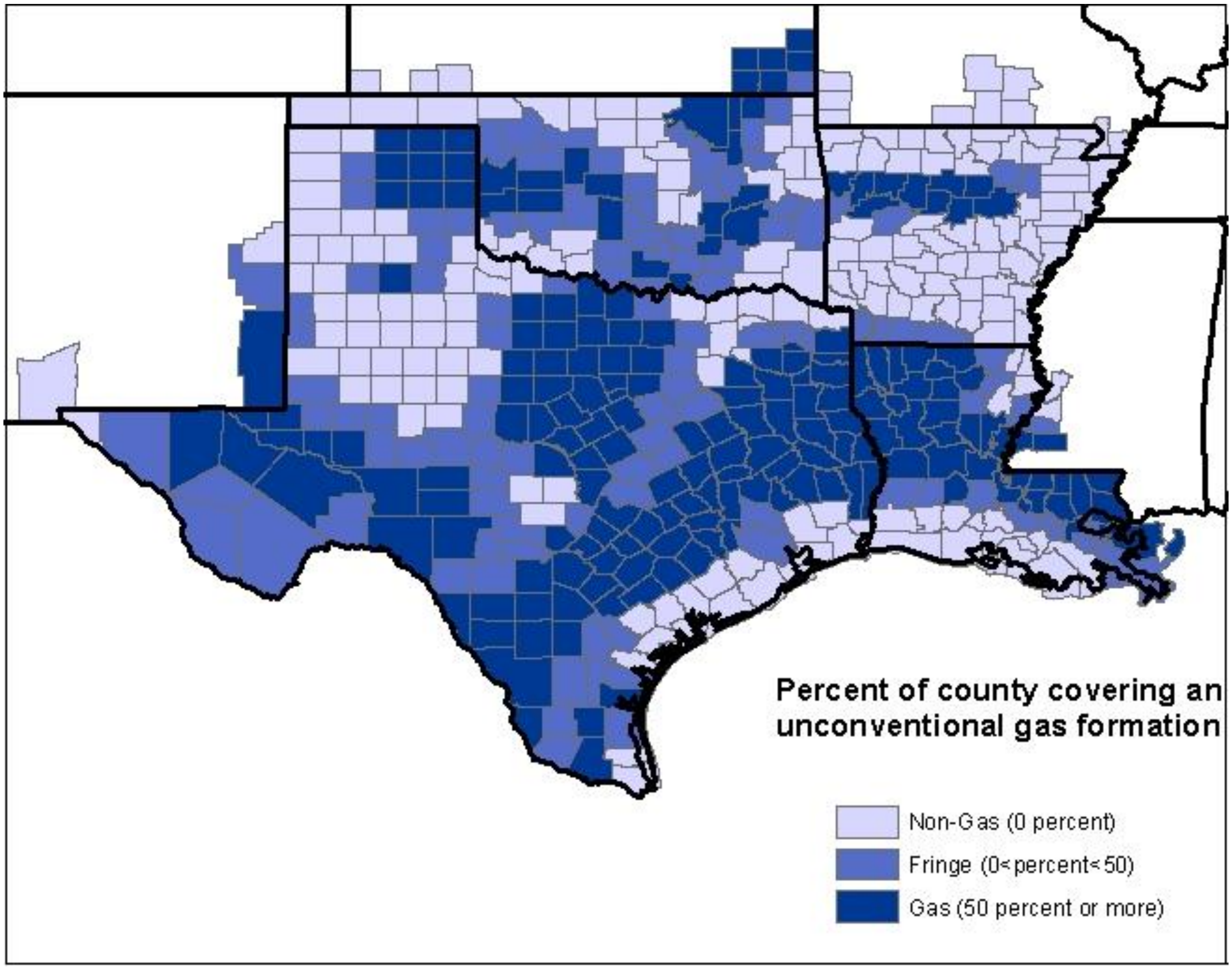

Figure A1: Counties by Percent of the County Covering an Unconventional Gas Formation

Note: GIS data on unconventional gas formations is from the Energy Information Administration.