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The Local Economic Impacts of Hydraulic Fracturing and Determinants of Dutch Disease*

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ABSTRACT

In this paper we quantify the local economic impacts of the development of unconventional shale oil and gas reserves through the controversial extraction procedure known as hydraulic fracturing or "fracking" and assess the possibility of the boom creating a "resource curse" for resource-rich counties. First, using government local economic data matched to highly detailed national oil and natural gas panel data, we estimate the effect that new "fracking" installations have on local job growth and average earnings, controlling for time-varying unobserved determinants of job growth, overall, by industry, and by region. We find that overall employment effects are substantial although smaller than some previous studies. Second, we show that shale development increases wages in manufacturing in counties with relatively tight labor markets and little prior oil and gas industry presence. Increased wages in the manufacturing sector suggests the possibility of a loss of competitiveness in some counties with shale oil and gas resources, raising the specter of a future resource curse.

Keywords: local employment, job growth, dutch disease, resource curse, hydraulic fracturing, shale gas

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1 Introduction

One of the foremost issues in U.S. domestic energy production has been the recent rise in the extraction of natural gas using hydraulic fracturing. Hydraulic fracturing, or "fracking," is a method of fossil fuel extraction whereby massive quantities of water and chemicals are forced into a well-bore at high pressure in order to fracture a subterranean shale formation. Most often, the purpose of fracturing the rock is to release natural gas that is stored in tight pockets within the rock. Once the rock is fractured, natural gas and other by-products flow back to the surface where they can be collected for use as energy.

The potential supply of energy available from shale is enormous. As noted by President Barack Obama in his 2012 State of the Union address, the energy contained in shale gas could supply every home in the United States with electricity for the next 100 years. Further, the Energy Information Administration projects that natural gas production in the United States will grow 44% between 2011 and 2044, mostly due to a 113% increase in the amount of natural gas produced from shale (EIA (2013a)). Beyond its use as an energy supply, natural gas derived from hydraulic fracturing also has the potential to reduce greenhouse gas emissions since it releases less CO_2 than coal when converted into electricity. Moreover, a shift to domestic energy supplies reduces geopolitical concerns derived from dependence on foreign sources of energy.

While hydraulic fracturing has a variety of potential environmental and national economic benefits, resource booms can also have dramatic local implications. A large literature has focused on the "resource curse," the idea that development of natural resources can reduce economic growth (Corden and Neary (1982), Sachs and Warner (1995)). There are a variety of explanations for how resource curses might develop. Under one type of resource curse, "Dutch Disease," local resource production booms increase costs for other tradable sectors. This can reduce growth if either the non-extractive tradable sector has a higher growth rate than the extractive sector or the resource boom ends suddenly, and is particularly pernicious when coupled with sector-specific human capital development or learning-by-doing in the tradable sector. Studies of the resource curse in the U.S. context have typically focused on boom-bust cycles of resource production, in particular on the aftermath of price-driven resource busts (Jacobsen and Parker (2014), Allcott and Keniston (2014)). However, the boom in shale development has been driven by technological innovations which have lowered the cost of production in boom areas, making a bust due to price decreases less likely in shale areas. Current projections are that the shale boom will last for several decades (EIA (2013a)). In fact, the Marcellus Shale has frequently been referred to in popular media as the "Saudi Arabia of Natural Gas". This suggests studying the local impacts of shale development in the absence of a bust.[1]

In this paper, we ask two questions: What were the local economic impacts of the recent shale boom, and could the boom induce Dutch Disease for resource rich counties? To answer these questions, we match a national database on oil and gas production to a publicly available government dataset on county level wages and employment to understand the relationship between new gas development and county level employment and income. We present results measuring the actual impact of the recent shale boom on local economic conditions for the entire country. Importantly, we can also measure the impact of hydraulic fracturing development on indirect employment by estimating the impact of additional wells on related industries like transportation and construction, in addition to "unrelated" industries like retail and hospitality. Lastly, we turn to geographic variation in the impact of the boom on the local economy and the manufacturing sector to examine the prospects that the current energy boom is setting the stage for a "resource curse" to take place in counties which are developing shale resources and search for factors that can lead to Dutch Disease taking hold.

[1]A number of other mechanisms for the resource curse have been proposed, including the corruption of institutions and strengthening of currency. We do not consider these mechanisms.

The issue of local economic benefits are relevant to policy makers in different ways, but both center on the balancing on the economic benefits of unconventional oil and natural gas development and potential negative environmental and health externalities. First, communities that already have oil and natural gas development may be concerned about allowing additional development of new wells given new information about risks. Second, communities that do not yet have any natural gas development, like those in New York State, will be interested in the costs and benefits associated with developing natural resources.

We use an instrumental variables strategy to estimate the impact of the recent shale energy boom on local labor markets. Our identification strategy employs the geology beneath the county to instrument for the potential endogeneity of shale development at the county level.[2] By examining county-level employment and wages in 2000 and 2010, we find that the elasticity of employment with respect to shale gas and oil wells is approximately 0.03, implying that a doubling of the number of wells drilled in a county will raise employment by approximately 3 percent. Further, we find that "boom" counties, those in the top 25% of well growth, had 24% higher employment than non-boom counties. The majority of job growth was contained in the Mining, Oil, and Gas extraction industry, with some job growth seen in the construction and retail sectors.

Our results indicate that the shale oil and gas boom which occurred during the last decade did in fact provide a significant boost to local employment. However, our results suggest that ex post *estimated* job growth fell well short of ex ante *projected* job growth. The increase in shale oil and gas development from 2000 to 2010 implies an estimated 239,596 local net jobs were created in non-urban counties.[3][4] There is also evidence for shale development being responsible for a growth in wages. We find that counties with shale development had

[2]Similar instruments have been used by Weber (2012, 2013) in the shale oil and gas extraction context.

[3]We drop these urban areas because they may have different employment patterns than rural counties. There are 62 counties considered urban.

[4]To be clear, our model would not pick up job creation that occurred outside of the county in which the drilling was taking place.

6% higher wages and "boom" counties saw wages increase by 10%. These gains in wages were not limited to the Mining, Oil, and Gas Extraction industry, which saw wages increase approximately 30%. We also find smaller gains in the non-tradable sector, with wages in increasing 6% in retail trade and 17% in the hotel sector.

While point estimates at the national level are positive, we do not find a statistically significant impact on wages, employment, or the number of firms in the (tradable) manufacturing sector, suggesting that the Dutch Disease has not occurred during the ongoing shale boom. However, analysis of the recent boom in geographically distinct parts of the United States reveals that manufacturing wages did in fact increase in the Mid-Atlantic and the West North Central Census Divisions.[5] Those two divisions had relatively low levels of unemployment and oil & gas sector presence before the boom. As oil and gas production also requires substantial inputs from other sectors, a lack of prior industry presence implies not just a need for labor in the specialized oil and gas sector, but also for labor in more broadly substitutable support services. When we allow the impact of the shale boom to vary based on measures of labor market tightness and prior industry presence, we find that the boom caused growth in tradable sector wages for those counties with tight labor markets and low prior industry presence. These results suggest that a necessary condition for Dutch Disease obtains when labor supply is inelastic and when resource production requires substitutable labor.

This paper makes two chief contributions. First, we reconcile seemingly inconsistent findings in the resource curse literature, showing that a resource curse might arise when labor markets are tight and there is little preexisting industry presence. This helps us understand why literature examining the 1970's and 80's oil boom and bust finds evidence of a local domestic resource curse (Jacobsen and Parker (2014)), but recent work examing the fracking boom in a subset of the country (Weber (2013)) and nationally (Allcott and Keniston

[5]These divisions contain the Marcellus and Bakken shale formations, respectively.

(2014)) does not. Second, we are the first *ex post* national analysis to focus exclusively on the local economic impacts of the recent boom oil & gas extraction.

The paper continues as follows. Section 2 provides background information regarding shale production as well as the relevant literatures. Section 3 provides an in-depth data description. Section 4 describes the empirical model and identification strategy. Section 5 discusses results for local employment impacts, while section 6 discusses resourse curse results. Section 7 concludes.

2 Background

2.1 Literature Review

This paper relates to several literatures. The first explores local impacts of natural resource development. Recent empirical papers exploring the resource curse using intranational variation have found mixed results. In the paper perhaps most similar to ours, Allcott and Keniston (2014) extend Matsuyama (1992)'s small open economy model to consider endogenous labor supply and show that the impact of a resource boom depends on the elasticity of labor supply. Using data from 1970 until present and national oil and gas employment as an indicator of an energy boom or bust, rather than county-level drilling activity, they find no evidence of Dutch Disease. They suggest and support a variety of explanations, including that booms also support local manufacturers and that manufacturers benefit from productivity spillovers. Similarly, Aragón and Rud (2013) find that the expansion of a Peruvian gold mine created broad local economic benefits by increasing the returns to local factors of production. These results contrast with Jacobsen and Parker (2014), who study the boom and bust in oil prices from the 1970's through mid-1980's and find positive employment effects during the boom but that post-bust income and employment are lower than they would have been without the boom.

In the context of shale development, Fetzer (2014) finds no support for a resource curse in this context. He argues that this is because an increase in energy supply coupled with regional transmission constraints lowers energy prices in shale areas. Weber (2013) focuses on county level employment and wage effects of natural gas production in a restricted geographic area. While studying Arkansas, Louisana, Oklahoma, and Texas, he focuses on the response of the local economy to all natural gas production and finds that an additional one billion cubic feet of production created 18.5 jobs. Furthermore, he finds that the same increase in production leads to 7.5 mining sector jobs and no change in manufacturing employment. We focus on the impact of wells rather than production because wells are labor-intensive to drill, but are not labor-intensive during production (Jacquet (2006)).

Another series of papers has projected or estimated the number of jobs which have been created by the recent shale gas boom. Ex-ante studies typically use simulation models such as IMPLAN and find very large effects. Considine et al. (2010) find that shale gas development would lead to approximately 88,000 jobs in Pennsylvania in 2010. Wobbekind and Lewandowski (2014) find that shale development will produce an average of 68,000 jobs in Colorado from 2015-2020. Nationally, projections range from 601,348 jobs in 2010 to 1,750,000 in 2012. Ex-post econometric analyses are few, far between, and often study a restricted or distinct scope. One econometric analysis, Weber (2012), finds that shale development created approximately 108,580 jobs in boom counties across Texas, Colorado, and Wyoming from 1999 to 2007.[6] While none of these estimates are strictly comparable, there are key takeaways: ex-ante simulation results are larger than ex-post econometric results, but the scope of coverage is limited.

A broad cost benefit analysis of gas production would of course consider nationwide effects and externalities. In particular, generating electricity from natural gas instead of coal substantially reduces both greenhouse gas emissions. A number of authors show that

[6]Based on his estimate of an average effect of 1780 jobs per boom county over 61 boom counties.

hydraulic fracturing has dramatically lowered United States greenhouse gas emissions by inducing fuel switching from coal to gas (Murray and Maniloff (2014), Cullen (2013), Holladay and LaRiviere (2013), EIA (2013b)).

In spite of the purported benefits from an expansion of hydraulic fracturing and development of shale resources in general, the subject remains controversial because of concerns that hydraulic fracturing might pose environmental risks to local communities. Anecdotal evidence of local air pollution, flammable drinking water, unhealthy livestock, and various health problems caused by hydraulic fracturing have been reported. Muehlenbachs et al. (2014) demonstrate that groundwater contamination, perhaps the most prominent risk, already seems to be affecting housing prices. Moreover, Hill (2013) finds an increased incidence of adverse birth outcomes for mothers residing within 2.5 kilometers of hydraulic fracturing wells in Pennsylvania. These potential risks to local communities come on top of other externalities like increased heavy truck traffic, noise pollution, and view-scape deterioration. Jackson et al. (2014) and Shonkoff et al. (2014) note that there is substantial scientific uncertainty about a variety of potential impacts.

The existing research highlights that shale development has both large potential benefits and significant potential costs. In particular, as individual communities decide how to regulate shale development they must weigh local employment benefits against potential costs in terms of quality of life, water contamination, etc. We quantify the employment benefits side of this tradeoff.

2.2 Overview of Shale Oil and Gas Production

It has been known for decades that shale formations hold tremendous reserves of oil and natural gas. One early well in the Bakken was drilled in 1953 and produced approximately 200 barrels per day (North Dakota Department of Mineral Resources (2014)). The difficulty has always been achieving large-scale production at economically viable costs. To that end, and in light of the oil crisis of the 1970's, the United States Energy Research and Development Administration and Department of Energy funded research into shale production starting in 1976. This research involved substantial numbers of test wells. Additionally, private firms have drilled shale wells, but large-scale production required technological innovations (Wang and Krupnick (2013)).

The boom in oil and gas production from shale resources came from the commercial deployment of two novel technologies: horizontal drilling and hydraulic fracturing. Horizontal drilling is the practice of drilling a well which is initially vertical (or nearly so), but turns to the horizontal at the target geologic layer. Horizontally drilled wells can run for large distances underground, allowing a single site on the surface to draw hydrocarbons from a large area. Hydraulic fracturing involves injecting high pressure materials underground through the well and into the targeted resource. These materials, primarily water and sand, create cracks in the shale formation which gas and oil can flow through to the well. These complementary technologies have dramatically lowered the cost of production from the United States's very large oil and gas reserves in shale formations.

The decrease in cost of production has lead to a dramatic increase in the development of shale resources. Many of these shale plays are in areas which also have a history of traditional oil and gas production (such as the Barnett in Texas or northeastern Colorado), but others are in locations without existing large-scale prior oil and gas industry presence, such as western Pennsylvania and North Dakota.

3 Data

To understand the impact of shale development on local labor markets and economies, we have compiled data from a variety of sources. First, we have pulled detailed oil and gas development data from DrillingInfo, an energy industry information services company. Second, we have gathered information on county level employment and wages from the County Business Patterns (CBP) dataset provided by the Census Bureau and from the Quarterly Census of Employment and Wages (QCEW) compiled by the Bureau of Labor Statistics. Third, we acquired county level control data from the USA Counties database, administered by the U.S. Census Bureau. Lastly, we obtained shale maps from the Energy Information Administration (EIA) to understand the energy potential for each county.

3.1 Oil and Gas Data

We use a detailed data set of U.S. oil and gas wells from DrillingInfo, a private sector data provider. This data provides us with the location of wells as well as identifying the geological reservoir. We identify "shale wells" as oil or gas wells which produce from shale reservoirs (e.g. Marcellus, Barnett, Bakken, etc.) and conventional wells as wells which produce from other reservoirs. We do not identify wells which were drilled but have no record of production. We make this restriction for two reasons. First, productive wells are likely to have different economic impacts compared to dry or experimental wells. Second, drilling or "spud dates" are not consistently reported in the dataset. Instead, we use the first report of monthly production quantities to place a well's inception in time.

Figure 1a shows the distribution of wells by county. Maps of the shale basins and plays and estimates of the reserves available are provided by the EIA. By prorating the quantity of reserves in a reservoir by the share of that reservoir which underlies a county, we can approximate the amount of reserves under each county. Figures 1b and 1c show the distribution of gas and oil reserves.

It is important to note that we are considering both oil shale and shale gas deposits and wells. Geologically, oil and gas deposits are often co-located. Economically, both oil and gas production include an employment pattern characterized by substantial labor requirements during initial drilling and much lower labor needs once a well has been drilled and has entered the production phase. And as a matter of data, reporting of well type varies by and within states.

3.2 Employment and Wages

The BLS compiles information on employment, number of establishments, and incomes at the county level and publishes them annually in the QCEW dataset. Annual employment counts are generally the average number of employees, full- or part-time, that a particular establishment had on payroll, taken over each quarterly report. QCEW employment counts are gathered from a combination of survey and administrative records, such as unemployment insurance records. The QCEW does not cover self-employed or employees of private households, and we only use privately owned establishments. In the case of multi-establishment businesses, employees are matched geographically to the establishment that employs them. Average weekly wages are calculated by dividing the annual average payroll in a county by the total number of jobs. Importantly, the BLS doesn't differentiate between part- and full-time employment. In counties with higher amounts of part-time labor, the average weekly wage figure will be an underestimate of the amount of wages earned in a week by a full time employee.

The QCEW database also provides a detailed panel of annual employment levels in each county by industry. Job counts are matched to establishments geographically and establishments are matched to NAICS industry codes.[7] Importantly, the QCEW censored information that could be used to identify a particular firm or individual. For example, if a county only had one firm in the Mining, Oil, and Gas Extraction industry (NAICS code 21), BLS would not publish the employment count and annual payroll information for that county in that year, since anyone with knowledge of the fact that this hypothetical county only had one

[7] The Census Bureau handles the crosswalk between 2000 SIC and 2010 NAICS data.

firm in that industry could infer confidential information.

For county-year-industry observations that are missing in the QCEW data, we cannot be certain that there is in fact zero employment and treat those counties as missing data. We handle county-year-industry observations that are censored in a similar fashion. For county-year-industry combinations that are missing data in the QCEW, we turn to the County Business Patterns (CBP) data to fill in. The CBP data is produced by the Census Bureau along very similar guidelines and from similar sources. However, there are significant differences in the application of disclosure censoring which allows us to supplement missing or censored data in the QCEW with the corresponding information in the CBP. We discuss how we address this censored data in Section 5.5. We do note that when CBP censors data, they provide a range of possible employment counts. We generally ignore this information since the bounds are not uniform. One exception is that we use the midpoint of the employment count range in order to calculate the manufacturing employment share in each county in 2000.

3.3 Geographic Information

In order to fully characterize the determinants of local labor market conditions and the incidence of shale oil and gas development, we turn to several sources for geographic information. First, we use Geographic Information Software (GIS) to calculate the average vertical slope of a county to control for the possibility that mountainous areas might have different job growth prospects. Second, we calculate a dummy variable that equals one if a particular county has an U.S. Interstate Highway running through it.

We obtained digital maps from the EIA which locate shale basins and shale plays in the continental United States. By overlaying a county boundary map on top of the shale map, we calculate 1) whether or not a county is over a shale formation, 2) what percentage of the county's area is over a shale formation, and 3) the number of square kilometers of shale formation lie beneath a county. Lastly, we combine the shale coverage map with estimates of the total quantity of oil and gas projected to be recovered from various shale formations, which is provided by the EIA. Figure 1b displays all counties in the U.S. shaded to indicate the amount of recoverable natural gas beneath them. Figure 1c displays a similar map which shades counties by the amount of recoverable shale oil. These last measures provide an estimate of the amount of energy beneath each county. These measures form the basis of our instruments which will be described below.

3.4 County Controls

We gather county-level control data for each county in the continental U.S. from the Census Bureau's *USA Counties* database. The *USA Counties* database pulls together various databases from the federal government and summarizes key information at the county level. This resource allows us to gather data on important economic indicators like poverty rates, unemployment rates, bank deposits, median housing prices, housing units, owner-occupancy rates, federal expenditures, and new housing permits. Additionally, we obtained various demographic measures such as total population, percent of the population over 65 years of age, percent of 25 year olds with a college degree, and percent of the population that is female, black, and hispanic.[8]

Table 1 provides summary means of the variables used in this study in 2000, 2010, and combined.[9] We can see that overall, the country had lower employment in the private sector in 2010 than in 2000 as a result of the Great Recession. Average county-level unemployment rates were only 4.337 percent in 2000 compared to 9.177 percent in 2010. However, there was an expansion in the number of Mining, Oil, and Gas extraction, compared to a decline

[8]For certain variables, American Community Survey data from 2009 was substituted for Census 2010 data because the 2010 version of the Census no longer collected that data.

[9]We note that Broomfield County, Colorado, was created during the sample period from sections of Adams, Boulder, Jefferson, and Weld counties. Given the panel nature of the data, we drop all five counties from the analysis due to inconsistency in their boundaries and data.

in manufacturing.

At the same time, there was an increase in the number of shale oil and gas wells. In 2000, the average county had 6.2 wells, or about 19,000 nationally. In 2010, the average county had 16.2 wells, or approximately 49,000 wells. This increase in drilling represents a 158% increase in shale development at a time when the economy was losing 2% of its jobs. 24% of U.S. counties had as least some part of shale formation underneath them while only about 16% of U.S. counties had at least one shale oil or gas well drilled by 2010.

Figures 2 and 3 plot the trajectory of shale oil and gas wells, total employment, and mining employment from 1990 to 2010. There was steady, flat growth in shale oil and well drilling prior to 2000, reflecting the experimental and costly nature of extraction hydrocarbons from shale formations. That changes after 2000, with growth in the number of wells accelerating. Total employment enjoyed robust growth during the 1990's, corrected around the 9/11 terrorist attacks, and then grew again up until the financial collapse in 2008. Mining, Oil, & Gas employment followed a different trend. Even during the expansion of the economy in the 1990's, total industry employment was on a steady decline until 2004, when employment in the industry began to skyrocket in accordance with the hydraulic fracturing boom. This continued until 2008 - 2009, when the economy and the price of natural gas began a downward path.

4 Empirical Model

4.1 Empirical Strategy

We consider two empirical models in our main analysis: One that ignores potential endogeneity and one that uses an instrumental variables strategy. Both strategies will take full advantage of the panel nature of our dataset, employing both county and state-by-year level fixed effects. To start, consider the following general regression that ignores the potential endogeneity:

$$\ln(E_{it}) = \alpha_t + \beta SD_{it} + \gamma' X_{it} + \delta County_i + \theta State_i \times t + \varepsilon_{it} \quad (1)$$

In Equation 1, E_{it} represents an economic outcome variable for county i in year t, e.g. the number of jobs or average income, and SD_{it} is some measure of shale development in county i in year t. X_{it} is a vector of control variables, $County_i$ is a county fixed effect, and $State_i$ is a state level fixed effect.

With two time periods, 2000 and 2010, we can present our model in differences, with the left hand side variable representing the growth in the outcome, E:

$$\ln(E_{i2010}) - \ln(E_{i2000}) = \tilde{\alpha} + \beta(SD_{i2010} - SD_{i2000}) + \gamma'(X_{i2010} - X_{i2010}) + \theta State_i + (\varepsilon_{i2010} - \varepsilon_{i2000}) \quad (2)$$

$$\Delta \ln(E)_i = \tilde{\alpha} + \beta \Delta SD_i + \gamma' \Delta X_i + \theta State_i + \Delta \varepsilon_i \quad (3)$$

Equation 3 represents the fundamental model of growth that we consider. The growth in employment or wages is a function of the changes in shale oil and gas development, changes in covariates, state fixed effects, and the difference between two mean zero disturbance terms.

4.2 Identification

We consider two identification concerns that could lead OLS estimation of Equation 3 to produce biased estimates of β. First, econometrically there could be correlation between $\Delta\varepsilon_i$ and ΔSD_i. In words, it could be the case that drilling into shale to extract hydrocarbons was not done randomly. Rather, drilling could have been correlated with negative shocks to economic activity over the period. Second, if counties which eventually received shale gas development were on preexisting differential growth trends, the presence of shale gas development could simply be a proxy for the continuation of below-average economic growth.

4.2.1 Correlated Unobservables

The concern about changes in unobserved determinants of growth can be illustrated in Table 2. Columns (1) and (2) show the difference in means between counties which had an active shale well in 2010 ("Fracking Counties") and those that didn't, for 2000 and the change between 2010 and 2000, respectively. In 2000, fracking counties had significantly less manufacturing jobs, higher unemployment, more poverty, lower housing prices, smaller populations, and a smaller proportion of college educated individuals. Over the period 2000 - 2010, fracking counties had better economic outcomes. These counties saw larger gains in income, jobs and larger decreases in unemployment and poverty. However, there were many differences in other observable attributes, such as building permits, housing prices, housing units, and federal expenditures. We might be concerned that these differences in the changes in observable attributes signal a difference in the change in unobservables. In this case, we should be worried that OLS estimation of β would be biased.

Given this concern, we want to instrument for the *changes* in shale development with measures of the shale geology available under the county. Accordingly, for the census years 2000 and 2010 we regress changes in the economic variable on changes in county attributes, which accounts for the county level fixed effect, and instrument for the shale development variable:

$$\ln(E_{i2010}) - \ln(E_{i2000}) = \tilde{\alpha} + \beta(SD_{i2010} - SD_{i2000}) + \gamma'(X_{i2010} - X_{i2010}) + \theta State_i + (\varepsilon_{i2010} - \varepsilon_{i2000}) \quad (4)$$

$$SD_{i2010} - SD_{i2000} = \lambda' ShaleAtt_i + \eta'(X_{i2010} - X_{i2010}) + \zeta State_i + (\nu_{i2010} - \nu_{i2000}). \quad (5)$$

This identification strategy is similar in spirit to that of Chay and Greenstone (2005), who use mid-decade Clean Air Act regulatory status to instrument for inter-censal changes in total suspended particulate concentrations at the county level. Equation (5) implies that changes in shale development are a function of the attributes of the shale underlying a county, $ShaleAtt_i$, changes in observable county level attributes, and state fixed effects. There are two requirements for our instrumental variables strategy to be valid. First, attributes of the shale formation beneath counties must have an effect on shale development, or in other words, $\lambda \neq 0$. Second, attributes of subterranean shale formations cannot be correlated with changes in unobserved determinants of the economic outcome variable: $E[(\varepsilon_{i2010} - \varepsilon_{i2000})ShaleAtt_i] = 0$. Intuitively, the first condition must hold, since there cannot be shale development where this is no shale. In practice, available maps for the local of shale resources cannot be expected to be completely accurate. This leads to a small amount of shale oil and gas development in places where shale formations have not be identified in publicly available maps. [10] Thus knowledge of oil and gas shale plays is plausibly exogenous to above-ground conditions during our study period. This strategy has been successfully implemented by Weber (2012, 2013) in the shale gas context.

In order to help control for time-varying unobservables, we propose using the following instruments for new shale oil and gas wells: an indicator for shale, the percentage of area of a county that is over a shale formation, and the estimated reserves of oil and gas under the county. Intuitively, since shale formations are subsurface geologic formations, it is natural to think that subterranean shale rock would have no impact on local economic conditions *except* for the way that shale formations facilitate the development of oil and natural gas, which in turn can impact local economic conditions.

The second requirement for our instrumental variable to be valid is that "shale counties"

[10] While the technology to economically produce oil and gas from shale plays is quite new, the plays have been known about for some time. For example, the United States Department of Energy conducted experiments in fracing shale plays in the 1970's. NETL (2007)

cannot be substantially different than non-shale counties in unobservable dimensions. While this is an untestable requirement, we can look to observable characteristics of shale counties to see if they are different in significant ways compared to non-shale counties. If not, we may gain some comfort that if the IV "balances" the observable characteristics, the unobservable characteristics would be "balanced" as well, implying that the instrumental variable is acting like a quasi-experiment. Of the 727 counties that have shale formations beneath them, only 340, or about 47%, have had a shale well drilled by 2010.

Columns (3) and (4) of Table 2 provide evidence for the validity of shale measures as an instrument. With few exceptions, in 2000 shale counties look very similar to non-shale counties on dimensions unlikely to be impacted by shale development. There are no significant differences in total employment, manufacturing employment, housing prices, population, or housing units. Over the period 2000 - 2010, shale formations are correlated positively with the outcome variables income and employment, as well as Mining, Oil, and Gas industry employment. Further, shale status is also correlated with larger growth in shale development, which is to be expected. Compared to the differences in means for fracking vs. non-fracking counties, shale and non-shale counties appear to have less statistically different changes in observables over the decade, both in levels and differences. With a few exceptions like poverty rates and housing prices (which could be endogenously determined), shale status appears to balance the observables, giving us confidence that shale attributes are not correlated with the second stage error term.

4.2.2 Preexisting Trends

A second source of endogeneity in Equation 3 comes from the possibility that counties with shale oil and gas development might have been on worse growth paths prior to 2000. If so, shale development will serve as a proxy for the continuation of a negative growth trend and bias estimates of the effect of shale development on economic variables downwards. Conversely, if counties with shale development were on higher trajectories, straightforward estimation of the impact of development on economic outcomes would result in overestimation.

In Figure 4a, we plot the average employment for counties that had an active well in 2010 and those counties who had not.[11] Counties will drilling appear to start to diverge from their counterparts around 1995, and by 2000, these counties appear to have substantially less jobs. Conversely, by 2005, drilling counties attain a higher growth trajectory, and maintain a higher growth in employment throughout the Great Recession. Column (5) of Table 2 reinforces this idea. Fracking counties has less growth in income, jobs, mining and transportation jobs, and higher rates of unemployment and poverty prior to 2000.

While the trends plotted in Figure 4a suggest that fracking counties had a worse trend, they are unconditional means. In order to test for a differential trend more rigorously, we estimate the following equation:

$$\Delta \ln(E)_i = \alpha + \beta_F \mathbf{I}\{FRACK_i\} + \gamma' \Delta X_i + \theta State_i + \Delta \eta_i. \tag{6}$$

In this regression, we regress growth in employment, $\Delta \ln(E)_i$ on an indicator for whether the county had shale wells, controls, and state fixed effects. The results of this regression are in Table 3, Column (1). Fracking counties had a significantly lower growth in employment over the period 1990 - 2000 which confirms our suspicion that fracking was associated with a lower pre-existing trend in employment.

In order for the presence and attributes of the shale formation underlying counties to serve as a valid instrument, shale counties cannot be associated with a negative existing pre-trend. In Figure 4b, we plot average employment for shale counties and counties without

[11]Specifically, the y-axis details the mean residual from a regression of ln(employment) on population, area, an indicator for an interstate, and slope of the terrain.

any subterranean shale formations. The two lines track each other more closely than when the sample is broken out by the presence of fracking wells, however, there appears to be a gap that grows in the late 1990s. If this is a significant difference, our instrumental variables estimates may be attenuated.

Column (6) of Table 2 provides the information for 2000 - 1990 when the two groups are defined by the presence of shale formations. The differences are still significant for many of the same variables as when the sample is split by fracking counties, but in each case, the difference is of a smaller magnitude. In part, this should not be unexpected since most counties that would fall into the "fracking" category would also fall into the "shale" category. However, there are some important differences. For example, shale counties have a statistically significant higher change in housing prices and higher reduction in the unemployment rate over the period. The estimates in Column (6) suggest that the nature of preexisting trends for shale counties is more nuanced.

Next, we test for a differential trend between shale and non-shale counties by estimating the following equation:

$$\Delta \ln(E)_i = \alpha + \beta_S \mathbf{I}\{SHALE_i\} + \gamma' \Delta X_i + \theta State_i + \Delta \eta_i. \tag{7}$$

This equation is identical to Equation 6 except for the use of an indicator function that equals one when the county has shale beneath it, and zero otherwise. The results of this regression are presented in Table 3, Column (2). Conditional on observables and state fixed effects, shale counties do not have a significantly different pre-trend going into the 2000s. This fact gives us confidence that our instrumental variables do not serve as a proxy for poor growth.

5 Local Economic Impacts

5.1 Overall Employment Impacts

Our first specification seeks to quantify the general differences between counties that have shale oil and gas development and those that do not. Accordingly, we measure shale development in discrete terms. Here, our outcome, Y_{it}, is the natural logarithm of the number of total jobs in county i at time t. Table 4 provides the OLS and IV regression estimates for Equations 3 and 4 & 5. Column (1) provides the OLS estimates of a regression of growth in jobs on an indicator for whether or not a county in on shale. This variable is one of our instruments and represents the Intent to Treat (ITT). Shale counties ended up with 4.4% more jobs than non-shale counties.

Column (2) provides the OLS estimates for when the treatment variable is an indicator for whether or not the county had a shale oil or gas well drilled before 2010. There were 479 such counties. The effect on employment is positive, but insignificant. Column (3) uses an indicator for whether a county was considered a "boom" county, defined as a county in the top 25% of shale oil and gas well growth from 2000 to 2010.[12] This criteria results in 98 counties being classified as boom counties. These counties experienced a 4.4% increase in employment, relative to non-boom counties.

Columns (4) and (5) present corresponding instrumental variables regressions. Here, each "treatment" variable is instrumented for with four separate IVs: an indicator for whether or not the county has shale beneath it, a continuous measure of the size of the area of the shale in square kilometers, and estimates of the recoverable natural gas and oil reserves contained in the specific shale formation over which the county lies, respectively. When comparing the results in Columns (2) - (3) to those in Columns (4) - (5), it's clear to see that the IV

[12] In general, "boom" results are similar in nature for different definitions of boom. When strengthening the boom criteria, for example the top 10% of well growth, employment effects are stronger. When weakening the definition, effects are weaker.

strategy has the effect of increasing precision and removing an apparent downward bias from the OLS estimates. This suggests that shale development is correlated with time-varying unobserved negative shocks.[13] Column (4) indicates that the average effect of shale oil and gas development prior to 2010 increased employment by 12.3%. Column (5) demonstrates that the effect for "boom" counties was more than twice as strong, as employment increased by approximately 24% in those counties.

Table 5 alters our definition of treatment to allow for the intensity of shale development to impact employment. We employ two continuous measures of shale development: the number of wells and the inverse hyperbolic sine of the number of wells.[14] The inverse hyperbolic sine is a convenient choice for a nonlinear specification because it is defined at zero and for a large portion of the real line, its derivative is equivalent to the derivative of the natural logarithm. Accordingly, we can interpret coefficient estimates as elasticities when the dependent variable is the natural logarithm of an outcome variable.

Columns (1) and (2) provide the estimates for Equation 3 when the dependent variable is the natural logarithm of employment and the independent variable of interest is the number of jobs and the inverse hyperbolic sine of the number of jobs. Both point estimates are positive and significantly different from zero. The linear estimate suggests that increasing the number of wells by 100 would increase employment by 1%. The elasticity estimate in Column (2) suggests an doubling of wells leads to a 0.7% increase in employment.

Columns (3) and (4) present the instrumental variable regression estimates for both the linear and nonlinear independent variable. Both regressions reveal a positive and significant relationship between the number of wells and employment. The linear IV estimates in

[13]Determining why wells are preferentially sited in counties with worse economic characteristics is beyond the scope of this study. Possibilities include lower costs, lower willingness to accept environmental harms on the part of residents, a more welcoming regulatory environment, and environmental justice. Distinguishing between these explanations would constitute an interesting avenue for future research.

[14]The inverse hyperbolic sine of x, often denoted as $arsinh(x)$ or $sinh^{-1}(x)$, is given by $sinh^{-1}(x) = \ln(x + \sqrt{x^2+1})$.

Column (3) are ten times larger than those in Column (1). Increasing the number of shale wells by 100 would increase employment by 11%. The results in Column (4) imply that the elasticity of employment with respect to shale oil and gas wells is 0.0308. For a county which doubled the number of wells inside its borders, the number of jobs would increase by 3.08%. Consistent with Table 4, the IV estimates have increased significance and also associate stronger job growth with the incidence of shale development.

5.2 Counterfactual Employment Estimates

While elasticity estimates are interesting in their own right, they are not useful for trying to understand what happens in a county that initially has zero shale oil and gas wells since a percentage change from an initial value of zero is undefined. In order to understand what our estimates imply for the number of jobs created by shale development, we calculate the counterfactual number of jobs each county would have had in 2010 if there had been no wells drilled. Specifically, we start by calculating the predicted growth in employment from the regression in Column (4) of Table 5:

$$\widehat{\Delta \ln E_i} = \hat{\alpha} + \hat{\beta}(IHS(SD_{i2010}) - IHS(SD_{i2000})) + \hat{\gamma}'(X_{i2010} - X_{i2010}) + \hat{\theta} State_i \tag{8}$$

Since the predicted growth is equal to $\ln \widehat{\frac{E_{i2010}}{E_{i2000}}}$, we get

$$\ln \widehat{\frac{E_{i2010}}{E_{i2000}}} = \widehat{\Delta \ln E_i} \tag{9}$$

$$\widehat{E_{i2010}} = \exp\{\widehat{\Delta \ln E_i}\} * E_{i2000} \tag{10}$$

(11)

Next, we calculate the predicted level employment in 2010 in the absence of shale development, $\widehat{E^{NS}_{i2010}}$ by the same process while setting the change in wells to zero. Then, the number of jobs that shale gas development was responsible for is given by

$$SHALEJOBS_i = \widehat{E_{i2010}} - \widehat{E^{NS}_{i2010}}. \tag{12}$$

By using the above process, it is possible to tabulate the number jobs that shale development was responsible for in each state. For each county, we estimate the number of jobs created and the lower and upper bounds of a 95% confidence interval. Then, for each state, we sum the counterfactual jobs estimate, the upper bound, and the lower bound over counties. The results of this exercise are presented in Table 6.

In non-urban counties, shale oil and gas development was responsible for approximately 239,596 new jobs as of 2010. The confidence intervals are large, but bounded away from zero. The states with the two biggest gains were Pennsylvania and Texas, with 76,548 and 52,829 new jobs created, respectively. The impact of the assumed non-linear relationship between shale wells and employment is on display in Table 6. For example, while both Texas and Colorado had more wells drilled than Pennsylvania over the decade, their combined estimated job growth is lower. This is because the growth in wells as a percentage was much higher in Pennsylvania since Texas and Colorado had some unconventional shale development at the onset of the decade.

It should be made clear that our estimation strategy only identifies the number of jobs created concurrently with drilling within the same county. Any employment gains or losses that might result through indirect channels across counties would not be captured in these estimates. Furthermore, if drilling companies employ workers from outside the county on a temporary basis, this would not be captured by our data. For example, if a drilling company sends an engineer from Houston to Western Pennsylvania to work on an assignment for six months while keeping the payroll for the engineer in Houston, the QCEW will count that worker as employed in Texas, not Pennsylvania. Our estimates would, however, capture any indirect economic activity induced by the consumption and spending that engineer brings to Pennsylvania.

5.3 Overall Wage Impacts

Our analysis of the impact of shale development on average weekly wages follows analogously to the section on overall employment. We follow the same estimation routine from Section 4, using average wages from the QCEW instead of total employment as our dependent variable. Table 7 provides the estimation results for the various discrete measures of shale development. Column (1) indicates that the Intent to Treat effect on wages is 2.0%. Columns (2) - (3) reveal OLS wage impacts from the development of shale resources, on the order of 2% to 3%, even for "boom" counties.

Columns (4) - (5) present the instrumental variables regression estimates. Counties that had at least one well drilled before 2010 experienced 6% higher wages. Boom counties saw a larger gain, with wages 10% higher than non-boom counties. We find less consistent evidence of improved wages when we try to control for shale development intensity. Table 8 provides OLS and IV estimates for changes in shale oil and gas wells. The linear OLS estimate is highly significant while the elasticity estimate is significant at the 10% level. The IV estimates look somewhat different. The linear estimate is precisely estimated, suggesting that an increase of wells by 100 resulted in an 11% increase in overall average weekly wages. The elasticity point estimate suggests that a doubling of wells would result in a 1.1% increase in wages. However, this estimate is not significantly different from zero. Taken together, these results suggest that county level average wages were significantly increased by the introduction of unconventional shale development.

5.4 Neighboring Counties

For some counties, the local labor market is completely contained within the political boundaries of the county. However, for many counties, this is not the case. Relatedly, it is not unconceivable that drilling activity in one county can have labor market impacts in neighboring counties. In this section, we investigate the possibility that drilling activity can have geographic spillovers into neighboring counties.

For each county and year, we create a count of the number of wells, both shale and conventional, for adjacent counties. Then, we include "neighbor shale wells" in the main specification, Equation (3), as additional endogenous regressors. Intuitively, if own-county drilling activity is endogenous and economic trends share a spacial correlation, other-county drilling will also be endogenous. We create a set of instruments that mirror the instruments used in the main analysis: neighboring county shale indicators, neighboring county shale coverage in square kilometers, and neighboring county shale oil and gas reserves.

Table 9 provides the results from four different regressions, two using employment as the dependent variable and two using wages. Column (1) presents the results from an IV regression of the natural logarithm of employment on the change in shale wells, both own-county and neighboring county. Column (2) repeats the analysis by using the inverse hyperbolic sine of well counts. Columns (3) and (4) mirror the first columns but use the log of wages as the dependent variable. In each of the four regressions, the point estimate and significance of the own-county effect are largely the same as the set of regressions where neighboring counties' well information were not included. Furthermore, conditional on own-county drilling activity, there appears to be no significant impact of neighboring counties' drilling activity on own-county employment and wages.[15]

[15] The analysis using discrete shale development treatments provides the same result as the continuous treatments.

5.5 Industry Specific Employment Impacts

The estimated gains in employment from Sections 5.1 and 5.2 are likely not distributed evenly across industries. Intuitively, we might expect a large surge in the number of Oil and Gas workers as the number of wells drilled increases. We might also expect supporting industries, like construction and transportation, to also see a gain in employment as increased shale oil and gas development requires local firms to pour concrete and deliver hydraulic fracturing fluids. Further, it is possible that increased economic activity will spill over into other sectors, like retail or hospitality.

In order to investigate spillover effects we repeat the regression from Equations 4 & 5 setting the dependent outcome variable to the natural logarithm of industry specific employment for Mining, Oil, and Gas Extraction, Food and Accommodation (hotel), Construction, Retail, Transportation, and Manufacturing. However, variation in the presence of industries across counties results in many counties having no employment for some industries in one or both years in our sample. Furthermore, counties with a very small numbers of firms in a given industry will see their data censored by BLS in order to maintain their confidentiality. For example, there are only 754 counties which have non-zero, non-censored employment in both 2000 and 2010 for the Mining, Oil and Gas Extraction industry.

The nature of the industry specific employment data forces us to alter our empirical strategy. For each industry, we must account for two sets of counties for our analysis. First, there are those with competitive labor markets, defined as counties that had non-zero employment in 2000 and a sufficient number of employers to prevent the industry level employment from being censored for confidentiality. Second, there are those with "new" labor markets, defined as those counties which had no employment in 2000 in a particular industry. This distinction requires us to consider the labor market impacts of shale oil and gas development differently for areas that have existing industrial presence and those for which there is not an industrial presence. We focus on counties with established industrial labor markets rather than trying to model the growth of an industry that didn't substantially exist, or wasn't competitive, in 2000.

Table 10, Panel A provides industry specific treatment effects for a binary variable indicating whether or not a county had a shale oil or gas well by 2010 for the set of counties with established competitive labor markets. For these markets, counties with shale oil and gas development had 86% more Mining, Oil and Gas workers. Furthermore, shale development brought about an increase of 5% in the retail trade industry and 15% in the construction industry. Food and accommodation, transportation, and manufacturing did not see any statistically significant change in employment. Interestingly, transportation employment does not expand as might be expected. Hydraulic fracturing, the main method for extracting hydrocarbons from shale rock, requires the utilization of immense quantities of water which must be trucked into drilling sites. Our null result could be evidence that the required transportation labor is hired outside of the county and brought in to service wells.

In Table 10, Panel B we repeat the analysis with the inverse hyperbolic sine of the number of shale wells as the independent regressor of interest rather than a binary indicator for shale development activity. Our results indicate a less pervasive effect of drilling on industrial labor markets than the binary indicator. We do find that the elasticity of Mining, Oil, and Gas Extraction employment with respect to shale wells is 0.249, implying that a doubling of wells increases Mining, Oil & Gas Extraction employment by 24.9%. Panel C reveals that the resource industry employment effects in boom counties were quite substantial. These counties saw more than an 150% increase in employment in that sector.

5.6 Industry Specific Wage Impacts

Next, we examine the impact that shale oil and gas development had on industry level wages. To analyze this question, we only deal with counties that had positive industry employment in 2000. We interpret the lack of employment in an industry in 2000 as an indicator of the absence of a labor market at all and treat the average wage in a non-existent labor market as undefined. Any analysis of the impact of shale oil and gas development would be restricted to competitive labor markets, which is to say, the effect on wages in industries that have many employers in the county.

Table 11, Panel A presents the regression results for the industry specific wage equations. We find that shale development has a significantly positive impact on wages in some sectors. The largest gain appears in Mining, Oil & Gas Extraction, with wages increasing 30%. There is mixed evidence for the impact on wages in the related industries of Construction and Transportation. We also find that wages in "spillover" industries like Food and Accommodation and Retail increase, gaining 17% and 6%, respectively. We do not find evidence that shale development increases wages in the (tradable) manufacturing sector, suggesting that shale development does not cause a Dutch disease-based resource curse. We will examine Dutch Disease further in the subsequent section.

Table 11, Panel B uses the inverse hyperbolic sine of well counts as the regressor of interest. With these specifications, we find different marginal effects. The income elasticity of additional wells is not precisely estimated for Mining, Oil & Gas wages or transportation industry wages. However, for the Hotel and Accommodation, Construction, and Retail industries there are positive, significant elasticities, ranging from 0.018 to 0.048. These effects are magnified in boom counties. Panel C reveals wages increased 37%, 19%, and 11% in the Food and Accommodation, Construction, and Retail industries, respectively, in boom counties.

5.7 Other Outcomes

Lastly, we examine the impact that shale oil and gas development had on other attributes of counties over the period. Table 12 details the regression results when using population, median housing prices, percent of college educated adults, and the number of business establishments as dependent variables. First, we note that shale oil and gas development was associated with an increase in population, with shale development counties experiencing 2.4% higher growth in population. This provides important context for the wage regression results since the increase in wages occurred in spite of an increase in population. It is entirely possible that short-term increases in wages do not persist as migrants increase the labor supply. However, as can be seen here, higher wages remained at the end of the decade, in spite of population migration.

Interestingly, the increase in employment, wages, and population we see in shale oil and gas counties was accompanied by 9% lower median housing prices. The estimated economic impacts would seem to indicate positive momentum for housing prices, however, these counties saw prices drop. While this is not a formal hedonic analysis, it suggests that shale oil and gas production could be seen as a disamenity by the housing market.

Finally, we return briefly to the notion of a "resource curse". The general concern with a "resource curse" is that if concentration in the extractive industry reduces long run competitiveness in the tradable sector, a local economy can be made worse off by the extraction of the natural resource. In Column (3) of Table 12, Panel A, we see that shale oil and gas development had a statistically negative impact on the percent of individuals that have a bachelor's degree. This might portend negative future economic outcomes if there is a reduction in individuals with high human capital[16]. Further, one might be concerned that the increase in competition in the labor market might drive out other businesses. In the long run, when the extractive industry is no longer present, the local economy may not regain the businesses which were driven out. In Column (4), we use the number of establishments

[16] Moreover, as suggested in Allcott and Keniston (2014), a natural gas boom could have the result of endogenously changing the quality of the labor supply, which in turn could manifest econometrically as a change in earnings per worker. These results, in combination with the results from the wage regressions, suggest that wages increased in spite of a reduction in apparent human capital.

in a county as the left hand side variable. While our point estimate is positive, we do not estimate the effect with precision. Lastly, in Column (5) we find no significant effect of shale development on the number of manufacturing establishments in the county. This further suggests that the extraction of the natural resource did not have a negative impact on the competitiveness of the tradable sector. In Panel B, when using "Boom County" status as a treatment, we find some of the impacts of shale development were magnified. Boom counties saw a larger increase population and a substantially larger decrease in median housing prices. This suggests that unconventional shale gas production presents itself as a disamenity to housing market participants if prices are falling even as population, and presumably the demand for housing services, increases.

5.8 Discussion

The overall conclusion that can be reached from the multitude of previous results is that shale oil and gas development has undoubtedly contributed to local economic growth, creating more jobs and raising average wages. It is natural to compare our estimated job gains to previously published predictions for the number of jobs that shale oil and gas development would create. However, such comparisons need to made with caution. *Ex Ante* predictions for the number of jobs that hydraulic fracturing would create were almost exclusively created from input-output matrix models like IMPLAN which relied on surveys of industry participants for projected expenditures.

Accordingly, such estimates count the number of jobs that would be created in all parts of the economy, not just the number of jobs drilling a well would have on the employment within the county. Our estimates cannot measure "systemic" employment effects that result from increases in labor demand at upstream suppliers. Our estimates would rightly be viewed as a lower bound on the number of jobs created.

Specifically, our estimates carry the interpretation of the expected impact shale development has on the community that has to coexist with the realities of shale oil and gas extraction. Jobs created outside of the county are not accounted for in our estimates and are likely to not be of interest to the residents and policy makers within a county. For example, county level stakeholders in New York are likely to be concerned with what they can expect in their local economy if they lift the hydraulic fracturing moratorium. Over the period 2000 - 2010, the average county that drilled its first shale oil or gas well had 44,938 jobs and drilled 45.6 wells. According to our estimates in Table 5, this average county experienced an increase in employment of 1,096 jobs, which represents a 2.4% increase.

Lastly, we find several pieces of evidence that suggest that the recent oil and natural gas boom does not display the systems of "Dutch Disease." We find that manufacturing wages, employment, and establishments are not significantly effected by shale oil and gas development in either direction. While it is too early to know whether or not long run economic prospects will have been damaged by the recent boom, the theoretical foundations of the resource curse do not appear to be present at the national level. In the next section, we press this issue further.

6 Regional Variation and Dutch Disease

Dutch Disease is most easily understood as a form of the resource curse whereby a resource is extracted at the expense of the tradable sector of the local economy. The county is left worse off if the tradable sector grows more quickly than the resource extraction sector or if the resource extraction sector busts and nontransferable human capital limits the ability of workers to transfer to the tradable sector. In either case, resource extraction crowds out employment in the tradable sector. This would manifest itself as a wage increase in the tradable sector.[17] We analyze manufacturing as a tradable sector.

[17] It is important to note that a wage increase in the tradable sector is not sufficient to identify a resource curse. For example, resource extraction could in principle grow more quickly than the tradable sector.

While we see evidence of wages increasing in fracking counties in Section 5, there doesn't appear to see an increase in wages in the manufacturing sector. In this section, we examine how the shale boom has differentially impacted different parts of the country, letting the estimated effects vary by Census Division. Initial conditions in 2000 varied greatly across the country so we endeavor to see if 1) the employment and wage effects were different, and 2) what can explain any differences we might find.

6.1 Divisional Variation in Local Economic Impacts

We begin our investigation of regional variation by examining the employment effect in boom accounts across the country. We break the sample into 9 groups according to the Census Divisions. Divisions 1 and 9, which comprises the New England and West Coast states, had no boom counties during the period and are ignored from subsequent analysis.

The first set of regressions we consider are analogous to Table 4, Column (5). Specifically, we run IV regressions using "Boom County" status as a treatment. The results are contained in Panel A of Table 13. Looking across the columns it is easy to see that the effect was very different in the various divisions. There are several divisions of note: Division 2 contains Pennsylvania, which is over the Marcellus Shale, Division 4 contains North Dakota, which is over the Bakken Shale, and Division 7 contains Texas, over the Barnett Shale. These are three of the most developed shale formations. Also, Divisions 3, 5, and 8 had significant activity in states like Michigan, West Virginia, and Colorado/Wyoming, respectively.

Divisions 4 and 7 had large, significant employment effects resulting from the boom, 48% and 15%, respectively. We estimate, imprecisely, that Division 2 saw a 14% increase in employment. The other divisions have estimates with very large standard errors. Panel A suggests that the boom was not the same in all parts of the country. Boom counties on the Bakken Shale in North Dakota experienced large significant increases in employment whereas those on the Marcellus Shale in Pennsylvania did not appear to. Its possible that the size of the 2nd Division is preventing precision.

If the employment impacts vary greatly across division, what about income effects? In Panel B of Table 13, we again see large variation in the estimated impact of the shale boom on wages. In Division 2, wages increased approximately 15%, while in Division 4 they went up by nearly one-third. Other divisions has no significantly estimated wage effects.

A curious pattern emerges: why did Division 2 have no significant job growth but significant wage impacts while Division 7 displayed the opposite? One hypothesis would be that unemployment varied across divisions, giving rise to differential wage impacts. Intuitively, in an area with slack in the labor market, wages should be less responsive to a shock to labor demand. In Table 14 we provide the population weighted unemployment rate within each division in 2005. We choose 2005 because it is closer to the onset of the boom than 2000 and 2005 is after both 9/11 and its associated recession. Both Divisions 2 and 4 had unemployment rates under 5% whereas Division 7 had an unemployment rate of 5.47%. While certainly not proof, these statistics point to the possibility that the wage impacts of a resource boom will depend on initial unemployment.

If the boom in shale development left geographic variation in employment and wage effects, it is possible that evidence of Dutch Disease also varies by geography or shale formation. In Panel C of Table 13 we provide division-by-division regressions of the log of manufacturing wage on boom county status. Divisions 2 and 4 have positive, and significant at the 10% level, estimated wage impacts for the manufacturing sector. Division 2 sees manufacturing wages jump 32.5% and Division 4 sees wages jump nearly 62%. However, Panel D reveals that there are no impacts on the number of people employed by the manufacturing sector for all divisions.

The variation in estimates suggests that national regressions mask the possibility of resource booms driving up manufacturing wages in select parts of the country. A natural question posed by Table 13 is: Why? One might hypothesize that areas for which there are low levels of initial oil and gas workers have to steal labor away from other industries. Relative to the costs of capital and lease acquisition, labor costs for energy costs are likely relatively small and the demand for labor inelastic. As a result, when shale developers move into a new area, they can easily bid up the price of labor. Table 14 also provides the population weighted county-level average fraction of workers at the beginning of the period that were in the Mining, Oil, and Gas Extraction industry in 2000.[18] Divisions 2 and 4 rank near the bottom of divisions in terms of percentage of Oil and Gas workers in 2000, especially when ignoring Divisions 1 and 9, which had no boom counties. Again, this is not proof that initial workers in the resource extraction industry can determine whether tradable sector wages will rise, but it certainly is suggestive.

6.2 Understanding Dutch Disease

Lastly, we wish to test whether unemployment and initial industry workers, which are suggested to impact the potential for Dutch Disease, do in fact impact wages. To proceed, we regress wages, both total and manufacturing, and manufacturing employment on a boom county indicator, a boom county indicator interacted with the 2005 unemployment rate, and the percentage of the workforce in 2000 that was employed in the Mining, Oil, and Gas extraction industry, employing the same set of instruments. The first regressor will account for the main impact of being a boom county, while the second and third will allow the marginal effect of boom county status to vary based on unemployment and initial oil and gas workers. The three regressions are limited to those counties with non-missing oil and gas worker data for 2000.

Table 15 reports the regression estimates from this exercise. Column (1) details the results for an IV regression of the log of total average wages on the three boom covariates. All of the coefficients are significant for at least the 10% level. Boom counties with higher

[18] This average is taken over counties that did not have censored industrial employment data.

initial levels of unemployment did in fact have lower gains in price. Furthermore, the regression estimates imply that boom counties with higher levels of oil and gas workers saw lower increases in wages. The results imply that in a boom county with no oil and gas workers, wages didn't increase at all if the county also had higher than 6.8% unemployment.

Column (2) confirms our suspicions about the drivers of Dutch Disease. While our analysis in Section 5 led us to believe that there was no risk of Dutch Disease with the energy boom in the past decade, allowing for a more flexible analysis reveals the opposite. The mean effect of the boom on manufacturing wages was positive, and that wage effect decreases with both higher unemployment and higher fractions of oil and gas workers at the onset of the decade. Both results conform to intuition. With higher unemployment, the demand for additional labor won't force manufacturing firms to increase their wages to compete. This result is consistent with Allcott and Keniston (2014)'s insight on the importance of the elasticity of labor supply. Furthermore, counties that already have substantial amounts of experienced workers see no competition between the resource extraction industry and the tradable sector. However, Column (3) indicates that higher wages have not yet translated into a reduction in employment.

Table 15 raises concerns that certain counties currently benefiting from the shale boom may have tougher times ahead. Consider the cases of Pennsylvania and Texas. Pennsylvania had low unemployment and low levels of existing oil and gas industry workers. Texas was the opposite. In the long run, our results suggest that Texan manufacturers might be comparatively better off since wages haven't increased in the short run. In Pennsylvania, however, manufacturers have seen their input costs jump as a result of the boom. If this puts them at a competitive disadvantage, they may not survive long into the future when the boom ends, hurting PA's long run economic prospects. However, we cannot conclude that Dutch Disease has taken hold yet, since manufacturers do not seem to have responded to higher wages by reducing employment. Since the dynamics of Dutch Disease can take years or decades, more time needs to pass before a definitive statement can be made, one way or the other.

7 Conclusion

The explosion in natural gas and oil extraction from shale rock formations has become one of the predominant issues in the domestic energy sector. The potential energy stored in shale formations that has become technologically and economically recoverable is hard to understate. Oil and gas extraction firms have instigated a modern day "gold rush" in North Dakota, Pennsylvania, Oklahoma, Arkansas, Colorado, Michigan, Montana and West Virginia. This rush to develop shale resources has brought concern to local stakeholders as evidence of local water contamination, infrastructure degradation, and air and noise pollution mounts.

While reports of negative externalities resulting from hydraulic fracturing have been repudiated by the industry and their backers, proponents of shale development have long touted the economic benefits that will accompany the rapid expansion of extraction. This paper is the first endeavor to specifically quantify the size and extent of the changes in economic activity associated with the recent shale oil and gas boom across the entire nation. Our analysis is *ex post*, which contrasts with existing industry-funded ex ante studies.

We find that the growth rate in employment from 2000 - 2010 was 12% higher in counties with productive shale oil and gas wells. "Boom" counties, those with a growth in the number of wells drilled in the top 25%, was approximately 24% higher than non-boom counties. The elasticity of employment with respect to new well drilling is approximately 0.03, indicating that a doubling of wells would lead to a 3% increase in jobs. Further, our model predicts that the shale oil and gas boom produced between 50,000 and 430,000 jobs over the decade.

Wages increased on the order of 6% to 10%, depending upon the intensity of drilling.

Interestingly, we find that Dutch Disease is a risk for those boom counties that had low levels of unemployment and low availability of industry workers. The result is intuitive since low unemployment would put upward pressure on wages in all sectors and low initial levels of workers in the extractive industry can cause competition for labor between the tradable and resource sector. Increased input costs in the tradable sector can impede the those firms ability to compete in the long run, hampering future economic prospects when the resource boom ceases. Local stakeholders must weigh the near-term employment benefits against both concerns about local externalities and the risk that shale development could reduce broader long-term economic growth by putting local manufacturers at a competitive disadvantage.

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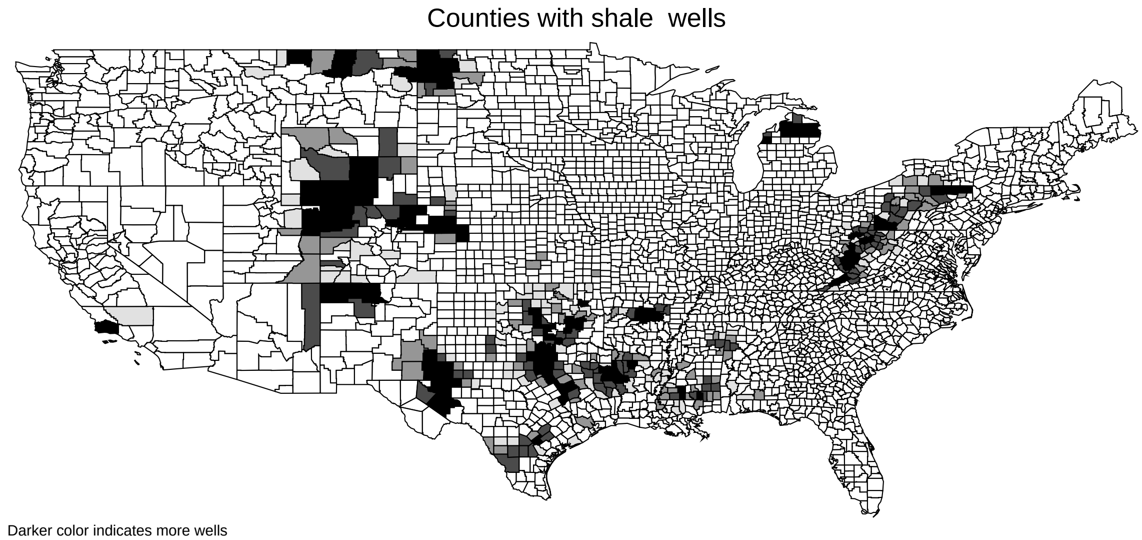
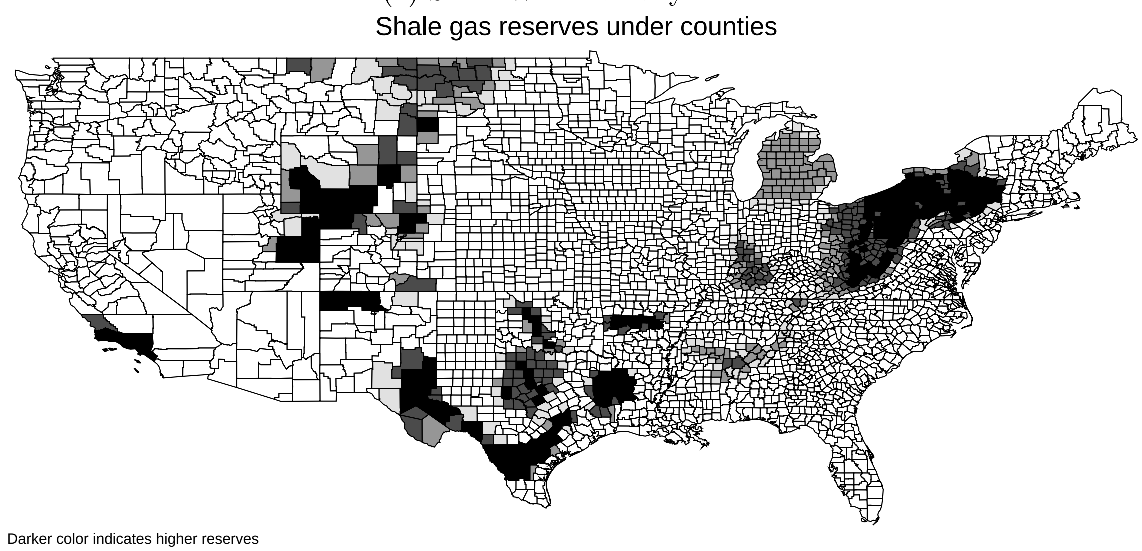
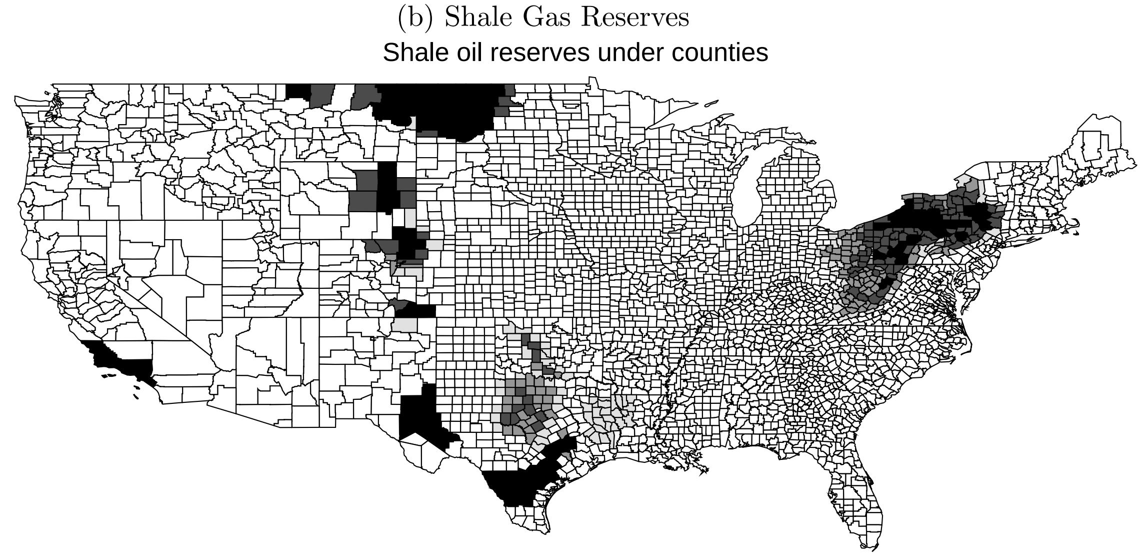
Figures



(a) Shale Well Intensity



(b) Shale Gas Reserves

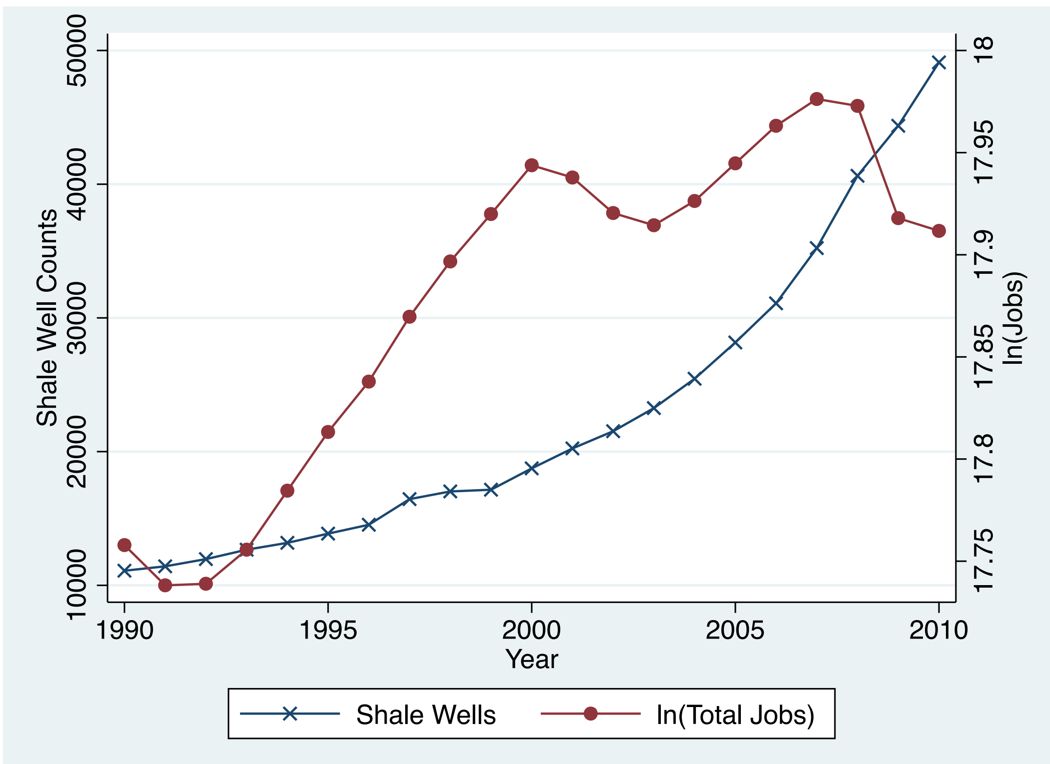


(c) Shale Oil Reserves

Figure 1: Shale Reserves

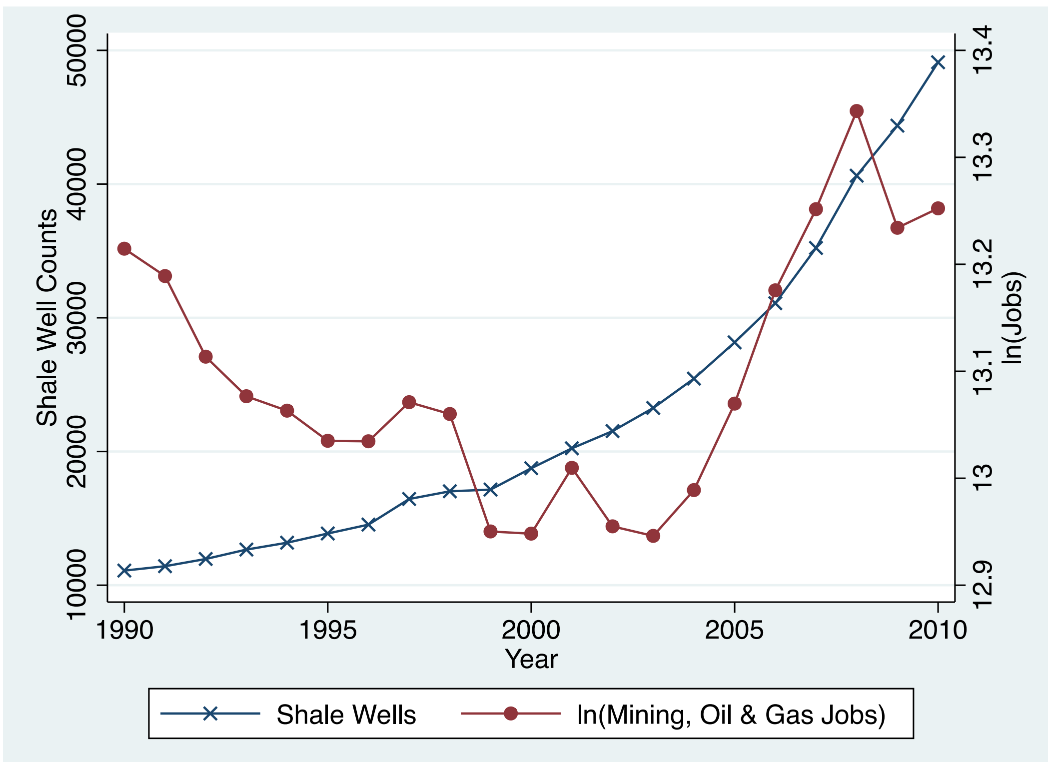
Notes: Reserves are calculated by first determining what fraction of a shale play lies beneath county, and then multiplying the known recoverable reserves of the county by that weight.

Figure 2: Shale Wells and Total Jobs



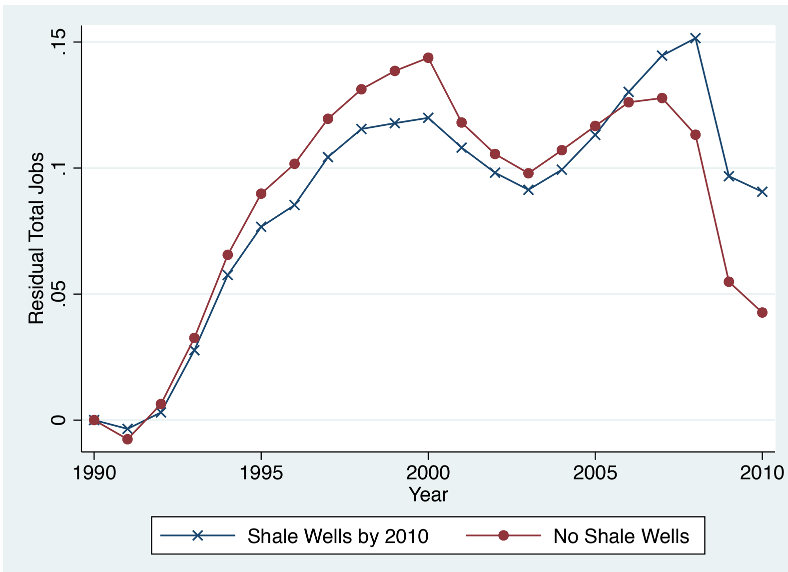
Notes: "Shale Wells" are the sum of all identified wells drilled into shale oil and gas formations, by year. ln(total jobs) represents the total jobs in the United States, summed over reported county level employment in the QCEW.

Figure 3: Shale Wells and Mining/OilGas Jobs

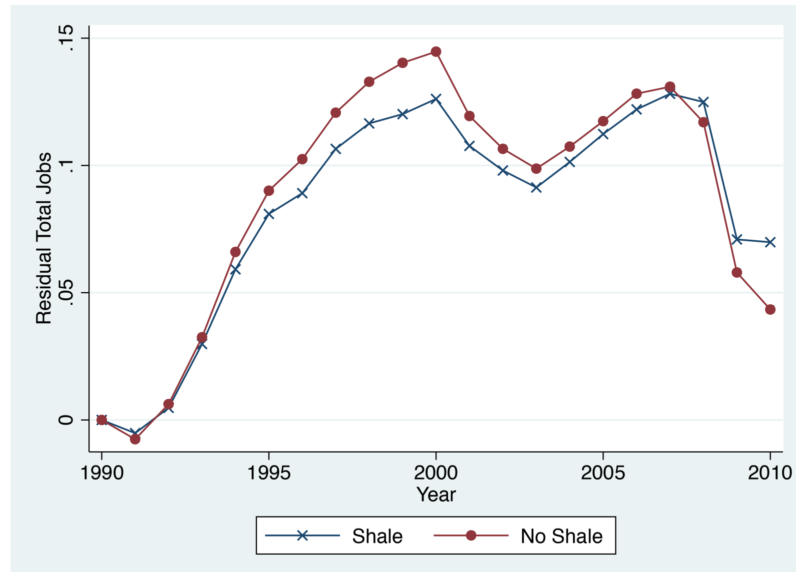


Notes: "Shale Wells" are the sum of all identified wells drilled into shale oil and gas formations, by year. ln(Mining, Oil, and Gas Jobs) represents the total sector jobs in the United States, summed over reported, non-censored county level employment in the QCEW.

Figure 4: Employment Trends



(a) Jobs by Shale Well Status



(b) Jobs by Shale Formation Presence

Notes: The y-axis plots the residual from a regression of the natural logarithm of employment on population, area, an indicator for presence of an interstate highway, and the average slope of the physical terrain in the county. These residuals are normalized relative to 1990 and can be interpreted as the approximate percent change in jobs relative to 1990.

Tables

Table 1: Summary Statistics

	Means		
	2000	2010	Total
Economic Indicators			
Total Employment	22,261.6	21,857.8	22,059.7
Avg. Income	478.1	652.1	565.1
Unemployment Rate	4.337	9.177	6.757
Mining & Gas Emp.†	172.3	237.2	204.1
Manufact. Emp.‡	4,438.4	3,062.6	3,759.6
Manufact. Emp. Share	0.210	0.210	0.210
Percent under Poverty Line	13.35	16.37	14.86
Total Bank Deposits	769.5	1365.0	1067.2
Median House Price	82,543.5	125,180.8	103,862.1
Percent Owner Occupied Units	0.637	0.599	0.618
No. Housing Units	26,754.5	30,621.0	28,687.7
Total Federal Expenditures	326,194.7	659,026.5	492,610.6
Shale Oil/Gas Variables			
Shale County	0.240	0.240	0.240
No. Frack Wells	6.189	16.21	11.20
Ever Frack	0.158	0.158	0.158
No. Conv. Wells	199.0	244.8	221.9
Demographic Variables			
Total Population	63,970.4	70,528.6	67,249.5
Population Density	56.18	61.22	58.70
Percent over 65	0.149	0.160	0.155
Percent of 25 yr College	0.162	0.189	0.176
Percent Female	0.504	0.500	0.502
Percent Black	0.0868	0.0891	0.0880
Percent Hispanic	0.0603	0.0810	0.0707
Observations	3,029	3,029	6,058

Notes:† 1,721 counties had usable data in 2000, 1,656 counties had usable data in 2010. Only 754 counties had usable data in both years.

‡ 2,777 counties had usable data in 2000, 2,704 counties had usable data in 2010. Only 2,579 counties had usable data in both years.

Table 2: Comparison of Means

Groups:	(1)	(2)	(3)	(4)	(5)	(6)
	Current Trends				Prior Trends	
	Fracking Counties		Shale Counties		Fracking Counties	Shale Counties
	2000	2010 - 2000	2000	2010 - 2000	2000 - 1990	2000- 1990
Local Economic Outcomes						
Avg. Weekly Wage	-12.31	40.95***	-15.19*	21.07***	-26.69**	-19.22*
	(-1.29)	(6.20)	(-2.05)	(4.07)	(-2.60)	(-2.40)
ln(employment)	-0.0532	0.0369**	0.0104	0.0357***	-0.0689***	-0.0335***
	(-0.73)	(3.17)	(0.18)	(3.93)	(-5.49)	(-3.42)
Mining & Gas Jobs	111.3**	245.8***	64.41*	111.6***	-105.7***	-64.06***
	(3.15)	(11.65)	(2.21)	(6.09)	(-5.44)	(-3.99)
Manufact. Jobs	-1360.6**	650.3***	-157.2	-21.22	-146.3	251.0**
	(-2.99)	(3.49)	(-0.45)	(-0.15)	(-1.22)	(2.72)
Production Variables						
No. Frack Wells	34.46***	68.89***	4.550	23.25***	8.979***	-0.679
	(7.93)	(12.41)	(1.33)	(5.26)	(3.54)	(-0.34)
No. Conv. Wells	459.0***	235.4***	203.7***	71.84***	5.552	16.34
	(10.48)	(13.30)	(5.88)	(5.08)	(0.37)	(1.40)
Economic Indicator Variables						
Manufact. Jobs Share	-0.00309	-0.00323	0.00327	-0.00310	0.000201	-0.000497
	(-0.45)	(-0.90)	(0.62)	(-1.11)	(0.04)	(-0.13)
Unemployment Rate	0.558***	-0.646***	0.188**	-0.0594	0.325**	-0.314**
	(6.43)	(-5.64)	(2.76)	(-0.66)	(2.66)	(-3.29)
Percent under Poverty Line	1.770***	-2.062***	1.121***	-0.523***	2.363***	1.323***
	(7.12)	(-13.30)	(5.76)	(-4.21)	(9.20)	(6.56)
Total Bank Deposits	-129.9	-218.0	-84.79	-185.6	14.97	51.50
	(-1.21)	(-1.03)	(-1.01)	(-1.12)	(0.20)	(0.88)
Median House Price	-4260.3*	-8916.0***	-2362.2	-9437.2***	656.6	2328.8*
	(-2.22)	(-4.76)	(-1.58)	(-6.47)	(0.53)	(2.39)
Percent Owner Occupied Units	0.00468	-0.000574	-0.000404	0.00287	-0.00179	-0.00423***
	(1.13)	(-0.24)	(-0.13)	(1.56)	(-1.15)	(-3.48)
No. Housing Units	-5334.6*	-1023.2*	-1413.1	-327.4	-822.7*	66.12
	(-2.17)	(-2.16)	(-0.74)	(-0.88)	(-2.12)	(0.22)
Total Federal Expenditures	-62853.2	-127236.4**	-21946.1	-38858.8	-7963.9	1449.4
	(-1.76)	(-2.73)	(-0.79)	(-1.07)	(-0.49)	(0.11)
Demographic Variables						
Total Population	-14104.6*	-1293.4	-4784.5	-90.48	-2384.9*	-375.7
	(-2.27)	(-1.21)	(-0.99)	(-0.11)	(-2.23)	(-0.45)
Population Density	-16.51*	-1.018	-13.20*	-0.926	-1.651	-1.252
	(-2.00)	(-0.70)	(-2.05)	(-0.81)	(-1.14)	(-1.10)
Percent over 65	0.00211	-0.00234**	0.000893	-0.00100	0.00238**	0.00178**
	(1.06)	(-2.96)	(0.58)	(-1.62)	(3.21)	(3.07)
Percent of 25 yr College	-0.0141***	-0.00214	-0.0101***	-0.00154	-0.00295*	-0.00273**
	(-3.83)	(-1.78)	(-3.48)	(-1.64)	(-2.57)	(-3.04)
Percent Black	-0.00670	-0.00113	-0.0118**	0.00000362	-0.000686	-0.000287
	(-1.29)	(-1.22)	(-2.91)	(0.01)	(-0.74)	(-0.40)
Percent Hispanic	-0.0134**	0.000561	-0.00201	-0.00200*	-0.00226	-0.00237*
	(-2.97)	(0.49)	(-0.57)	(-2.26)	(-1.76)	(-2.37)
Observations	3029	3029	3029	3029	3029	3029

t statistics in parentheses

=† $p < 0.10$ * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$

Notes: Coefficients are differences in means between counties with shale development (fracking) and those without and between"Shale" Counties and "Non-Shale" Counties, respectively. Each variable is demeaned by state-level averages. t stats in parenthesis below the difference in means estimates.

Table 3: Test of Pre-trends

	(1) 1990 - 2000	(2) 1990 - 2000
Fracking County	-0.030**	
	(0.014)	
Shale County		-0.010
		(0.011)
Constant	0.082***	0.079**
	(0.031)	(0.031)
Observations	2,994	2,994
Controls	Yes	Yes
State Fixed Effects	Yes	Yes

Notes: Dependent variable in the above regressions is the difference in the natural logarithm of employment from 1990 to 2000. Controls include conventional wells drilled, percent of population in poverty, total bank deposits, median home value, percent of homes owner-occupied, number of housing units, total federal expenditures, population, percent of population over 65, percent of 25 year olds with a college degree, percent black, and the percent hispanic. Heteroskedastic robust standard errors in parentheses. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 4: Employment Effects from Shale Development: Discrete Treatments

VARIABLES	(1) OLS	(2) OLS	(3) OLS	(4) IV	(5) IV
Shale County	0.044***				
	(0.010)				
Ever Frack		0.011		0.123***	
		(0.011)		(0.028)	
Boom County			0.044**		0.241***
			(0.019)		(0.074)
Observations	3,029	3,029	3,029	3,029	3,029
Controls	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes

Notes: Heteroskedastic robust standard errors in parentheses. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The dependent variable in all specifications is the natural logarithm of employment at the county level. All urban counties have been dropped from the regressions. Controls include manufacturing job share in 2000, conventional wells drilled, percent of population in poverty, total bank deposits, median home value, percent of homes owner-occupied, number of housing units, total federal expenditures, population, percent of population over 65, percent of 25 year olds with a college degree, percent black, and the percent hispanic. Instruments include an indicator for the presence of shale, the square kilometers of shale within the county, and estimates of the shale oil and gas in each county.

Table 5: Employment Effects from Shale Development: Well Counts

VARIABLES	(1) OLS	(2) OLS	(3) IV	(4) IV
Δ Shale Wells	0.0001**		0.0011***	
	(0.000)		(0.000)	
IHS(Shale Wells)		0.0070*		0.0308***
		(0.004)		(0.010)
Observations	3,029	3,029	3,029	3,029
Controls	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes

Notes: Heteroskedastic robust standard errors in parentheses. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The dependent variable in all specifications is the natural logarithm of employment at the county level. All urban counties have been dropped from the regressions. Controls include manufacturing job share in 2000, conventional wells drilled, percent of population in poverty, total bank deposits, median home value, percent of homes owner-occupied, number of housing units, total federal expenditures, population, percent of population over 65, percent of 25 year olds with a college degree, percent black, and the percent hispanic. Instruments include an indicator for the presence of shale, the square kilometers of shale within the county, and estimates of the shale oil and gas in each county.

Table 6: Estimated Job Creation for Selected States, non-Urban Counties

State	Change in Wells	Lower 95%	Counterfactual Jobs	Upper 95%
Arkansas	2,949	7,493	21,533	35,574
California	4	2,365	6,696	11,027
Colorado	2,541	-84	3,288	6,661
Kansas	195	431	1,410	2,389
Louisana	801	-10,273	9,803	29,879
Michigan	3,256	798	2,152	3,506
Mississippi	163	1,412	5,781	10,150
Montana	1,558	677	1,893	3,108
New Mexico	164	252	2,901	5,551
New York	13	1,732	4,526	7,321
North Dakota	1,933	989	2,671	4,354
Ohio	41	-425	4,328	9,081
Oklahoma	1,839	3,441	11,158	18,874
Pennsylvania	1,101	28,448	76,548	124,648
Texas	11,419	10,124	52,829	95,534
Utah	118	709	1,919	3,129
Virginia	196	244	653	1,063
West Virginia	1,935	14,341	36,351	58,362
Wyoming	329	70	1,442	2,814
United States	30,361	49,188	239,596	430,005

Notes: Estimated job creation is calculated as the difference between fitted job creation implied by a regression of log employment on the inverse hyperbolic sine of shale well counts and the fitted job creation implied by the same regression when the number of wells drilled is assumed to be zero. Confidence intervals reported are constructed by calculating the upper/lower bound for each county and summing over all counties in the state.

Table 7: Income Effects from Shale Development: Discrete Treatments

ln(wages)	(1) OLS	(2) OLS	(3) OLS	(4) IV	(5) IV
Shale County	0.020***				
	(0.006)				
Ever Frack		0.020***		0.061***	
		(0.007)		(0.019)	
Boom County			0.031**		0.098*
			(0.014)		(0.051)
Observations	3,028	3,028	3,028	3,029	3,029
Controls	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes

Notes: Heteroskedastic robust standard errors in parentheses. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The dependent variable in all specifications is the natural logarithm of average weekly wages at the county level. All urban counties have been dropped from the regressions. Controls include manufacturing job share in 2000, conventional wells drilled, percent of population in poverty, total bank deposits, median home value, percent of homes owner-occupied, number of housing units, total federal expenditures, population, percent of population over 65, percent of 25 year olds with a college degree, percent black, and the percent hispanic. Instruments include an indicator for the presence of shale, the square kilometers of shale within the county, and estimates of the shale oil and gas in each county.

Table 8: Income Effects from Shale Development: Well Counts

ln(wages)	(1) OLS	(2) OLS	(3) IV	(4) IV
Δ Shale Wells	4.68e-05***		0.001***	
	(1.61e-05)		(2.22e-04)	
ΔIHS(Shale Wells)		0.005*		0.011
		(0.003)		(0.008)
Observations	3,029	3,029	3,029	3,029
Controls	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes

Notes: Heteroskedastic robust standard errors in parentheses. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The dependent variable in all specifications is the natural logarithm of average weekly wages at the county level. All urban counties have been dropped from the regressions. Controls include manufacturing job share in 2000, conventional wells drilled, percent of population in poverty, total bank deposits, median home value, percent of homes owner-occupied, number of housing units, total federal expenditures, population, percent of population over 65, percent of 25 year olds with a college degree, percent black, and the percent hispanic. Instruments include an indicator for the presence of shale, the square kilometers of shale within the county, and estimates of the shale oil and gas in each county.

Table 9: Local Economic Impacts Controlling for Neighboring Counties

	(1) Employment	(2) Employment	(3) Wages	(4) Wages
Δ Shale Wells	0.001***		0.001**	
	(3.58e-4)		(2.08e-4)	
Δ Neighbor Shale Wells	4.78e-4		1.50e-4	
	(0.001)		(3.38e-4)	
Δ IHS(Shale Wells)		0.033***		0.010
		(0.011)		(0.009)
Δ IHS(Neighbor Shale Wells)		0.082		-0.029
		(0.087)		(0.061)
Observations	3,029	3,029	3,029	3,029
Controls	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes

Notes: Heteroskedastic robust standard errors in parentheses. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The dependent variable in the column title. All regressions are instrumental variable regressions. All urban counties have been dropped from the regressions. Controls include manufacturing job share in 2000, conventional wells drilled, percent of population in poverty, total bank deposits, median home value, percent of homes owner-occupied, number of housing units, total federal expenditures, population, percent of population over 65, percent of 25 year olds with a college degree, percent black, and the percent hispanic. Instruments include an indicator for the presence of shale, the square kilometers of shale within the county, and estimates of the shale oil and gas in each county.

Table 10: Competitive Labor Market Employment Effects by Sector: IV

	(1) Mine/Gas	(2) Hotel/Acc	(3) Construction	(4) Retail Trade	(5) Transport	(6) Manufact
			Panel A: Discrete Treatment			
Ever Frack	0.856***	0.054	0.146**	0.049**	0.007	0.049
	(0.201)	(0.041)	(0.063)	(0.025)	(0.105)	(0.068)
			Panel B: Continuous Well Counts			
IHS(Shale Wells)	0.249***	0.015	0.020	0.013	-0.037	0.002
	(0.065)	(0.015)	(0.025)	(0.009)	(0.036)	(0.024)
			Panel C: Boom Counties			
Boom County	1.579***	0.110	0.193	0.106*	-0.198	0.047
	(0.502)	(0.103)	(0.161)	(0.062)	(0.241)	(0.155)
Observations	754	2,731	2,688	2,971	2,171	2,579
Controls	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Heteroskedastic robust standard errors in parentheses. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The dependent variable in all specifications is the natural logarithm of employment at the county level. All urban counties have been dropped from the regressions. Each regression only uses the set of counties with non-zero, non-censored employment levels in 2000 for that particular industry. Controls include manufacturing job share in 2000, conventional wells drilled, percent of population in poverty, total bank deposits, median home value, percent of homes owner-occupied, number of housing units, total federal expenditures, population, percent of population over 65, percent of 25 year olds with a college degree, percent black, and the percent hispanic. Instruments include an indicator for the presence of shale, the square kilometers of shale within the county, and estimates of the shale oil and gas in each county.

Table 11: Income Effects by Sector: IV

	(1) Mine/Gas	(2) Hotel/Acc	(3) Construction	(4) Retail Trade	(5) Transport	(6) Manufact
	Panel A: Discrete Treatment					
Ever Frack	0.299**	0.167***	0.063	0.057***	0.137*	0.051
	(0.138)	(0.062)	(0.047)	(0.022)	(0.083)	(0.041)
	Panel B: Continuous Well Counts					
IHS(Shale Wells)	0.047	0.048**	0.027*	0.018***	0.025	0.009
	(0.042)	(0.021)	(0.016)	(0.006)	(0.033)	(0.014)
	Panel C: Boom Counties					
Boom County	0.374	0.373**	0.186*	0.114**	0.199	0.064
	(0.257)	(0.164)	(0.107)	(0.049)	(0.221)	(0.088)
Observations	754	2,731	2,688	2,971	2,171	2,579
Controls	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Heteroskedastic robust standard errors in parentheses. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The dependent variable in all specifications is the natural logarithm of average weekly wages at the county level. All urban counties have been dropped from the regressions. Each regression only uses the set of counties with non-zero, non-censored employment levels in 2000 for that particular industry. Controls include manufacturing job share in 2000, conventional wells drilled, percent of population in poverty, total bank deposits, median home value, percent of homes owner-occupied, number of housing units, total federal expenditures, population, percent of population over 65, percent of 25 year olds with a college degree, percent black, and the percent hispanic. Instruments include an indicator for the presence of shale, the square kilometers of shale within the county, and estimates of the shale oil and gas in each county.

Table 12: Other Outcome Variables: IV

	(1) ln(population)	(2) ln(price)	(3) Percent College Ed.	(4) No. Establishments	(5) No. Manufact Estab
	Panel A: Effects by Binary Drilling Indicator				
Ever Frack	0.024**	-0.086***	-0.007**	9.683	-0.032
	(0.012)	(0.021)	(0.003)	(60.454)	(5.453)
	Panel B: Effects by Boom Status				
Boom County	0.056*	-0.232***	-0.013	-60.906	7.085
	(0.030)	(0.065)	(0.008)	(113.895)	(10.209)
Observations	3,032	3,032	3,032	2,995	2,540
Controls	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes

Notes: Heteroskedastic robust standard errors in parentheses. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The dependent variable in each specification is provided in the column title. All urban counties have been dropped from the regressions. Controls include manufacturing job share in 2000, conventional wells drilled, percent of population in poverty, total bank deposits, median home value, percent of homes owner-occupied, number of housing units, total federal expenditures, population, percent of population over 65, percent of 25 year olds with a college degree, percent black, and the percent hispanic. Instruments include an indicator for the presence of shale, the square kilometers of shale within the county, and estimates of the shale oil and gas in each county.

Table 13: Economic Impacts by Census Division

	(1) Div 2	(2) Div 3	(3) Div 4	(4) Div 5	(5) Div 6	(6) Div 7	(7) Div 8
Panel A: Employment Effects by Division							
Boom County	0.1391	-0.0856	0.4774**	-0.1621	0.5959	0.1462**	0.0216
	(0.089)	(0.270)	(0.223)	(0.113)	(1.602)	(0.065)	(0.122)
Observations	139	430	611	574	360	461	271
Panel B: Wage Effects by Division							
Boom County	0.1476**	0.1584	0.3298***	0.0272	-0.3136	0.0363	0.0144
	(0.073)	(0.155)	(0.099)	(0.104)	(0.593)	(0.044)	(0.068)
Observations	139	430	611	574	360	461	271
Panel C: Manufacturing Wage Effects by Division							
Boom County	0.3251*	-0.0982	0.6193*	0.0311	-1.8577	0.0640	0.5481
	(0.178)	(0.278)	(0.338)	(0.285)	(2.319)	(0.116)	(0.391)
Observations	138	410	470	516	326	359	192
Panel D: Manufacturing Employment Effects by Division							
Boom County	0.3325	0.1866	-0.1895	-0.4343	-1.5468	0.0946	0.1974
	(0.241)	(0.656)	(0.597)	(0.456)	(2.651)	(0.219)	(0.362)
Boom Counties	8	11	8	16	2	40	13
Observations	138	410	470	516	326	359	192
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Heteroskedastic robust standard errors in parentheses. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The dependent variable in each specification is provided in the column title. All urban counties have been dropped from the regressions. Controls include manufacturing job share in 2000, conventional wells drilled, percent of population in poverty, total bank deposits, median home value, percent of homes owner-occupied, number of housing units, total federal expenditures, population, percent of population over 65, percent of 25 year olds with a college degree, percent black, and the percent hispanic. Instruments include an indicator for the presence of shale, the square kilometers of shale within the county, and estimates of the shale oil and gas in each county.

Table 14: Divisional Attributes

Division	Unemployment	Unemployment Rank	O&G Percentage	O&G Rank
1	4.72	4	0.08	1
2	4.97	5	0.23	4
3	5.94	9	0.22	3
4	4.66	3	0.43	5
5	4.61	1	0.56	6
6	5.72	8	1.08	7
7	5.47	6	1.91	9
8	4.63	2	1.24	8
9	5.56	7	0.19	2

Notes: Unemployment is mid-decade, population weighted county-level average unemployment, by division. "O&G" percentage is the population weighted county-level average of initial fraction of workers in the Mining, Oil, & Gas Extraction industry, taken over counties with non-censored industry employment data.

Table 15: Characterizing Dutch Disease: IV Regressions

	(1) Total Wages	(2) Manufacturing Wages	(3) Manufacturing Emp
Boom County	1.247**	3.092*	1.455
	(0.627)	(1.644)	(1.780)
Boom × Unemployment	-0.183*	-0.509*	-0.341
	(0.105)	(0.279)	(0.290)
Boom × O&G %	-4.619*	-10.914*	0.857
	(2.541)	(6.119)	(8.105)
O&G %	0.754**	1.751	0.812
	(0.297)	(1.189)	(1.323)
Unemployment Rate	-0.002	0.032**	-0.042**
	(0.005)	(0.016)	(0.019)
Constant	0.391***	0.150	0.003
	(0.034)	(0.093)	(0.121)
Observations	1,715	1,429	1,429
Controls	Yes	Yes	Yes
State Fixed Effects	Yes	Yes	Yes

Notes: Heteroskedastic robust standard errors in parentheses. *,**,*** indicate statistical significance at the 10%, 5%, and 1% level, respectively. The dependent variable in each specification is provided in the column title. All urban counties have been dropped from the regressions. Controls include manufacturing job share in 2000, conventional wells drilled, percent of population in poverty, total bank deposits, median home value, percent of homes owner-occupied, number of housing units, total federal expenditures, population, percent of population over 65, percent of 25 year olds with a college degree, percent black, and the percent hispanic. Instruments include an indicator for the presence of shale, the square kilometers of shale within the county, and estimates of the shale oil and gas in each county.