Too Many Heads and Not Enough Beds:

Will Shale Development Cause a Housing Shortage?

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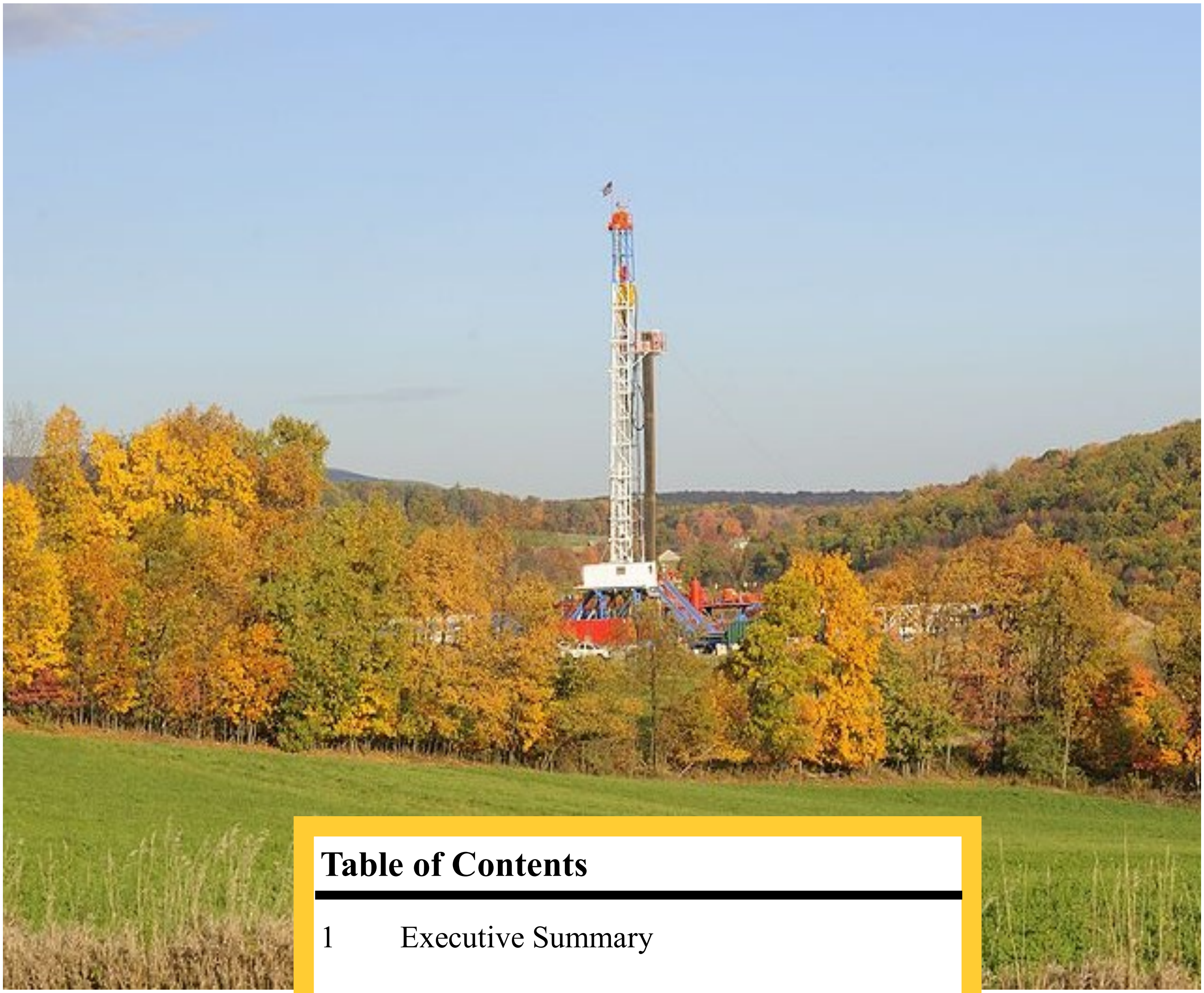
The Swank Program in Rural-Urban Policy
Summary and Report

FEMA Picture: new home construction in Greensburg, KS after the tornado.



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The Ohio State University

The Swank Program in Rural-Urban Policy Summary and Report June 2013

Executive Summary

This policy brief is the third in a series of papers about the effects of oil and gas extraction from shale in Ohio. The previous two briefs, "The Economic Value of Shale" (Dec. 2011) and "Making Shale Development Work for Ohio" (June 2012) examined the employment and earnings benefits and the short and long run costs of shale development. To extrapolate what will happen in Ohio, this brief examines the impact of shale development on housing by examining the Pennsylvania counties where shale gas drilling is ahead of Ohio. We examine the first four years of Pennsylvania's boom period (2007-2011) and then extrapolate this to what we expect to occur in Ohio during its first four years of its boom (2012-2016). Because Pennsylvania's drilling region shares many similarities to the rural Eastern Ohio counties that will experience significant drilling, this provides the best guidance into what Ohio should expect in the first few years of shale development.

When shale development is booming, it brings new workers into the area. The housing needs of these workers vary from temporary to permanent. This increase in housing demand is met largely through hotels, apartments, or houses. The strain on the housing market depends on the extent of the shale boom and the community's ability to construct new housing. The ability of a community to meet housing demand is determined by a number of factors including the level of surplus housing stock and whether significant numbers of workers in-migrate, placing demands on local housing.

Shale development in Ohio and neighboring Pennsylvania is mostly occurring in rural counties with smaller surplus housing stocks to absorb new workers. Additionally, many of the counties involved are part of the Appalachian region which often has more substandard housing compared than a typical rural county. This means that the vacant housing which does exist might not be of sufficient quality to attract even temporary workers. Many of the counties are also remote. Workers in remote counties are less likely to commute from nearby communities that may have been able to alleviate some of the strain on the housing market.

One of the primary questions facing these communities is whether the adjustment in the housing market will occur through higher housing prices, expansion of new home construction, or a mix of the two effects. With the most pronounced shale boom in the United States, Williston, ND has experienced a significant strain on its housing market, in which the Williston region had a limited housing stock due to its very sparse population and remoteness that makes commuting challenging. There have also been media reports from Pennsylvania that the surge in shale gas drilling and its accompanying workforce has driven up demand for local housing to the point that market rents have doubled and even tripled. In this report, we quantitatively analyze the correlation of increases in energy employment and shale gas wells drilled in Pennsylvania with several county-based measures of housing availability and affordability listed below. In general we find that:

- **Population**: A 1% increase in total employment directly linked to the oil and gas energy sector is associated with a 0.5% increase in county population. Thus, shale drilling places some population pressures for new housing in intensely drilled counties. Our analysis suggests that Bradford County, PA, the Pennsylvania county most impacted by shale drilling, experienced additional population growth of 1.75% due to shale energy development over the 2007-2011 period. For comparison, we expect Carroll County, OH to experience a similar energy development pattern as Bradford County.

- **Fair Market Rent**: The Fair Market Rent (FMR) reported by the Department of Housing and Urban Development is positively associated with numbers of shale wells only in the most intensely drilled counties, such as Bradford County, PA. Our analysis suggests that Bradford County experienced about 3.6% higher FMR due to shale energy development over the 2007-2011 period. Yet, changes in energy sector employment are not statistically associated with changes in the FMR, supporting the notion that FMR is not greatly affected by this new development.

- **Housing Construction Permits**: Increases in total employment linked to oil and gas sector employment are not statistically associated with the number of new residential construction permits issued, but each new shale gas well drilled was statistically related to more than 2.5 additional housing permits**.** We take this as evidence that housing construction is positively affected by drilling activity.

- **Median Home Value**: Shale development, as measured by energy sector employment's share of total employment and the number of shale wells drilled, is not statistically linked to median home values—possibly because housing starts are responsive to drilling activity.

- **Vacancy Rate**: Shale development had no discernible statistical impact on a county's vacancy rate.

The Pennsylvania Housing Finance Agency approved funding for 25 housing projects in 19 counties totaling $7.6 million to improve availability and affordability of housing in the Marcellus shale region (Pittsburgh Post-Gazette, 2013). There are reports in Ohio that the impact on temporary housing is already evident (Hoover, 2013). Despite this, our data analysis seems to show that shale development is generally not associated with significant adverse effects on housing affordability and availability.

Recent newspaper articles tell a very different story, however. For example, Williamsport, PA in Lycoming County was named one of the top ten housing markets where prices rose during the Great Recession (Stockdale & McIntyre, 2011). *The Daily Review* reported in January 2010 that the average rent in Bradford and Lycoming counties had doubled or tripled (Loewenstein, 2010). There have even been reports of displaced renters sleeping under bridges in Towanda, the county seat of Bradford County (Falcheck, 2012). Nonetheless, expansions in the housing stock due to market forces and construction of hotels may be sufficient to meet the expected housing demand in most counties. However, the data show that counties experiencing significant drilling activity such as Bradford, Lycoming and Tioga counties in Pennsylvania experienced more notable housing market effects associated with shale development.

It is important for shale development counties in Ohio to monitor the housing availability and affordability in their communities. This vigilance will be most important in Carroll, Harrison, Jefferson and Columbiana counties in Ohio, which are poised to see the most drilling over the next few years. Carroll (which encompasses 35% of the current or permitted shale wells in the state) and Harrison counties may be especially vulnerable to the housing impacts of shale development. They are more rural than Bradford and Tioga counties in Pennsylvania (Pennsylvania's most impacted counties) in terms of population, though less remote for commuting purposes (which mitigates housing impacts).

Monitoring housing availability and affordability in these counties will help ensure these counties can appropriately respond to housing needs before the strain on the housing market becomes severe. However, housing experiences from Pennsylvania suggest that Ohio will generally not experience significant adverse effects, especially if hotels are constructed and new housing is not constrained through excessive regulations.

Too Many Heads and Not Enough Beds: Will Shale Development Cause a Housing Shortage?

Introduction

Recent shale development in the U.S. has raised concerns about the impacts on communities from shale oil and gas extraction. This policy paper is the third in a series of briefs from the Swank Program in Rural-Urban Policy on the impacts of shale development, focusing on the Marcellus and Utica shale region which broadly covers Ohio, Pennsylvania, New York, West Virginia, and Virginia. Innovations in hydraulic fracturing and microseismic technology have spurred shale development in this region and elsewhere in the U.S. The resulting boom in shale oil and gas production has impacted various aspects of these communities, including the environment, public infrastructure, and local economies.

The first brief, "The Economic Value of Shale Natural Gas in Ohio," found that Ohio should expect modest impacts to employment and more significant impacts on earnings based largely on the experience of Pennsylvania. Pennsylvania provides an excellent example to predict the impacts of shale development in Ohio. Pennsylvania is further along in the shale development process but is very similar to Ohio in other respects such as traditional industry structure and its Appalachian nature in the most intense drilling regions. It is important for policymakers and residents to have an accurate estimate of the economic impacts on local communities as they weigh these and other benefits against the costs of extraction.

There are many costs associated with the boom and bust nature of resource extraction. Short term costs include increased traffic and road use as well as an additional strain on other public services and utilities directly resulting from drilling. Public services also experience an increased strain from population growth from oil and gas workers moving into the area. The long term costs are less obvious as they pertain to the 'natural resource curse' caused by the distorting effects of the boom. The second brief, "Making Shale Development Work for Ohio," emphasizes the importance of counteracting both the short term and long term costs associated with natural resource extraction in order to maximize the benefit to communities.

In previous reports, we only briefly mentioned the potential impact on the local housing market associated with a sudden influx of oil and gas employees. In Williston, ND, where the national shale boom is most pronounced, the flood of workers into the small and remote region has placed a serious strain on housing availability and cost. The rental price for a two bedroom apartment reportedly rose from \$350 to \$2,000 (Oldham, 2012)—though Williams County (Williston's) Fair Market Rent as determined by the U.S. Department of Housing and Urban Development only rose by 59% for a single bedroom apartment between 2003 and 2013 (the average national growth in FMR (1-bedroom) over this same period was 34%).

Five hotels are in the process of being built in Williston as well as other means of alleviating the strain on housing demand such as "mancamps" and campgrounds. The increased strain on housing also burdens public services and utilities. Higher rental rates will also affect longtime residents, especially low income households, the elderly, and the disabled. Additionally, rural areas such as Williston and many of the counties across the Marcellus/Utica shale regions do not have the surplus housing or development capacity to meet demand. Public policy intervention may be warranted depending on the severity of the problem and the housing market's ability to adapt.

Thus, this report examines whether shale gas drilling had measurably impacted housing markets in the Marcellus region of Pennsylvania over the 2007-2011 period. We then extrapolate these effects to form our expectations for Ohio in the 2012-2016 period, assuming development proceeds at a similar pace in Ohio. (i.e., this corresponds to the first-four years of shale drilling activity in their respective regions). In what follows, we first describe how drilling activity may affect local housing markets before turning to some background on Marcellus drilling. We then provide some descriptive data showing rents and housing prices in the region before turning to some statistical analysis. We conclude with policy analysis and concluding thoughts.

Shale Development

The impact of shale development on housing is inextricably linked to the various stages of oil and gas extraction and employment. Each stage of shale development determines the number and type of new workers coming into the area. This, in turn, drives the shift in housing demand. The previous two policy briefs from the Swank program discuss the hydraulic fracturing process in more depth; here we focus on the stages of development and how it relates to changes in employment and the housing needs of workers.

The initial stage of drilling involves a significant amount of drilling site selection and land leasing activities before a drill pad can be constructed. Workers filling these roles will often come from elsewhere, although legal, real estate, surveying, and other services may be hired locally. Once the site is selected, it typically takes between 1 to 2 months to prepare the site and construct the drilling pad. Following construction of the drilling pad, there is about 1 month of rig work which includes drilling the well and encasing it in concrete. Figure 1 shows a well being drilled in Lycoming County, PA. Large quantities of water are either trucked in to the drilling site or siphoned from nearby waterways and stored in large containment ponds for later use in hydraulic fracturing. The hydraulic fracturing process takes just 2 to 5 days to inject a mixture of 1 to 8 million gallons of water with sand and chemicals.[1] This injection fractures the shale, allowing the oil and gas it contains to escape. About half the water comes back up as wastewater and must be stored onsite until it is transported to long-term disposal sites in containment vessels or injection wells. Basic construction and trucking needs may be met by local contractors, but during the initial stages of development, many of the high skilled drilling crews will come from elsewhere (Kelsey et al., 2011).

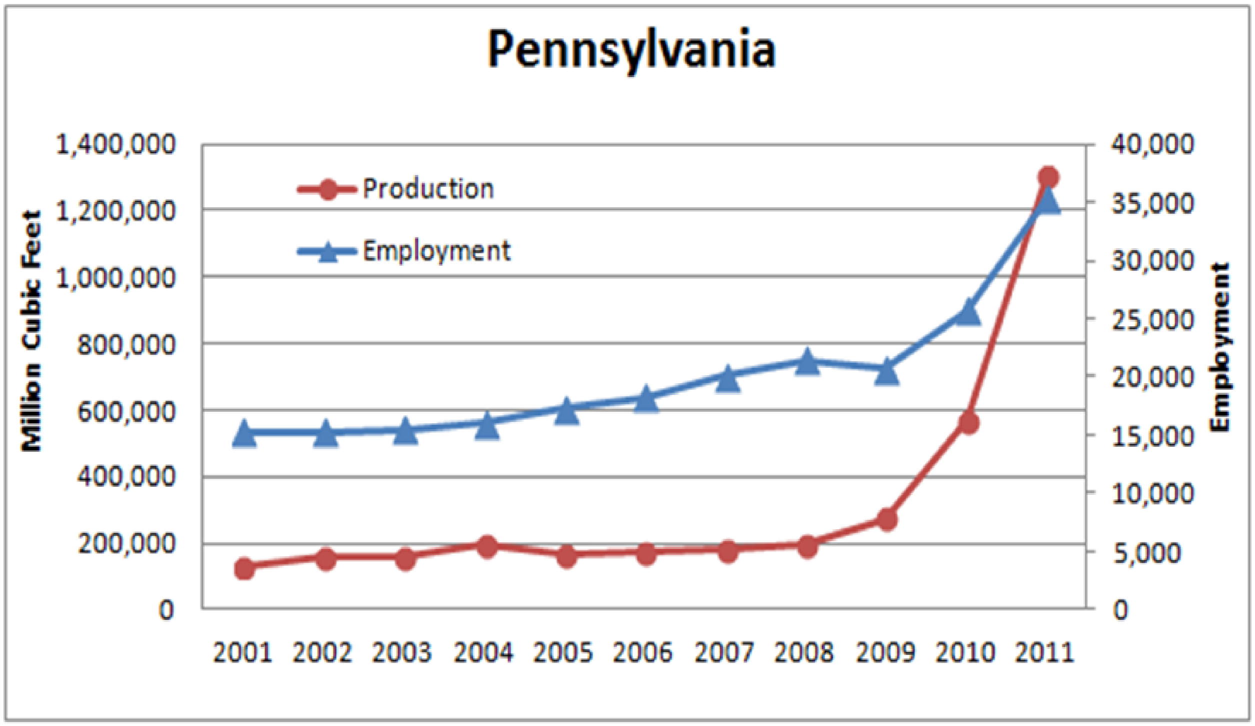
After the fracturing, gathering lines are constructed to feed the gas to compressor stations and metering sites nearby which are then connected to larger pipelines to bring the gas to market. Although some estimate that a well can continue to flow for up to 30 years, the highest flow rates of natural gas are in the first weeks and then decline over time.[2] Once the well has been fractured its employment needs decline significantly. Thus, the level of shale gas employment is more directly related to the number of recently drilled wells rather than the amount of natural gas extracted. Figures 2 and 3 on the next page illustrate the increase in oil and gas employment in Pennsylvania relative to the number of shale wells drilled and the production of natural gas. Figure 3 shows that 2007 is the beginning of tangible drilling activity in the Pennsylvania Marcellus region. Figure 2 shows that between 2007 and 2011, Pennsylvania natural gas production increased by over 650%, whereas employment only increased about 75%.

Figure 1: A Horizontal Drilling Rig in Lycoming, PA

Source: Wikimedia

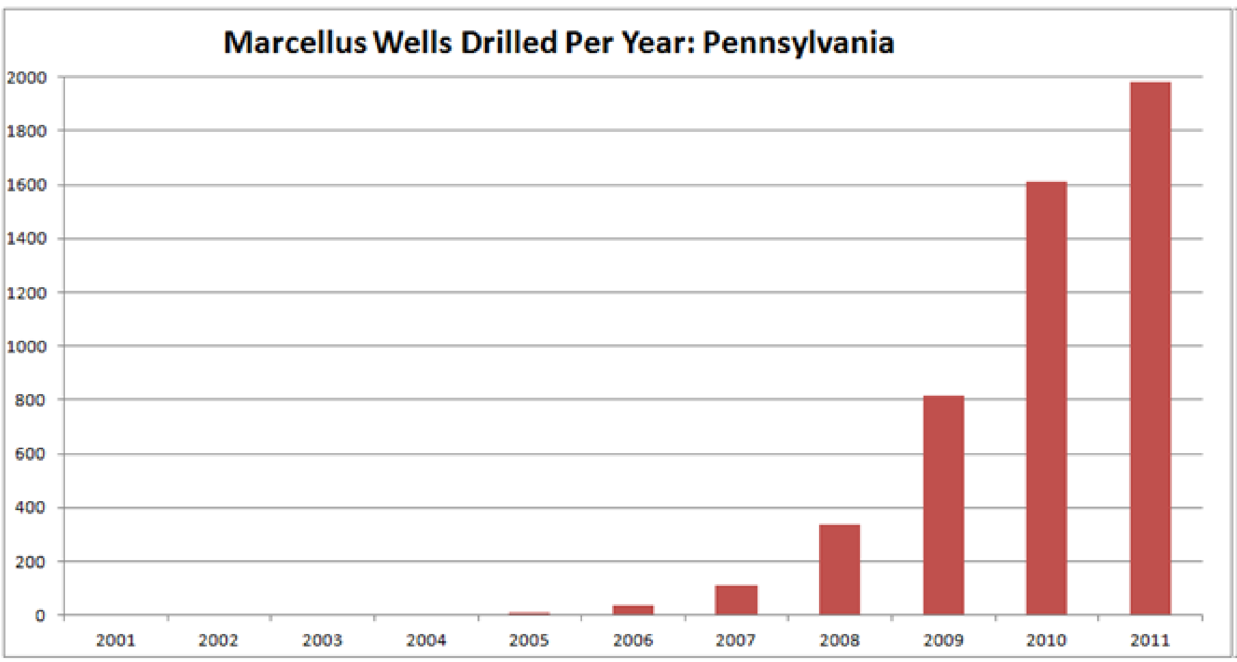
1. Paleontological Research Institute.
2. Ibid.

Figure 2: Natural Gas Production and Employment in Related Industries[3]



Source: U.S. EIA production data and U.S. BLS employment data.

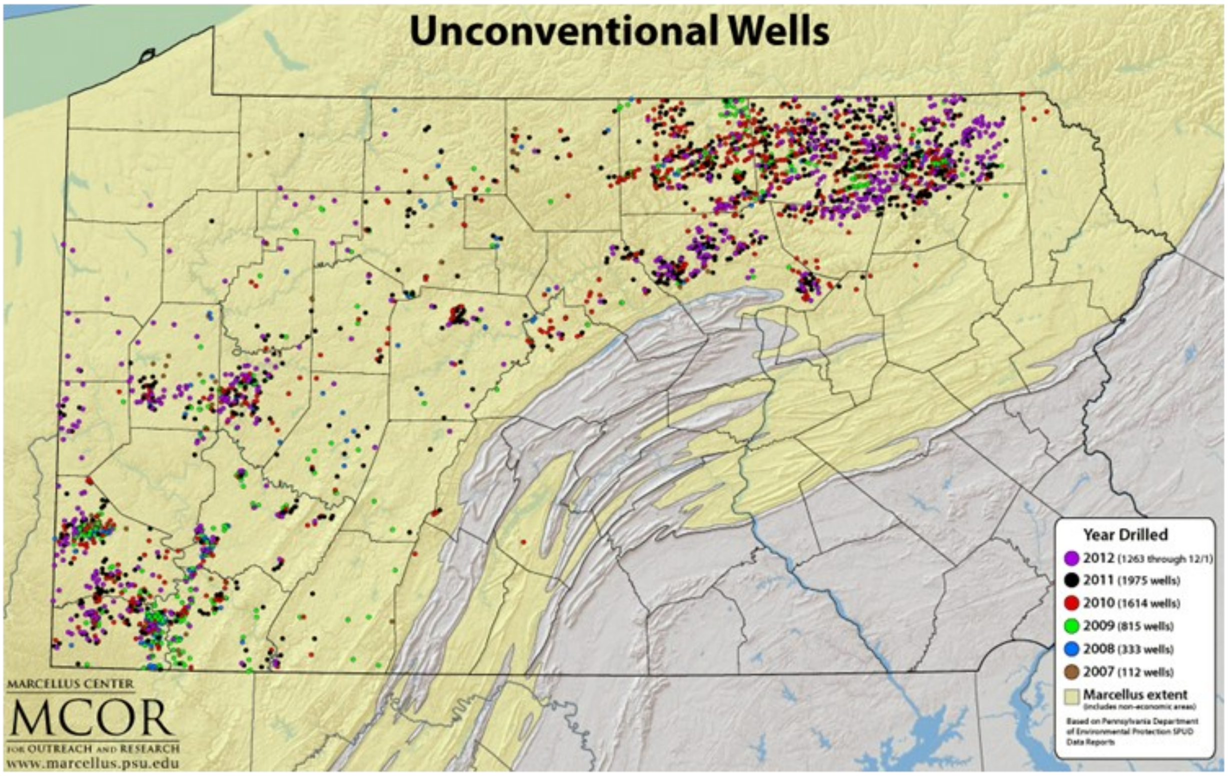
Figure 3: Marcellus Well Activity



Source: Pennsylvania Department of Environmental Protection

3. The following industries are used: 21111-Oil and gas extraction 213111 - Drilling Oil and Gas Wells 213112 - Support Activities for Oil and Gas Operations 541360 - Geophysical Surveying and Mapping Services 238912 - Nonresidential Site Preparation Contractors 333132 - Oil and Gas Field Machinery and Equipment Manufacturing 486210 - Pipeline Transportation of Natural Gas 237120 - Oil and Gas Pipeline Construction

Figure 4: Pennsylvania Unconventional Wells Over Time



Source: Marcellus Center for Outreach & Research (MCOR)

Shale development will typically occur on a regional basis, as energy companies seek to minimize the costs of moving their drilling assets. Figure 4 shows unconventional wells drilled across Pennsylvania over time. It shows how shale development has progressed across Pennsylvania. Northeastern Pennsylvania (Bradford, Tioga, Lycoming, and Susquehanna counties) has experienced the largest boom in shale development. This can also be seen in Table 1 which shows population and employment comparisons over time between the primary drilling counties in Ohio and Pennsylvania.

Shale Worker Housing Demand

Shale development affects local employment (and earnings), which in turn affects the demand for housing by affecting local incomes and net migration patterns. The initial phase of development requires mainly temporary workers, many of whom will be from outside the region and even outside of the state, especially those in jobs requiring specialized training. One estimate finds that more than half of Chesapeake's Marcellus workers come from outside the state (Rubinkam, 2010). Kelsey et al. (2011) estimate that approximately 37% of all Marcellus workers are from outside the state, although this percentage is expected to decrease over time as more local area workers are trained. Out-of-state workers will increase local housing demand more than employing local workers, whose housing needs have already been met. This first wave of temporary workers will require short term housing such as hotels, RVs and campgrounds. However, temporary workers may prefer hotels over other housing options, as hotels provide additional amenities without the inconvenience of long-term leases.

As drilling activity expands, many companies that require more permanent workers will open small offices and regional headquarters. Regional headquarters are more likely to be located in counties that are the most established in shale development. These counties will experience the largest increase in employment and the greatest increase in housing demand. These counties include Bradford County with Chesapeake Energy's regional headquarters and Lycoming County with regional headquarters for Anadarko Petroleum and Range Resources (Williamson and Kolb, 2011). This expansion brings about another wave of workers that are more

Table 1: Population and Employment Comparisons in Primary Drilling Counties over Time

Comparison of Primary Shale Drilling Counties in Ohio and Pennsylvania										
	Year: 2000			Year: 2007			Year: 2011			
County	Population	Total Employment	Shale Development Employment Share	Population	Total Employment	Shale Development Employment Share	Population	Total Employment	Shale Development Employment Share	Total Shale Wells Drilled as of 2011
Bradford, PA	62,756	30,657	1.36%	62,343	31,129	2.11%	62,917	33,823	5.63%	962
Tioga, PA	41,309	18,570	1.61%	41,371	18,843	2.09%	42,419	19,123	3.23%	689
Washington, PA	203,008	93,841	3.39%	206,259	103,494	4.18%	208,282	107,803	5.36%	562
Lycoming, PA	119,851	66,538	1.39%	116,524	67,376	1.87%	116,747	66,987	3.84%	464
Susquehanna, PA	42,260	15,000	1.76%	43,310	16,532	2.34%	43,192	17,886	4.94%	454
Greene, PA	40,591	15,515	3.02%	39,096	17,738	8.06%	38,623	19,647	10.07%	409
Carroll, OH	28,851	11,186	3.18%	29,062	11,973	4.89%	28,782	11,366	4.97%	-
Columbiana, OH	112,048	47,057	2.20%	109,153	44,990	3.17%	107,570	42,965	2.94%	-
Harrison, OH	15,854	5,220	1.79%	15,901	4,971	3.23%	15,850	4,645	2.07%	-
Jefferson, OH	73,663	31,631	1.65%	70,114	32,187	2.13%	68,828	29,664	2.01%	-

Source: U.S. Bureau of Economic Analysis, Economic Profiles, and EMSI Employment data.

permanent with more diverse housing needs. Long-term workers will typically prefer to rent apartments and homes or purchase homes. Their preferences are also dependent on their demographic characteristics. For example, younger workers, unmarried workers, workers without dependents or those who do not plan on moving their family with them generally prefer to rent rather than buy a house. Much of this depends on how long the worker plans on staying in the new location.

Oil and gas workers may prefer to commute from larger cities with higher quality housing, hotels, or other local amenities. For example, workers and their families may prefer to live in neighborhoods with better school districts or near larger selections of shopping areas, restaurants, and entertainment venues than what is available near some of the rural drilling areas. Housing costs may also be lower in surrounding communities, further incentivizing commuting. Commuting workers will limit the impact on local housing demand in drilling areas but may also place additional demands on nearby areas with minimal or no drilling activity.

Drilling activity will affect housing demand through an increase in oil and gas employment, but also by changing the value of land directly through mineral rights. Demand for real estate in drilling areas may increase as buyers expect that large leasing and royalty payments may accompany land purchases. However, drilling may also have moderating effects on the demand for housing. Concern about water quality and other negative environmental amenities associated with drilling may reduce the desire for housing in drilling areas (Gopalakrishanan and Klaiber, 2012).

Previous research has shown that negative environmental amenities, such as pollution or presence of a nuclear power plant, have a negative impact on real estate values, whereas positive environmental amenities such as forests, open land, and waterways have a positive effect on housing values (Simon and Saginor, 2006; McGranahan, 2008). Thus, it is possible for drilling to have a net negative impact on housing demand in an area. The net change in housing demand will be largely dependent on the pace and scale of drilling in an area.

Shale County Housing Stock

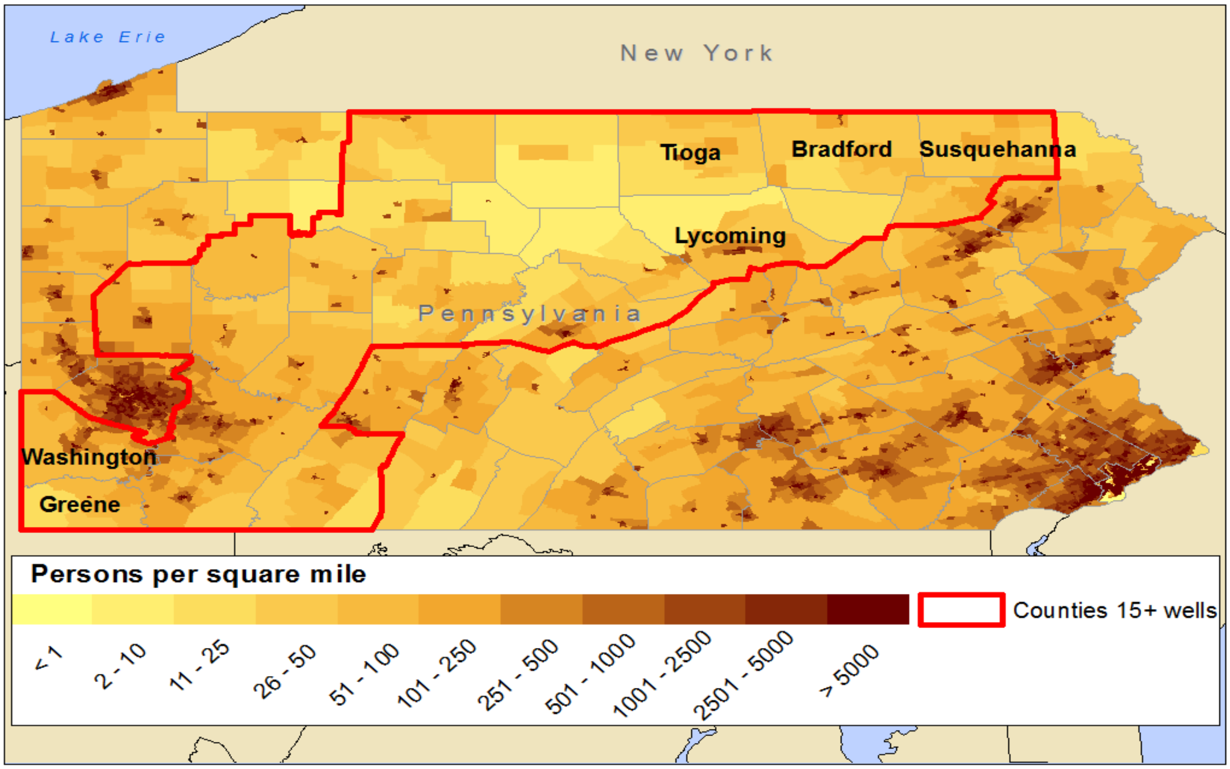
The response of the housing market to the change in housing demand will be largely dependent on the characteristics of the county itself and its housing stock. Counties that are better able to accommodate the increase in housing demand with hotels, rentals, available housing stock, or other means will not experience as large an increase in housing prices.

The counties experiencing the highest drilling activity in the Marcellus and Utica shale region are typically rural counties in Appalachia. Rural counties with small populations are not likely to have a large stock of housing and especially not a large reserve of vacant housing to meet increased housing demands. Figures 5 and 6 show the population distribution in Pennsylvania and Ohio in the year 2000, before the boom period. In Figure 5 (and most of the remaining map figures), we place a outline around the section of Pennsylvania with a greater intensity of drilling. In Figure 6, we note the four Ohio Counties that have experienced the most intensive drilling to date: Carroll, Columbiana, Harrison, and Jefferson.

A comparison of Figure 5 with the intensity of drilling in Figure 7 verifies that drilling is mainly occurring in rural counties. Houses in Appalachian Ohio are typically older, smaller, and lower-valued. According to some reports, Ohio's Appalachian region has a higher share of substandard housing and unconventional rental units such as mobile homes and RVs. Additionally, the housing stocks of many Appalachian counties in Ohio are already lacking affordable housing (Vogt Santer Insights, 2012). Therefore, rural housing stock may be inadequate in terms of both the quantity and quality of housing.

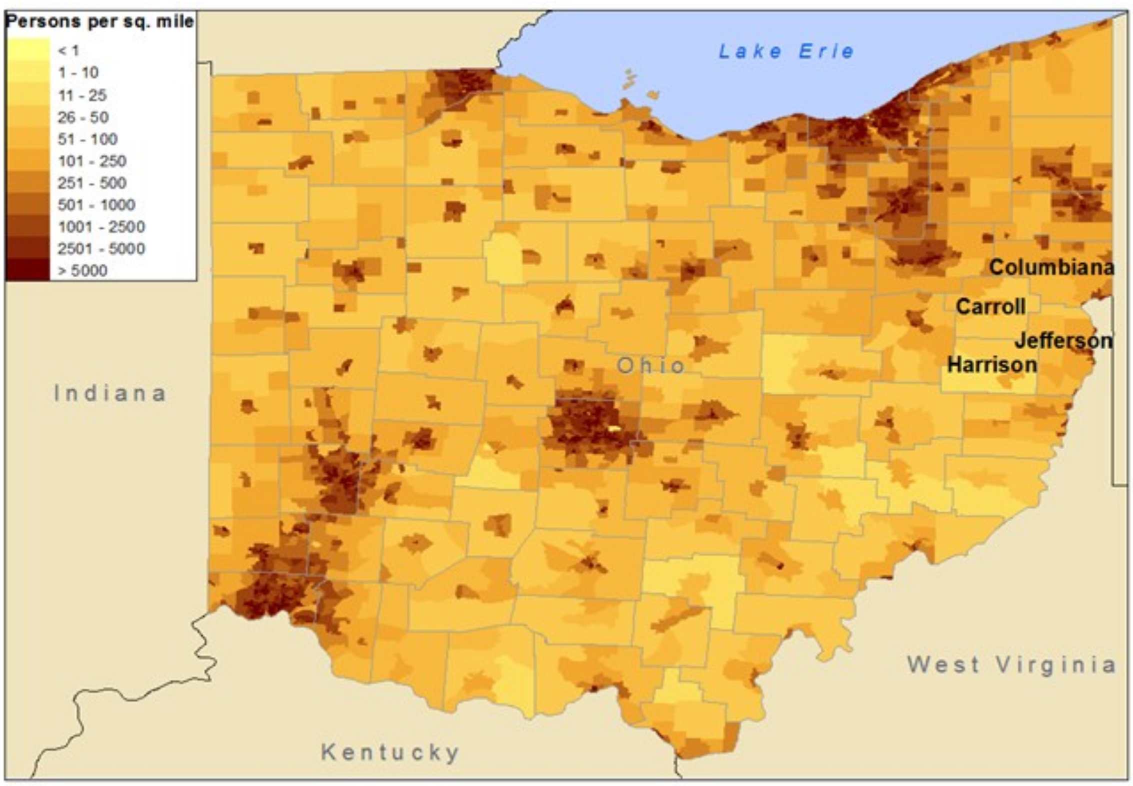
On the other hand, many rural counties in the Appalachian region have been experiencing population declines and out-migration, which leaves more housing available. Figure 7 below shows the change in population by county for the study region before the shale boom, while Figure 8 shows the time period during shale development. Figure 9 confirms that population declines have contributed to increased vacancy rates in the area. Although

Figure 5: Pennsylvania Population Density Prior to Shale Development



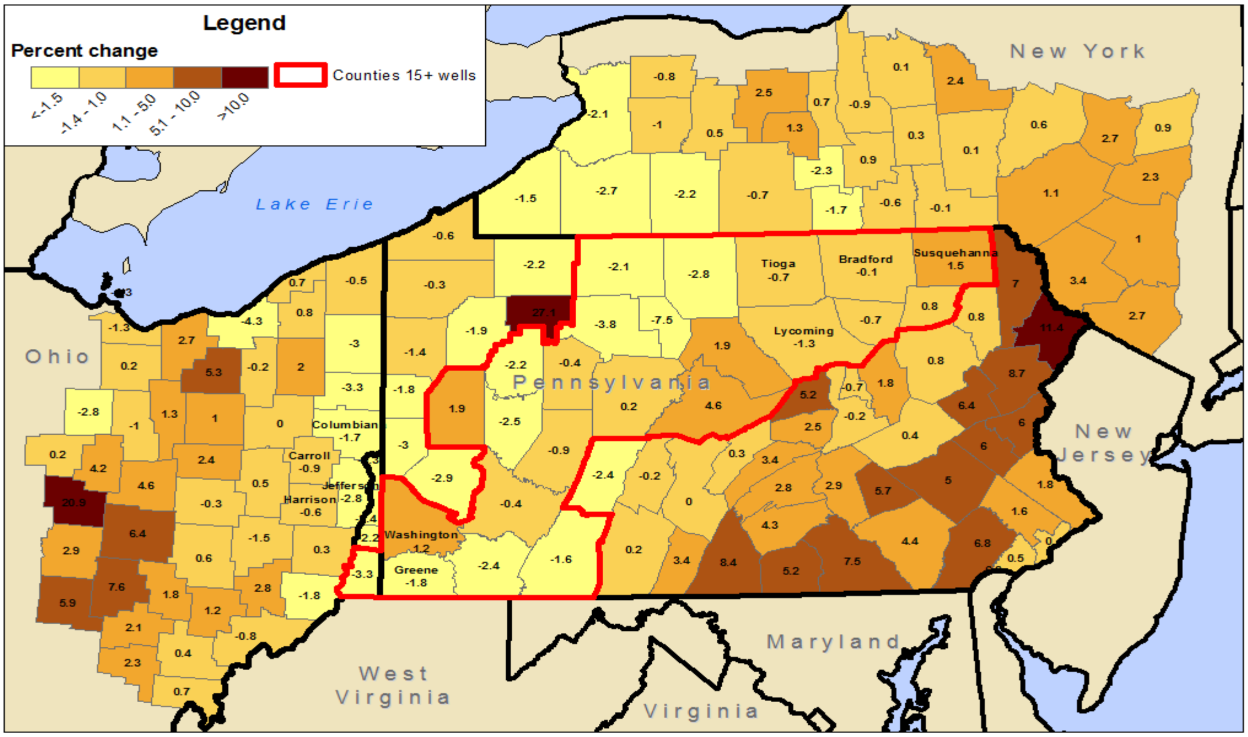
Data Source: U.S. Census Bureau, 2000 Decennial Census.

Figure 6: Ohio Population Density Prior to Shale Development



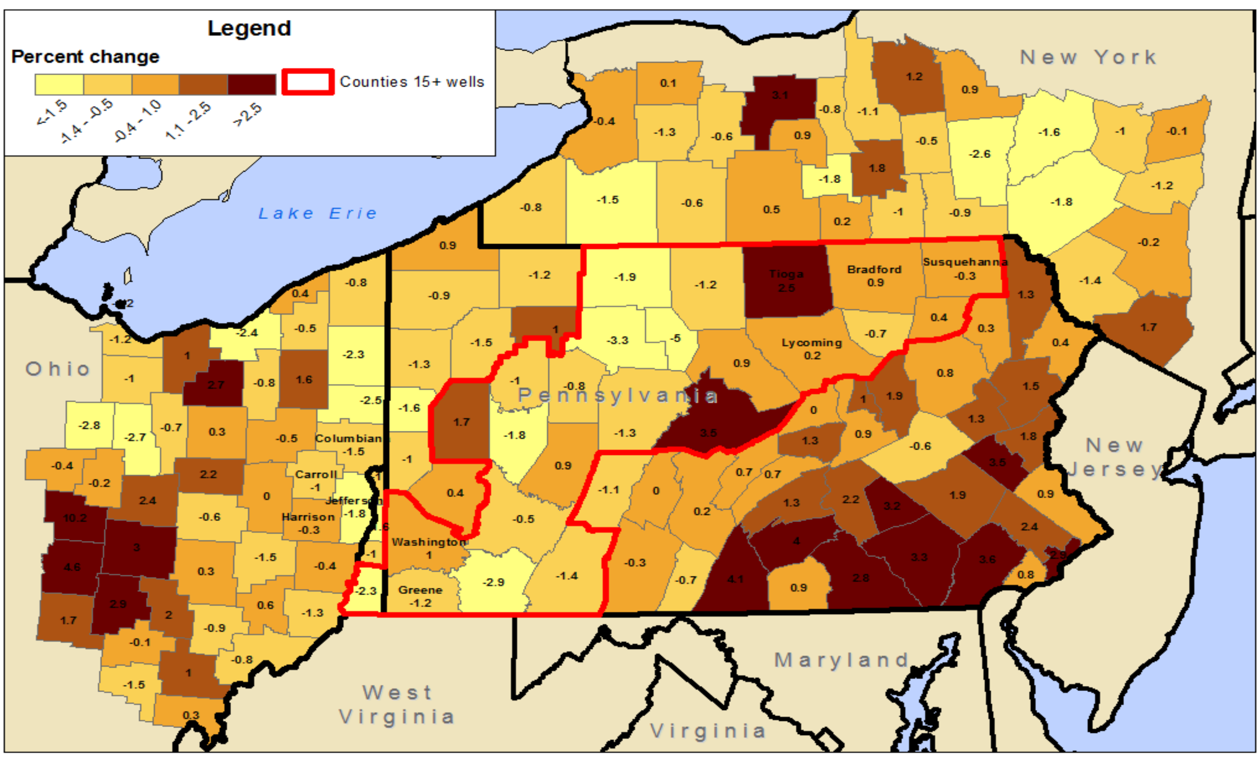
Data Source: U.S. Census Bureau, 2000 Decennial Census.

Figure 7: Percent Change in Population 2003-2007



Data Source: U.S. Bureau of Economic Analysis, Economic Profiles 2003, 2007

Figure 8: Percent Change in Population 2007-2011



Data Source: U.S. Bureau of Economic Analysis, Economic Profiles 2007, 2011 out-migration could free up housing in these areas, the homes made available may be substandard.

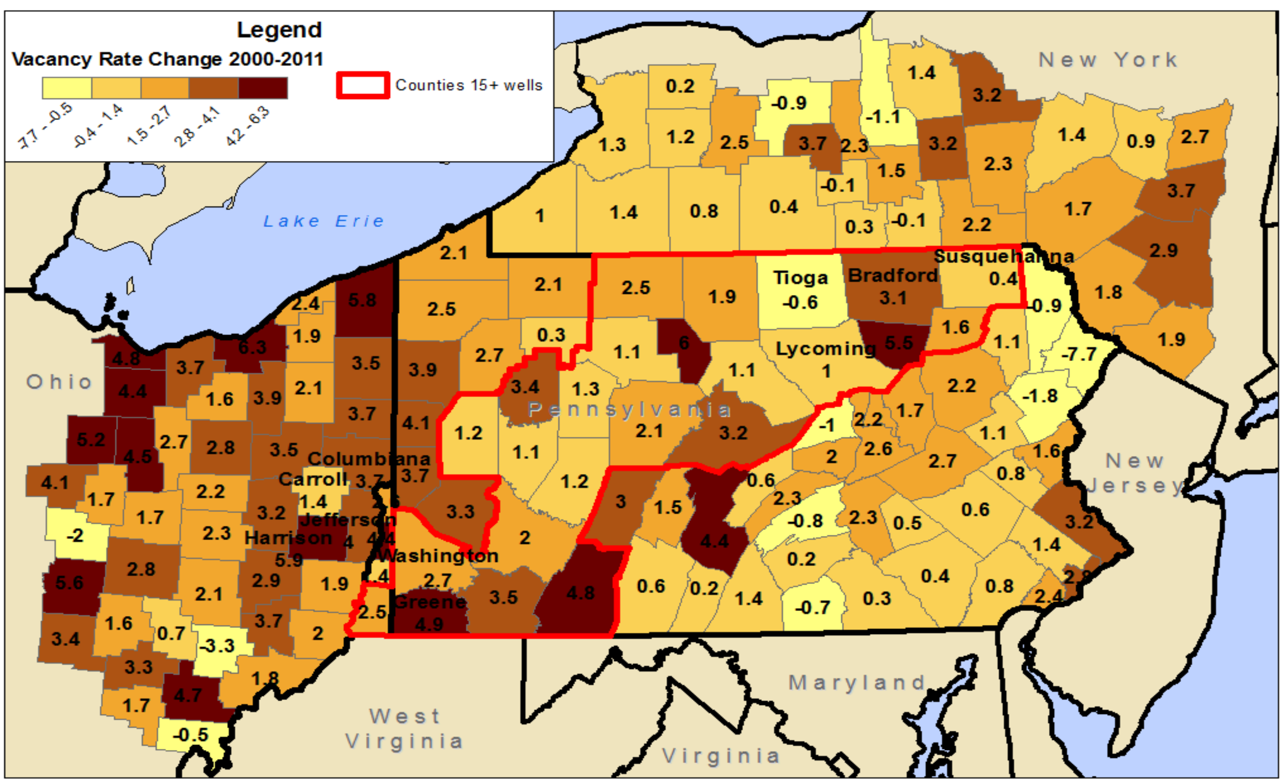
Less remote counties can rely on the housing stock of neighboring counties to make up for any lack in housing availability. Drilling counties in southwest Pennsylvania, such as Greene and Washington, can rely on nearby Pittsburgh and Allegheny County to help supply housing to their energy workers. More remote counties, such as those in northern Pennsylvania and eastern Ohio, are less likely to be able to rely on the housing stock of neighboring counties.

Rural counties with a small and inadequate housing stock may still be able to meet the increase in housing demand by building hotels, apartments, houses, and mobile home parks. County building and zoning regulations can have a substantial effect on the ability of the local housing market to respond to shifts in demand. Counties with fewer barriers to construction are able to respond to increases in housing demand through residential construction rather than higher housing prices and rents (Saks, 2008).

However, rural counties, especially those declining in population and not accustomed to significant amounts of new construction are unlikely to have the local construction capacity to respond quickly to increased demand for housing. In addition, there will be competition for construction assets with the energy sector (The Institute for Public Policy & Economic Development, 2011). Local utilities and public services may also be unprepared for new population and residential construction. As evidence of the building capacity in these rural counties, even the county with the most wells drilled, Bradford County, Pennsylvania had no new subdivisions under construction as of 2011 (The Institute for Public Policy & Economic Development, 2011). On the other hand, four hotels have been built in Lycoming County (Schwartz, 2012).

Some counties have turned to creative ways of meeting housing demand. For example, a school in Washington County, Pennsylvania was converted into 1 bedroom units (Williamson and Kolb, 2011). In some cases, the drilling industry itself helps ensure that their workers have adequate housing. Chesapeake built a $7 million residential complex and training center to house up to 280 workers in Bradford County (Rubinkam, 2010).

Figure 9: Vacancy Rate Change 2000-2011



Data Source: U.S. Census Bureau, 2000 Decennial Census and 2011 American Community Survey 5-Year Estimates

Resource Booms and Housing Markets

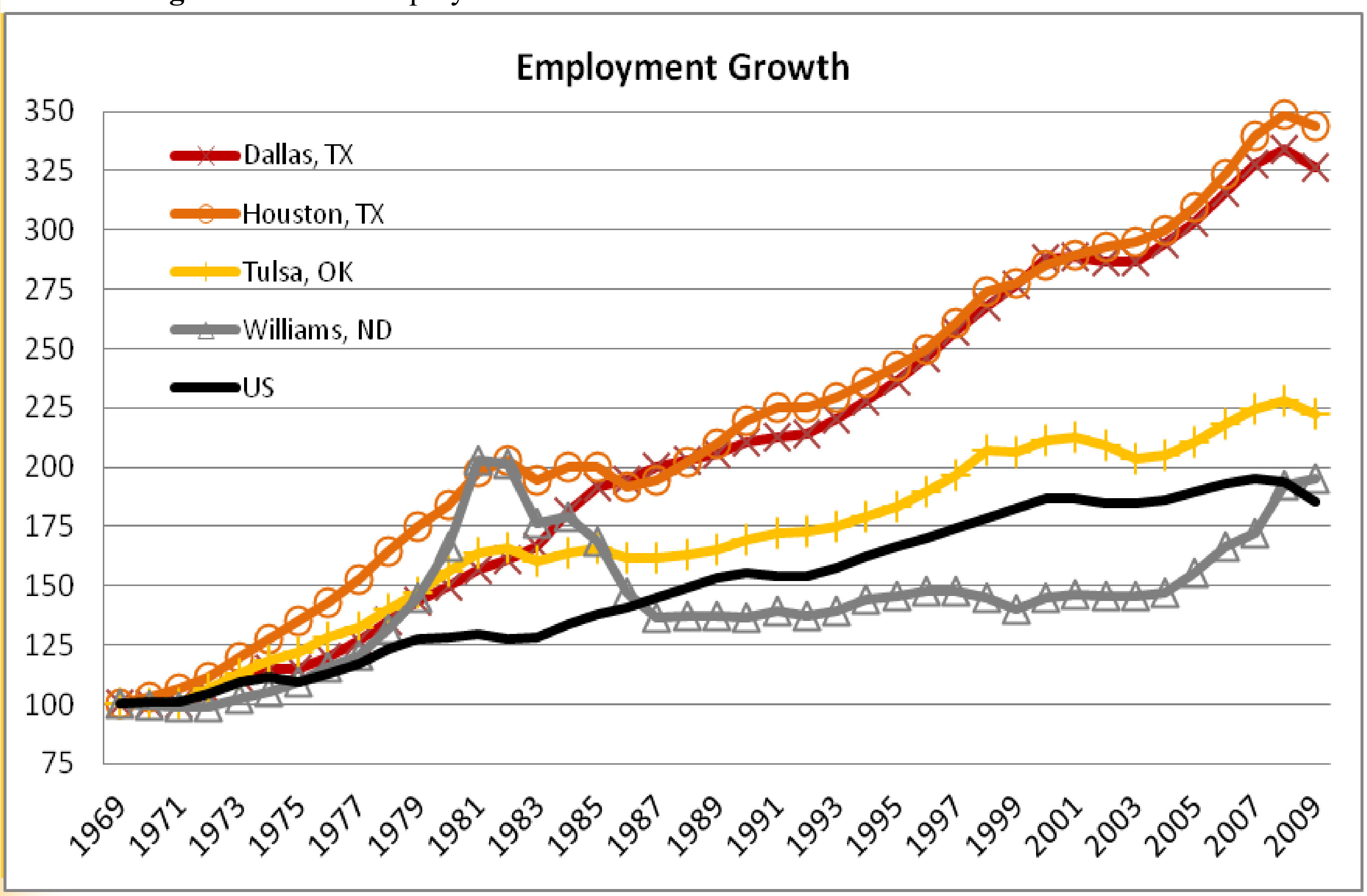
Previous natural resource booms provide insights into the local economic impact of the ensuing shale boom. The 1970s oil boom and the subsequent bust in the 1980s can be seen using employment data in Figure 10. Particularly important is the example of rural Williams County, ND (Williston) versus the larger cities shown – rural areas generally do not keep the gains in employment/population they experience during the boom and regress back to their pre-boom levels.

Figure 11 shows the housing price index during the same time period (Williams County, ND is unavailable). Housing prices generally increased during the energy boom periods of the late 1970s to the early 1980s and after 2005. Yet, the general story is that even in these relatively fast growing metropolitan areas, housing prices lag the U.S. average growth, showing that lax land-use restrictions found in Texas and Oklahoma can greatly dampen price increases in affected markets. Conversely, Boxall (2005) finds that residential property values in Alberta, Canada were negatively impacted by gas development (measured by the number of gas wells located within 4 kilometers). The impact on housing prices in Alberta seems to reflect the change in the value due to the lack of local environmental amenities.

Previous Studies on Marcellus Shale Housing Impacts

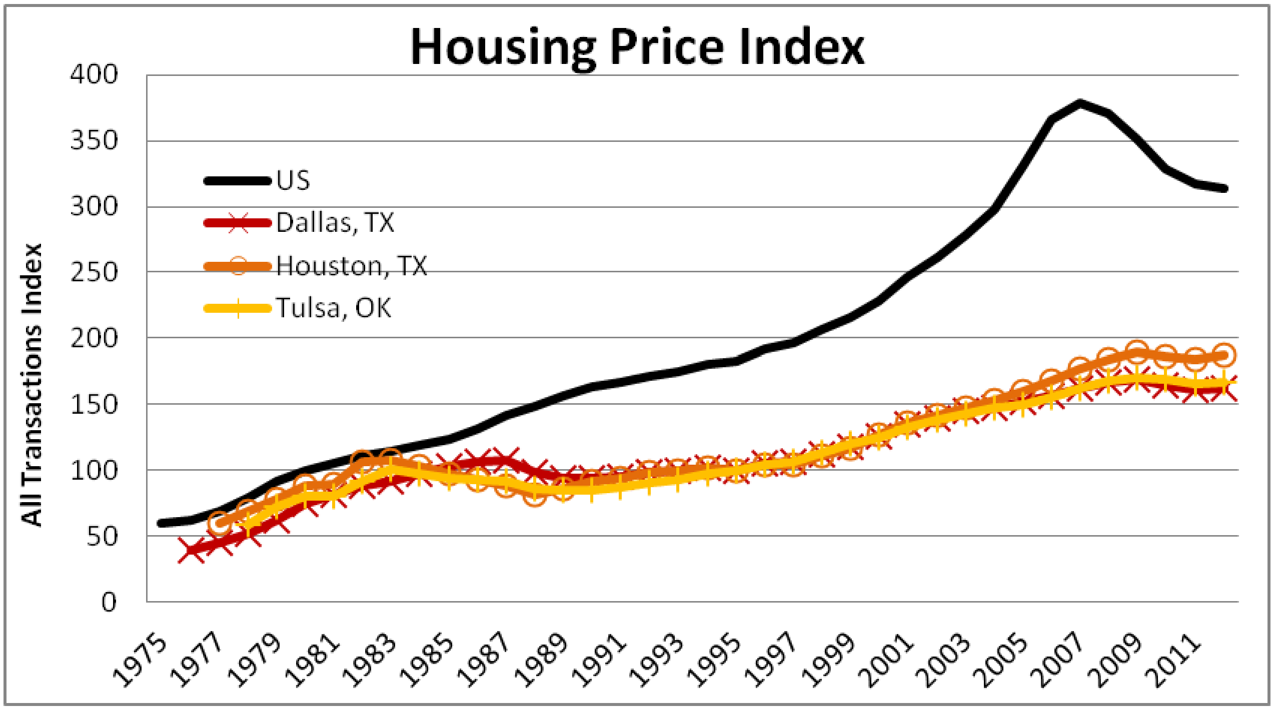
Economic theory and previous experiences have con-

Figure 10: Total Employment in Selected Cities and Previous Oil Booms in the U.S.



Source: US Bureau of Economic Analysis. Reproduced from Farren, Partridge, and Weinstein (June, 2012)

Figure 11: Housing Costs Over Time for Selected Cities



Source: Federal Housing Finance Agency

flicting implications for the potential impact of shale development on housing prices. Kelsey et al. (2012) provides a descriptive analysis of the impact on housing market values using assessed valuations for tax purposes. Although there is no clear pattern at the county level, Kelsey et al. (2012) find that drilling activities increase total market values in townships or boroughs with drilling activity. Municipalities with more than 20 wells are associated with a 15.8% increase from 2007 to 2009 in market value compared with a state average of 12.2% (Kelsey et al., 2012). Because these increases were only partially translated into the total assessed value, the increase in total market value most likely reflect an increase in housing demand and improvements to properties. However, Kelsey et al. (2012) warn that these results do not necessarily reflect the impact on individual properties, some of which may actually experience a negative impact of drilling due to their proximity to noisy gas compressor stations or other shale gas-related factors.

Combining real estate data with shale well data, Gopalakrishnan and Klaiber (2012) are able to examine the impact of Marcellus drilling wells on individual houses in Washington County, PA from 2008 to 2010. They find that household valuations are negatively impacted by shale drilling, with each additional shale well being associated with a 1.5% decrease in housing price. The impacts are more severe for houses with a private water well and those surrounded by agricultural lands, presumably because farmland is more likely to be drilled. In a similar analysis on Washington County, Muehlenbachs, Spiller, and Timmins (2012) find even larger negative effects on housing values with about a 24% decline being attributable to the risk of groundwater contamination, which more than offsets the positive impact of about 11% attributable to other economic factors, such as lease payments.

The Housing Impact of Shale Development

Our investigation into the effects of shale gas drilling on factors affecting housing availability and price utilized a wide variety of data sources and methods of analysis.[4] The region covered by the analysis includes the counties in Ohio, Pennsylvania, New York, and West Virginia the region which overlies portions of either the Marcellus or Utica shale with oil or gas resources, as defined by the Marcellus Center at Penn State University and the Ohio and U.S. Divisions of Geologic Survey. The maps, such as Figure 12, show the study region. The only counties of West Virginia included in the analysis belong to the Northern Appalachia region and constitute the northern panhandle of the state, making those counties comparable to most of the other Ohio, Pennsylvania, and New York counties included in the analysis. Thus, our study provides a broader look at the impact of shale development on housing in the region than previous studies.

To measure the effects of shale gas drilling, two measures of shale gas drilling intensity are used: the number of wells drilled each year (as reported by the various state departments of environmental protection/natural resources) and oil and gas drilling employment as a share of total employment in each county (as calculated by EMSI). Five specific housing-related metrics are used to compare areas with intensive drilling efforts against those without drilling activity in order to determine pressures on local housing markets:

1. **Population**
2. **Fair Market Rent (FMR)**
3. **Residential housing permits issued**
4. **Median home value/rental rate**
5. **Vacancy rate**

We consider the effect of both the number of wells drilled within a county and total county employment in the oil and gas industry on housing cost and availability. Our dependent variables include county-level measures of population, fair market rent, the median rental rate, new home construction permits, vacancy rate, and median home values. We use several linear regression techniques to ensure the robustness of our results. We first use a two-way fixed effects estimator applied to county-level panel data from 1997-2011 to determine the effect of the number of wells drilled and changes in oil and gas employment on our county-level measures of housing cost and availability. As expected, changes in oil and gas employment have different effects on the housing measures than the number of wells drilled.

Next, we use instrumental variable regression to account for omitted variables that are possibly affecting housing outcomes and associated with shale gas development. Lastly, we use a Difference-in-Difference (DiD) estimator to determine whether changes in housing measures over the boom period were different in shale drilling counties compared to non-drilling counties. The advantage of Difference-in-Difference methods is that they control for many unobservable factors that could potentially affect our statistical results. Analyzing the data using several statistical methods helps assess the robustness of our results.

In addition to subjecting the data to several statistical methods, we consider several possible statistical concerns. First, it is possible the number of wells drilled and changes in oil and gas employment might have a non-linear relationship with the housing measures we consider– that is, the numbers of shale wells drilled might have a larger effect for counties with large numbers of wells drilled than counties with only modest numbers of shale wells drilled. If a non-linear relationship exists, the effect of the variables of interest may change once the number of wells reaches a certain threshold. We did find evidence of non-linear effects in many instances, indicating that small numbers of shale wells drilled generally had a negative association with the housing measures, but a positive association with the housing measures in counties with very large numbers of shale wells drilled—though this did not hold in all cases.

4. The data utilized for the analysis was obtained from the U.S. Census Bureau, the 2000 Census and 2011 Annual Community Survey (ACS) (5-year estimates, 2007-2011), the U.S. Department of Housing and Urban Development, the U.S. Bureau of Economic Analysis, the U.S Energy Information Agency, the Pennsylvania and West Virginia Departments of Environmental Protection, the Ohio Department of Natural Resources, EMSI (Economic Modeling Specialists Intl.), an economic data clearinghouse and consulting firm.

We control for county differences in economic structure, demographic conditions, and geographic locations. It is particularly important to control for differences in county industry composition. Doing so allows us to isolate the effects on housing from changes in oil and gas employment from county-wide employment changes over time in order to isolate what happens due to energy development from what would have occurred without energy development.[5]

We include variables to account for the effect of each county's population, median personal income per capita and the percent of the population below the poverty level. Lastly, we include variables to account for the specific county-based and year-based differences in the data – in this way, we are not mistakenly comparing the effect of Alleghany County, Pennsylvania (home to Pittsburgh) to a more isolated, rural county like Bradford County. Also, our approach accounts for the cyclical effects of the Great Recession, so that they do not confound our energy results.

1) Population

Shale gas drilling activities generally require drilling rig workers with specialized training from outside the region until a local labor pool can be developed. Therefore, there may be a connection between the drilling activities in a county and population increases. An initial examination of population changes during the shale boom period (Figure 8 compared to Figure 7 suggests that shale boom counties are modestly increasing in population relative to their pre-boom path).

Our regression results indicate that a 1% increase in total employment directly related to the oil and gas energy sector employment is associated with a 0.5% increase in county population, all else equal.[6] To give an upper range for this effect, Table 1 shows that between 2007-2011, Bradford County experienced about a 3.5% increase in total employment directly linked to the oil and gas industry, which is one of the largest increases in energy industry employment share. Thus, we expect about a 1.75% (0.5 × 3.5) increase in Bradford County population associated with energy development, all else equal. However, the number of shale gas wells was not strongly linked to population growth, suggesting that the links found above are somewhat tenuous.

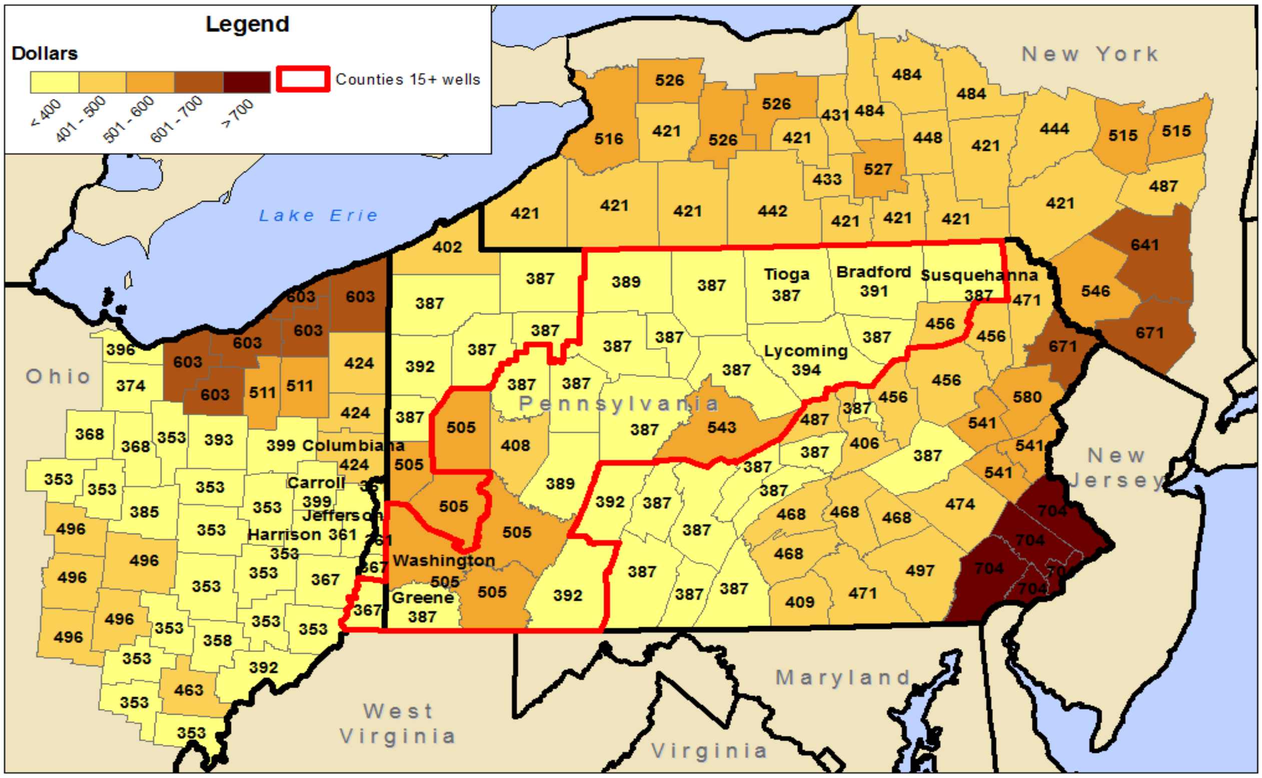
2) Fair Market Rent

As shale gas workers increase the demand for short-term housing including hotel rooms and rental units, increases in rent will be reflected in the Fair Market Rent (FMR) calculated by the U.S. Dept. of Housing and Urban Development (HUD).[7] FMR's strength is that it is reported annually across the U.S. One weakness of the FMR is that HUD does not fully survey every county every year. In those cases, HUD assumes an annual FMR growth rate depending on the rent changes in the nearest major city or region of the country in which the county is located. This could affect some of the results in our rural sample. Figure 12 and Figure 13 show the FMR in 2003 and 2011 for 1 bedroom units.

We find that increases in total employment associated with the energy sector are statistically associated with smaller increases in the FMR, which was unexpected. The number of shale gas wells is also associated with FMRs for low numbers of wells drilled each year, but the relationship becomes positive for higher numbers of wells. Thus, the county with the most wells drilled, Bradford, actually experienced an increase in FMR. The estimated breakeven point, where the number of wells drilled per year has no effect on FMR, ranges from between 340 and 430 wells (or between 785 and 910 wells over the entire shale boom time period), suggesting that Bradford County's FMR increased by about 3.6% due to drilling activity. For comparison,

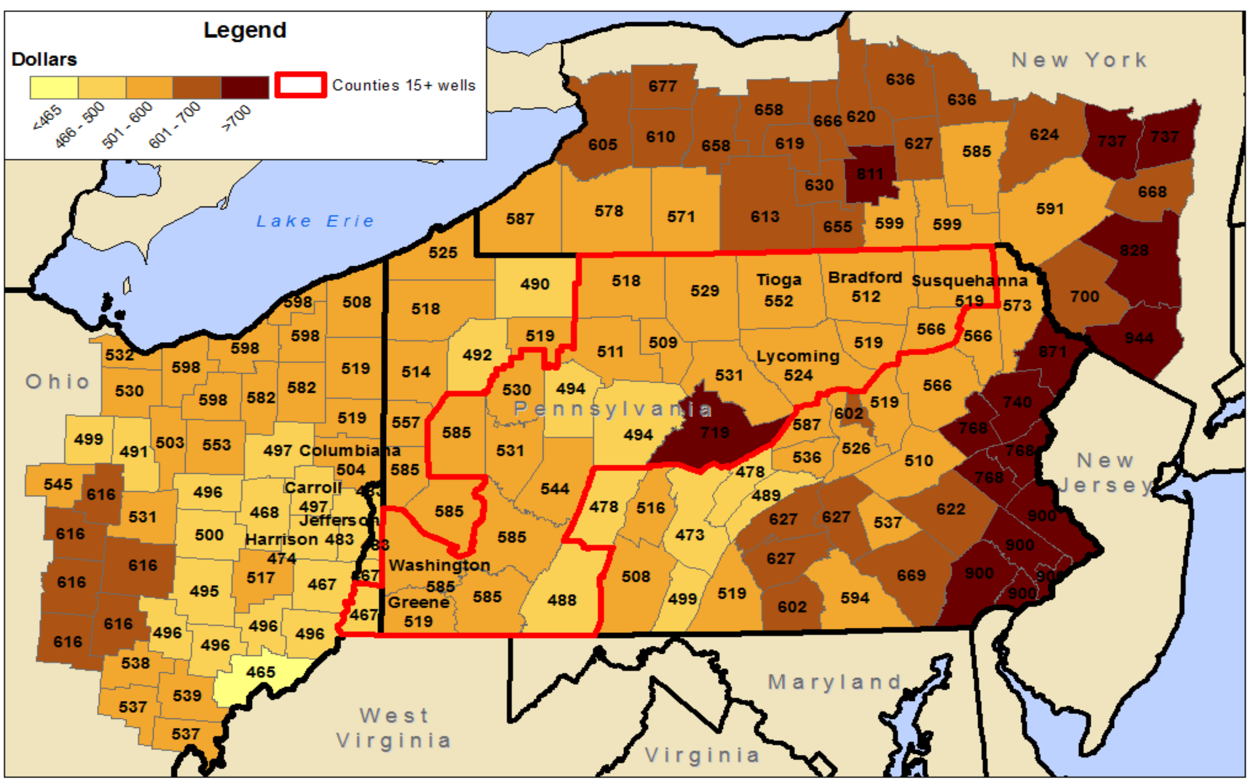
5. To do this we include a variable that accounts for the change in employment in the county, assuming that each industry in the county grew at its national growth rate.
6. Partridge et al. (2012) review the long literature on the relationship between employment growth and population growth. They find that a 1% increase in jobs in a regional economy is associated with about 0.8% population growth before 2000. After 2000, 1% job growth is only associated with 0.2-0.25% population growth, suggesting more jobs are going to locals. In our case, this suggests more energy jobs went to outsiders compared to typical growth across all sectors.
7. The FMR is generally defined as the level of rent which is above 40% of the rental values in the housing market and below the other 60% (the actual proportions vary by county and for a few counties, the numbers are 50%, in which case the FMR is equal to the median rental cost).

Figure 12: 1 Bedroom Fair Market Rent 2003



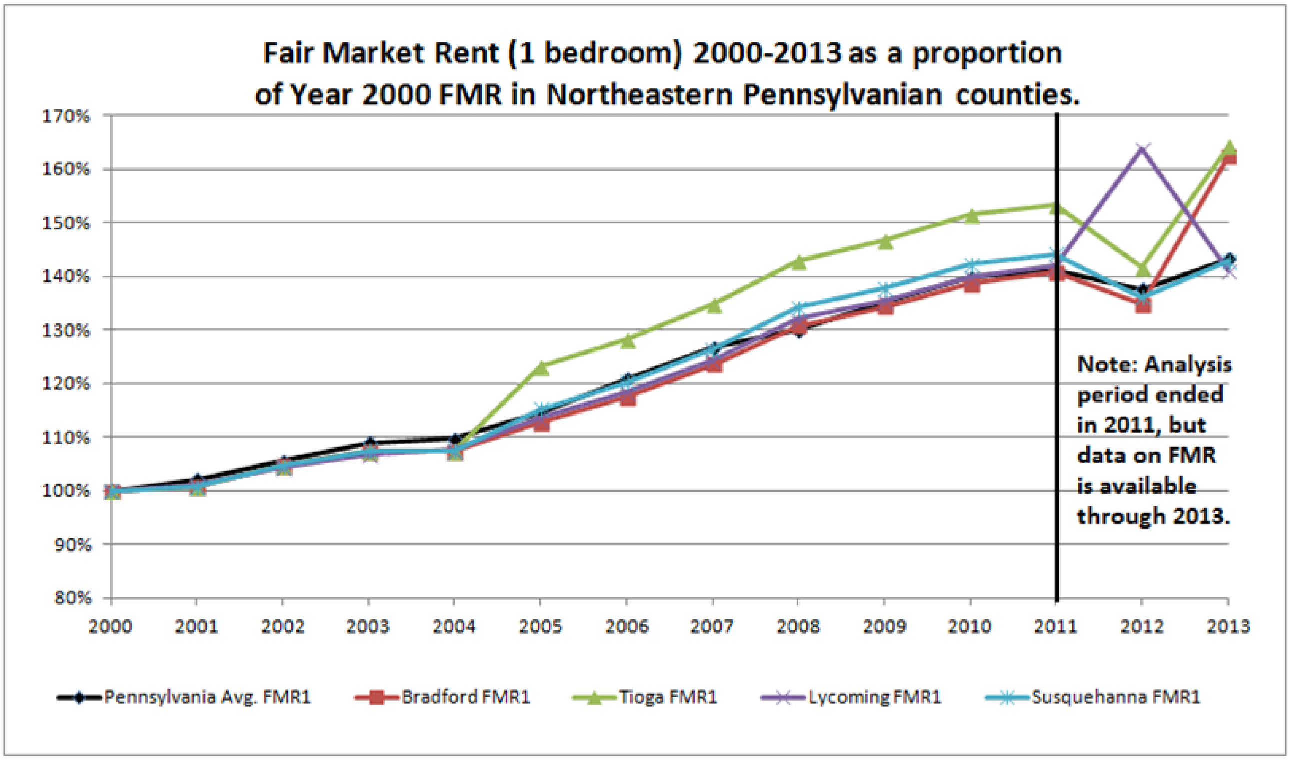
Data Source: U.S. Department of Housing and Urban Development

Figure 13: 1 Bedroom Fair Market Rent 2011



Data Source: U.S. Department of Housing and Urban Development

Figure 14: Pennsylvania Rental Market Changes



Source: U.S. Department of Housing and Urban Development.

377 and 397 wells were drilled in Bradford County during 2010 and 2011 respectively. Tioga County, the county experiencing the second most intense drilling activity, had 276 and 273 wells drilled during this time period.[8] In sum, we find no strong statistical link between FMR and drilling activity.

Figure 14 shows that, in general, the growth patterns of the counties with the most drilling have been comparable with the state as a whole over the 2007-2011 period. When examining two years after the regression sample period (2012 and 2013), there were volatile movements in the Fair Market Rent for Bradford, Tioga and Lycoming counties – the same counties which have been the center of the controversy regarding shale gas effects on housing affordability (Bradford and Tioga experiencing large increases and Lycoming holding flat over the time).

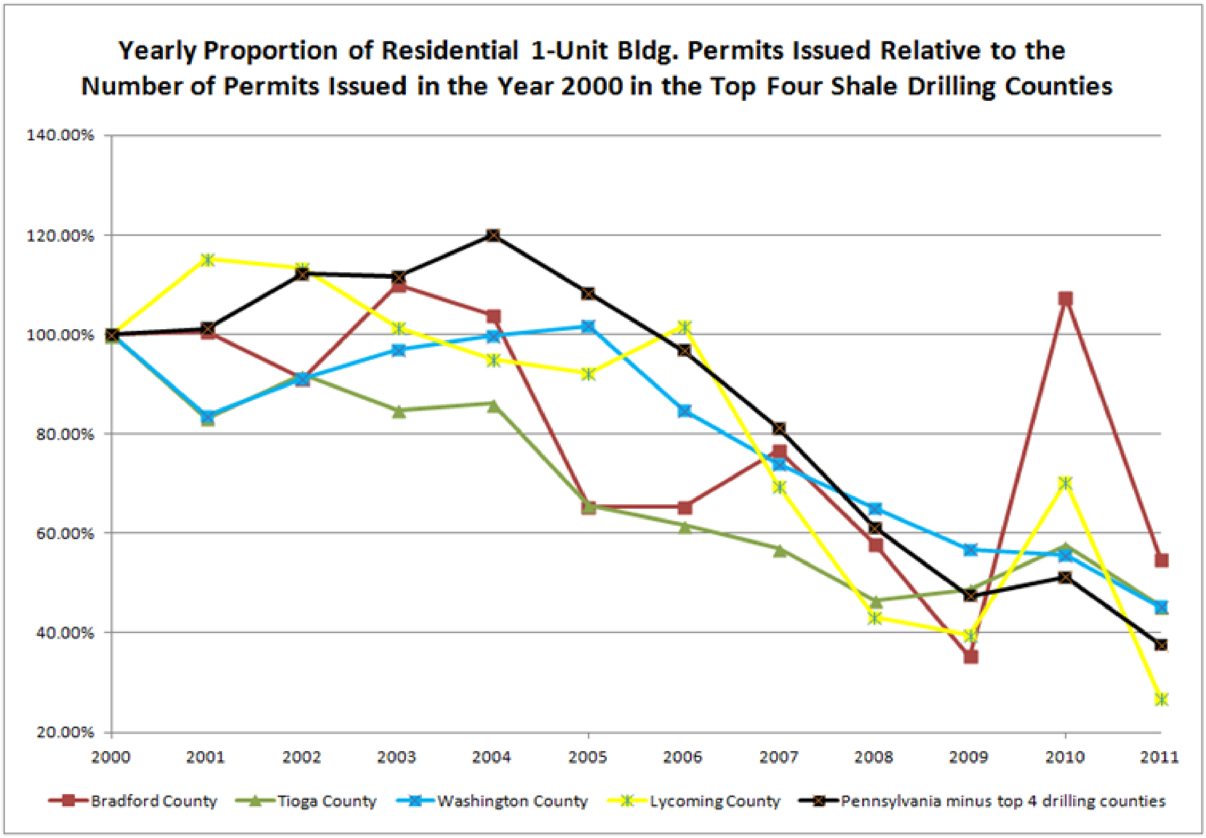
Given the data concerns with the FMR measure, we also considered an alternative rent measure provided in the 2000 Census of Population and the 2011 American Community Survey (ACS) in which renters are asked their rental rate. A shortcoming with the 2011 ACS is that if one wants data for all counties regardless of population, they have to use the five-year average over the 2007-2011 period. These alternative regression results show a strong positive relationship with the median rental rate at low drilling intensity, but a negative effect for large numbers of drilled wells, which is the exact opposite pattern as found for the FMR.[9] Together, we conclude that drilling activity likely only has a modest impact on FMR.

3) Housing Permits

As the supply of available rental and housing properties dries up, an increase in the construction of residential buildings would help meet the increased housing demand. Yet, an increase in residential

8. During the entire shale development time period in our sample, there were a total of 962 wells drilled in Bradford County, while there were 689 wells drilled in Tioga County.
9. This pattern is likely because Bradford County experienced a much smaller percentage change in median rents over the period than in other counties, creating an outlier that affects the general results. Graphs displaying this result and illustrating the generally scattered nature of the data are provided in Appendix 2.

Figure 15: Pennsylvania Housing Permits



Source: U.S. Census Bureau, Residential Construction Branch

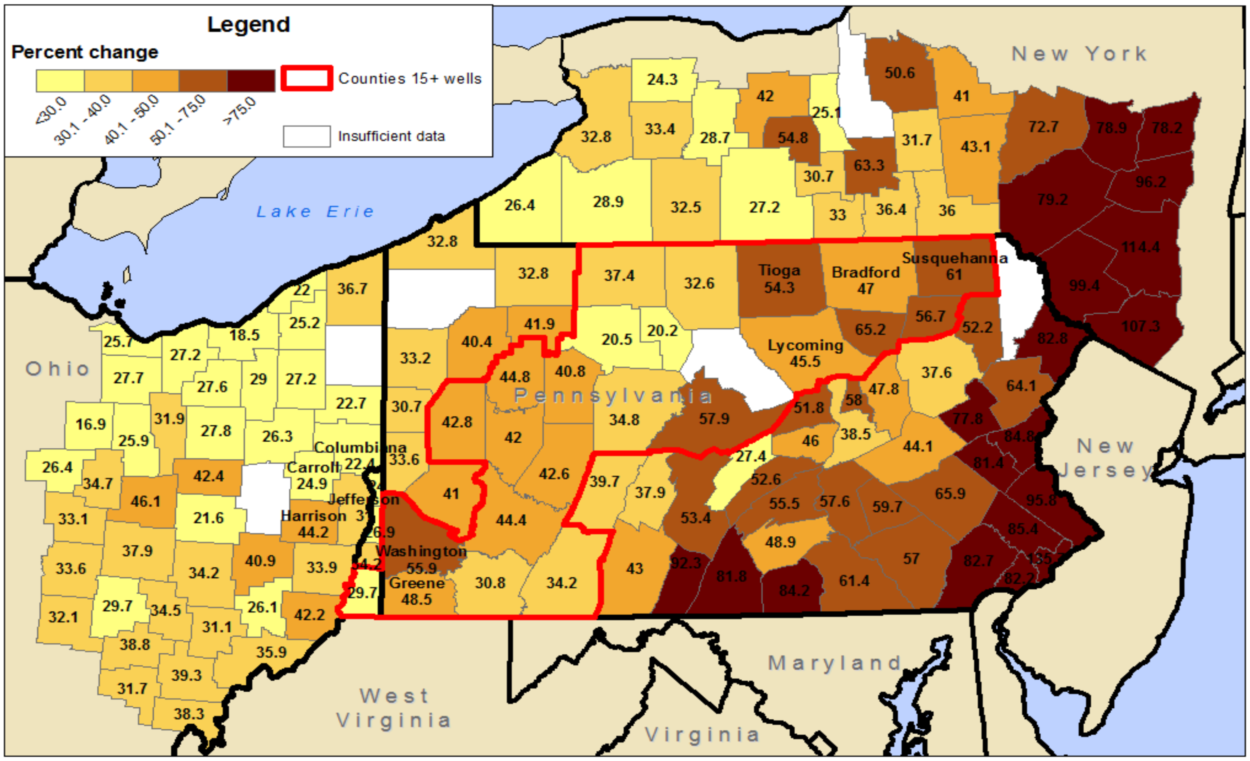
building permits may indicate that local residents enriched from leasing and royalty payments are building new homes, which would do little to alleviate a housing shortfall.

Our results suggest that an increase in energy sector employment and the number of wells drilled is generally associated with an increase in the number of residential building permits. On average, each new shale gas well drilled is associated with more than 2.5 additional housing permits. Figure 15 shows the proportion of residential building permits approved each year relative to the year 2000 for the four counties in Pennsylvania experiencing the largest boom in shale development. The graph shows a substantial spike during the years of greatest drilling intensity. These results present some encouraging findings that housing markets are appropriately responding to the increased demand for housing by building new units.

4) Median Home Values

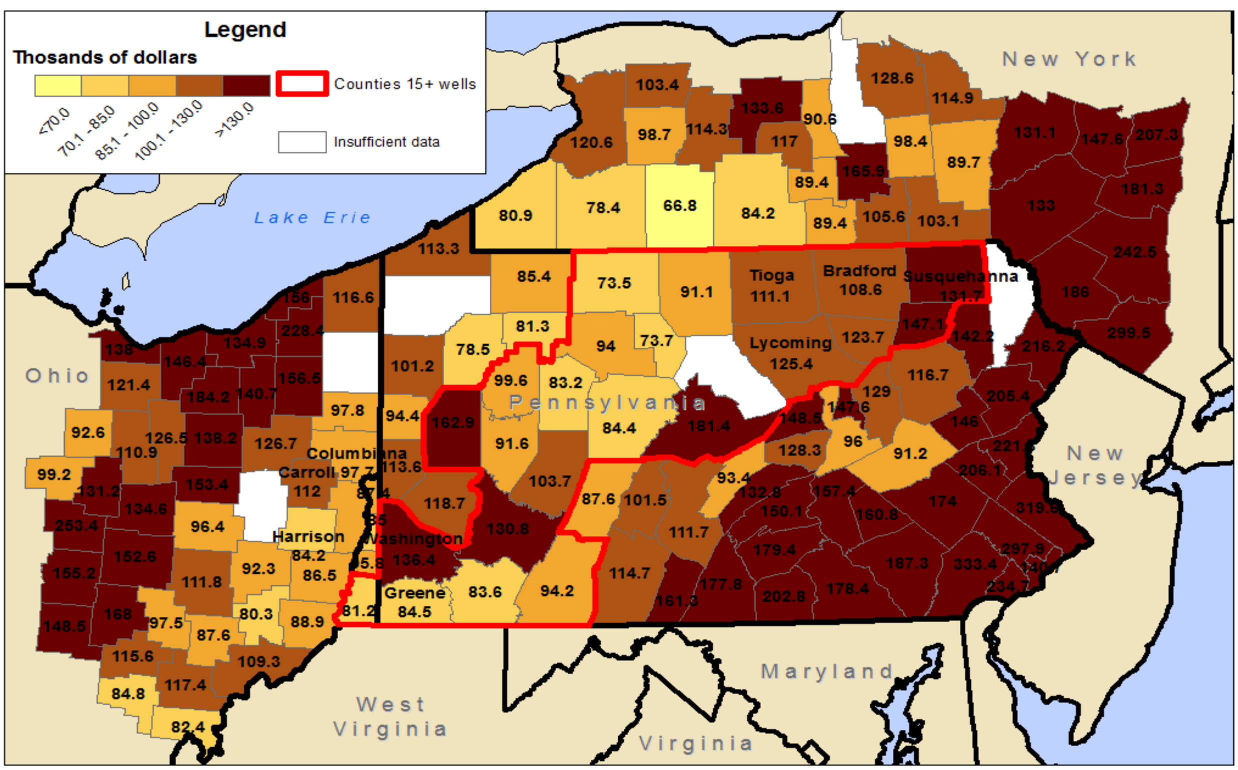
If shale development is affecting housing markets, then the effects would also likely appear in changes in housing values. To examine this, we use the median housing value reported in the 2000 Census of Population and the 2011 ACS. One shortcoming of this data is that it is self-reported by the home owner. Another is that for the 2011 ACS, it again reflects the 2007 to 2011 five-year average value. Figure 16 shows the percent change in median home values from 2000 to 2011. Figure 17 shows the median home value in 2011. Our regression analysis estimates the relationship between the percentage change in median housing

Figure 16: Percent Change in Median Home Values 2000-2011



Source: U.S. Census Bureau, 2000 Decennial Census and 2011 American Community Survey 5-Year Estimates

Figure 17: Median Home Values 2011 in Thousands of Dollars



Source: U.S. Census Bureau, 2000 Decennial Census and 2011 American Community Survey 5-Year Estimates value and energy sector employment or the number of wells drilled over the 2007-2011 period. The analysis showed that shale gas and oil development had inconsistent effects on the median housing value that tended to be statistically insignificant.

5) Vacancy Rates

We expect the influx of energy sector workers into shale boom counties to drive down the vacancy rate of residential units in the county as housing demand increases. Our statistical analysis suggests that energy sector employment and the number of wells drilled are associated with a decrease in vacancy rates, though the results are not statistically significant. In fact, Figure 9 shows the vacancy rate changes from 2000-2011, illustrating that counties with intense shale development do not show consistent vacancy rate decreases. Our results provide some evidence that the vacant housing stock in many of these rural areas is not being used by incoming workers, perhaps because it is substandard. Thus, oil and gas workers may be turning to other housing sources rather than filling vacant houses.

Bradford, Susquehanna and Tioga Counties

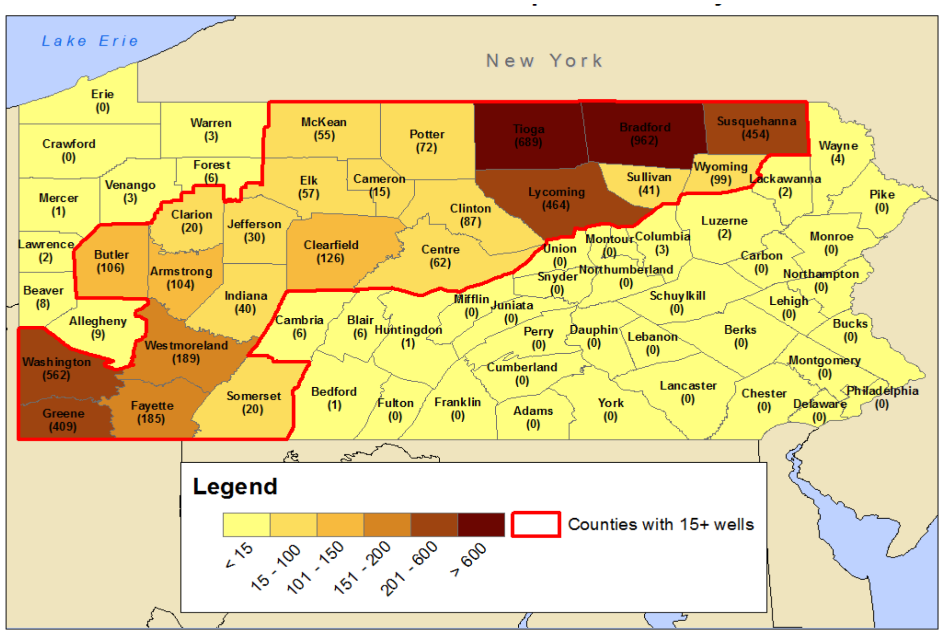
Our results generally show that the impact of shale development on housing affordability and availability is small until drilling activity becomes sufficiently large in a handful of counties, though home building seems to respond to drilling activity. In the Marcellus region, Bradford County and Tioga County have experienced the most pronounced increased in shale development (see Figure 18). These counties are most likely to experience pressures on their housing markets. Bradford, Tioga and Susquehanna counties were part of the focus of our Dec. 2010 policy brief, where their experience of the shale gas boom was compared with three similar counties outside the drilling area (Union, Carbon and Columbia). An updated comparison between these groups focusing on housing measures is provided in Table 2.

Focusing on the "Drilling Period" in the middle panel of Table 2, we see that population growth and building permits are about equal across the drilling and non-drilling counties, but employment growth, shale drilling employment, and FMR rose faster in the drilling counties (the third column shows the difference in results across the two groups). Comparing the 2007-2011 drilling period to the 2003-2007 pre-drilling period, the drilling counties made significant gains relative to the non-drilling counties for population growth, employment growth, shale drilling, and building permits. Yet, FMR actually grew much faster in drilling counties compared to non-drilling counties during the pre-drilling period. Similarly, considering median house prices over the entire decade in the bottom panel, prices rose about 5 percent faster in non-drilling counties. This comparison further illustrates that even when considering the most-intense drilling counties, housing prices and FMRs were fairly well contained, even though drilling counties experienced faster economic growth.

Bradford and Tioga, the most prominent Pennsylvania shale drilling counties, are rural, Appalachian counties with populations of 62,622 and 41,981 (in 2010), respectively. They are more remote than other heavy drilling counties in the Southwest portion of Pennsylvania near Pittsburgh. During their shale development between 2007-2011, Bradford and Tioga have experienced population gains of 0.9% and 2.5%, which is larger than their respective losses of 0.1% and 0.7% between 2003 and 2007 (refer to Figures 7 and 8). These modest population increases may have led to housing shortages and housing price increases in Bradford and Tioga.

Yet, the FMR for single bedroom apartments for these counties seem to grow at around the same rate as the state average (Figure 14). (Though our results suggest that these counties would have experienced even lower growth in FMR had shale development not took place). Meanwhile, the number of new single-unit residential home permits approved nearly tripled in Bradford County in a single year (2010) during the height of the shale drilling boom. It seems that even in those counties most affected by shale development, the housing market is responding to the increase in rent and decrease in availability by building houses.

Figure 18: Number of Shale Gas Wells per County through 2011



Data Source: Pennsylvania Department of Environmental Protection

Table 2: Comparing Drilling and Non-Drilling Counties

Average Performance of Selected Counties during the Pre-Drilling and Drilling Periods of the Shale Gas Boom for Factors Affecting Housing Availability and Affordability			
Pre-Drilling Period	Average Percent Growth of Shale Drilling Counties[1] (2003-2007)	Average Percent Growth of Non-Drilling Comparison Counties[1] (2003-2007)	Difference in Percent Growth between Drilling Counties and Non-Drilling Counties (2003-2007)
Population	0.22%	4.50%	-4.28%
Employment	1.10%	3.51%	-2.42%
Shale Drilling Employment	0.44%	0.11%	0.33%
FMR (1-bedroom)	19.33%	12.73%	6.59%
Single Unit Res. Bldg. Permits[2]	0.59%	1.11%	-0.51%
Drilling Period	Average Percent Growth of Shale Drilling Counties[1] (2007-2011)	Average Percent Growth of Non-Drilling Comparison Counties[1] (2007-2011)	Difference in Percent Growth between Shale Energy Counties and Comparison Counties (2007-2011)
Population	1.06%	1.07%	-0.01%
Employment	6.11%	-0.03%	6.14%
Shale Drilling Employment	2.73%	-0.15%	2.88%
FMR (1-bedroom)	13.89%	11.12%	2.76%
Single Unit Res. Bldg. Permits[2]	0.40%	0.52%	-0.12%
Census-based Data[3]	Average Percent Growth of Shale Drilling Counties[1] (2000-2011)	Average Percent Growth of Non-Drilling Comparison Counties[1] (2000-2011)	Difference in Percent Growth between Drilling Counties and Non-Drilling Counties (2000-2011)
Population	1.72%	8.03%	-6.31%
Employment	10.85%	6.62%	4.23%
Shale Drilling Employment	3.56%	0.16%	3.40%
Median Rent	44.88%	43.71%	1.17%
Median Home Value	54.09%	59.15%	-5.06%
Vacancy Rate	0.99%	0.60%	0.38%

[1] - These are the counties experiencing heavy shale drilling in northeastern Pennsylvania and the counties outside the drilling region that were selected as good comparison cases from our Dec. 2010 policy brief, 'The Economic Value of Shale Natural Gas in Ohio.' The shale drilling counties selected were Bradford, Tioga and Susquehanna. Their counterparts were Union, Carbon and Columbia.

[2] - This is the average annual percent growth in single unit residential building permits approved relative to the total housing stock in the county recorded by the 2000 Decennial Census.

[3] - Median Rent, Median Home Value and Vacancy Rate data were only available from the 2000 Decennial Census and the 2011 American Community Survey 5-Year Estimates (2007-2011), so these parameters were not available for the specific Pre-Drilling and Drilling periods.

Source: U.S. Census Bureau, 2000 Decennial Census, 2011 American Community Survey 5-Year Estimates, and Residential Construction Branch, U.S. Bureau of Economic Analysis, Economic Profiles, U.S. Dept. of Housing and Urban Development, and EMSI Employment data

Policy Implications and Conclusion

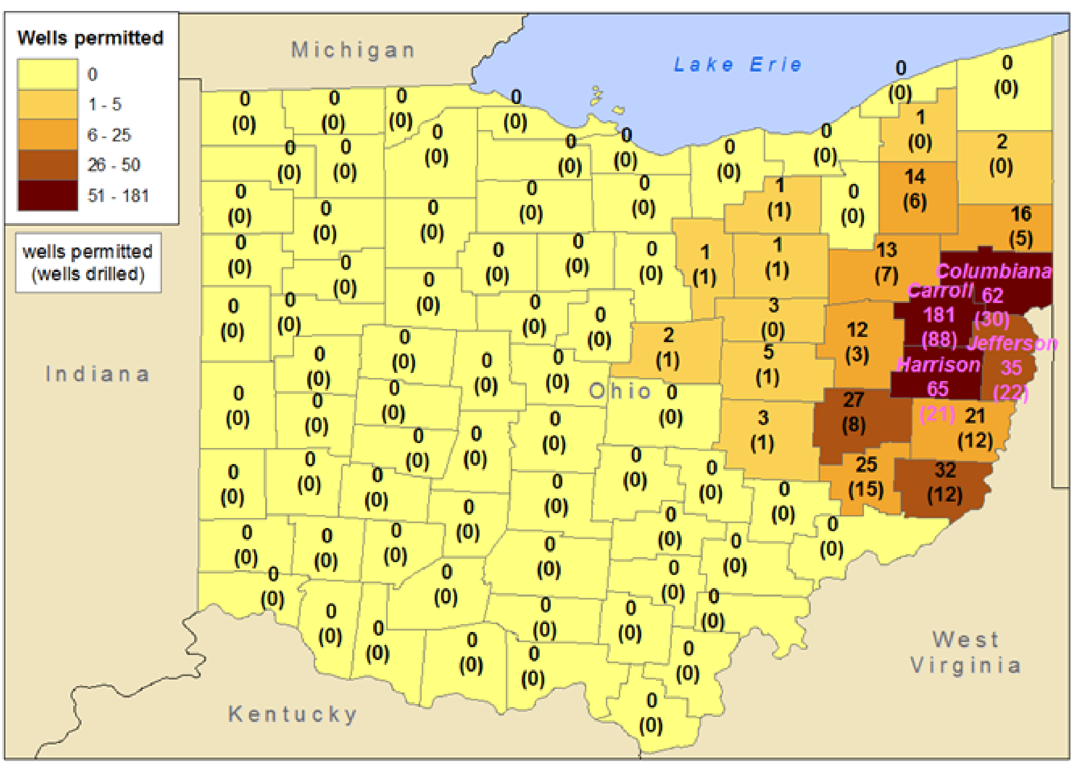
Because shale development doesn't seem to substantially increase rental values in most counties, there does not seem to be urgent need for policy intervention at this time. The existing housing stock, especially hotels for temporary workers, may be sufficient to meet the increased demand in housing. Despite the small impact on rental values and median home prices, housing markets also seem to be appropriately responding to the increase in housing demand and any housing shortages through new development. However, our results do suggest that there may be an increased need for policy intervention once shale drilling reaches a high threshold.

In those counties experiencing the largest increase in drilling activity, policy intervention may be warranted especially if the county is rural, lacking in amenities, and relatively distant from larger cities that could provide housing for commuters. These counties may see a significant increase in rental rates and housing prices. Survey respondents from the drilling counties Bradford, Lycoming, Greene, and Sullivan reported shortages in available rental properties and rents that had doubled or even tripled in some cases (Williamson and Kold, 2011), though our data did not support these stories as being a widespread phenomenon.

Oil and gas workers are prepared to pay higher prices for housing, but local residents may not. In extreme cases, local residents may be evicted from their homes as rental rates increase and forced into substandard housing or even become homeless. Those households on the economic fringe such as low income households, the elderly, and the disabled are the most vulnerable. Tioga County opened its first homeless shelter (Reddy, 2012). Towanda, PA in Bradford County recently opened Grace House offering transitional housing for the homeless (Falchek, 2012).

These may be isolated incidents, but it may also indicate that housing markets do not immediately respond and to build more housing, especially when the shale development is sudden and large. Thus, it is important that drilling counties in Ohio monitor the pace and scale of drilling and how it is affecting the affordability and availability of local housing, especially for those most vulnerable to these effects. Pennsylvania has already responded to the housing needs in counties with extensive shale activity. The Pennsylvania Housing Finance Agency has a grant to build 40 low-income housing units in Bradford County (Falchek, 2012). The Pennsylvania Housing Affordability and Rehabilitation Enhancement (PHARE) Fund and impact fees are being made available to improve housing for low income

Figure 19: Total Wells Drilled in Ohio



Data Source: Ohio Department of Natural Resources, Division of Mineral Resources Management households. These funds will address housing shortages by funding construction, rehab, and rental assistance (Swift, 2012). Because many of the shale workers are temporary, focusing on temporary housing, such as hotels, will be especially effective in addressing the housing impacts. A recent Ohio University report suggested developing apartment complexes, mobile homes, and other temporary housing. The report also suggested rehabbing abandoned homes, which would also reduce neighborhood blight (Ohio University, 2013).

The counties in Ohio most likely to face such issues include Jefferson, Harrison, Columbiana and especially Carroll. As of January 19, 2013, Carroll County had 181 shale wells either drilled or permitted, which is nearly triple the number of wells in nearby counties and accounts for 35% of the 522 total wells drilled or permitted statewide (Ohio Department of Natural Resources, 2013). Figure 22 below shows the number of wells permitted and drilled per county in Ohio. Carroll and Harrison counties may be especially vulnerable to housing market concerns since their populations are even lower than Bradford and Tioga counties. This vulnerability may be mitigated by the relative closeness of larger nearby cities, such as Canton, New Philadelphia, Steubenville and Wheeling, WV for commuting.[10]

Conclusion

Shale boom counties in the Pennsylvania region have experienced a substantial increase in drilling, but at a different pace and scale than the shale oil drilling near Williston, ND. Although many shale boom counties are rural like Williston, they are not as remote. Thus, we would expect the impact of Pennsylvania and Ohio shale development to be more moderate than Williston and the Bakken region of North Dakota. Although Pennsylvanian counties such as Bradford and Tioga have already experienced a sizeable shale boom with measurable impacts on its housing market, our analysis suggests that the impact on housing markets in most Pennsylvania shale counties is fairly small. We expect the same pattern to develop in Ohio over the next two to three years.

The impact on population in most drilling counties in Pennsylvania was small, though counties with the highest level of drilling activity did experience population increases because of the influx of workers. In terms of housing prices, shale drilling is correlated with a reduction in Fair Market Rent in most counties. Again, only those counties with the most shale activity (Bradford and Tioga) experienced increases in Fair Market Rent due to shale development. Regardless of the minimal impacts on housing prices, housing markets in shale counties seem to be responding to the increased housing demand or expected increase in housing demand from shale workers by building single-unit residential housing. The increase in housing development could also be in response to the increase in earnings or income from lease and royalty payments.

Many counties in the Utica and Marcellus shale region can rely on the housing stock of neighboring counties if necessary, whereas hotels can fill the needs of the temporary workforce. In fact, commuting should be a more viable option in Ohio drilling regions, reducing pressures on local housing markets. Until the intensity of drilling increases, major public intervention in the housing market in Ohio seems unnecessary. Yet, policymakers should support the development of hotels, modest increases in low-income housing, and the facilitation of home building through streamlined regulations and financing.

10. The 2011 populations of Bradford and Tioga counties are 62,917 and 42,419 , respectively, compared to Jefferson (68,828), Harrison (15,850), Columbiana (107,570), and Carroll (28,782) in Ohio (Bureau of Economic Analysis, Economic Profiles, 2011).. The county seat of Carroll County (Carrollton) is about 25 miles from both Canton and New Philadelphia while the county seat of Harrison County (Cadiz) is about the same distance from Steubenville and Wheeling, WV (Mapquest, 2013).

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Appendix 1: Statistical Methodology

In our statistical analysis, we primarily use fixed effects panel regression and difference-in-difference (DiD) estimators. We also estimate first-difference regressions when limited by data availability. Our shale gas well data is from the Department of Environmental Protection Office of Oil and Gas Management in Pennsylvania and West Virginia and contains the 'spud date' or the beginning of well drilling for Pennsylvania wells and the well completion date for West Virginia wells between 2000 and 2011. Because it is annual data and the process of well drilling in general only takes a matter of weeks, the start date and completion date occur in the same year for the vast majority of our observations and so combining these two datasets does not raise serious concerns. The other states included, Ohio and New York, had not commenced significant shale well drilling activities before 2012 and so no drilling data is available for them. Because much of the drilling activity did not start in Pennsylvania until 2007, we used that year as the separation between when pre- and post-shale development effects would be evident. We note that some preliminary drilling and other preparations did occur before 2007, but because so few wells were drilled, we believe they have little effect on our results.

We also utilize high-quality employment data from EMSI (Economic Modeling Specialists Intl.), an economic data clearinghouse and consulting firm, as another measure of shale development activities.[11] We use four-digit North American Industry Classification System (NAICS) codes to classify which industries are directly impacted by shale development. The benefit of using this data is that it is not constrained by privacy restrictions in the same way as publicly available data. In order to protect employer privacy, the U.S. Bureau of Labor Statistics (BLS) does not report employment information for counties where only a few employers exist within a certain industry. This often means many small rural counties have incomplete data for more specific industries, such as the ones we use in our analysis. The EMSI employment data accounts for this limitation and provides an imputed employment level for each industry.

We investigate how nearby shale development might affect a number of metrics related to the local housing market. First, we use population changes and vacancy rates to determine whether shale gas development is bringing people to the area and whether those new migrants are occupying existing housing. Since shale development requires importation of specialized workers into the county for relatively short durations, we also looked at the median rental rate, available from the U.S. Census Bureau, and the Fair Market Rent (which most often corresponds to the 40th-percentile rent), calculated by the U.S. Department of Housing and Urban Development. Shale development also creates long term employment. Accordingly, we also analyze how the median home values changed and whether an effect could be seen in the number of new residential housing construction permits approved. Both the median home value data and the construction permit data are from the U.S. Census Bureau.

To control for other primary factors affecting the local housing market, we include variables for county population, median per-capita income, poverty rate, and expected economic growth based on a county's initial industry composition. We obtained annual county-level data from the U.S. Bureau of Labor Statistics regarding population and median per-capita personal income. The poverty data is from the U.S. Census Bureau via the Small Area Income and Poverty Estimates (SAIPE) program. Expected economic growth is calculated using EMSI data by multiplying the employment share of each four-digit industry in the county by the industry's national growth rate and summing across all industries in the county. This provides the expected percentage increase in employment assuming that the county's four digit industries all grew at the national rate. Accounting for expected employment growth is important so that we can decompose what would have happened in the county if there was no drilling as compared to what happens with drilling. We also control for level of urbanization and cultural and geographic influences by including

11. The specific NAICS codes we utilized to capture shale development employment effects are: 2111-Oil and Gas Extraction; 2131-Support Activities for Mining; 5413 –Architectural, Engineering, and Related Services; 2389–Other Specialty Trade Contractors; 3331–Agriculture, Construction, and Mining Machinery Manufacturing; 4862–Pipeline Transportation of Natural Gas; 2371–Utility System Construction

dummy variables for whether a county was part of a Metropolitan Statistical Area (MSA), as defined by the U.S. Census Bureau, and whether it belonged to the Appalachian region, as defined by the Appalachian Regional Commission.

The data from the U.S. Census Bureau for median rent, median home value, and vacancy rate is only available in the decennial Census and the recently implemented American Community Survey (ACS). Since many of the counties included in the analysis have low populations, county-specific ACS data is only available in the form of 5-Year Estimates. Therefore we analyzed how these measures changed between the 2000 U.S. Census and the 2011 ACS 5-Year Moving Average Estimates (which span 2007-2011, centered on 2009). This provides us with a pre-shale development measure and an averaged mid-development measure. The limited data is likely a large part of the reason why these regressions show the least significance for the shale development metrics we use.

Each model was estimated with the dependent and explanatory variables in levels, logs and percent change. We use two specifications for each model: one which included shale wells drilled as the key explanatory variable and one which includes shale-related employment as the key explanatory variable. The results from the regression of levels show how the values of the dependent variable are correlated with the key explanatory variables. When the dependent and explanatory variables are in natural logarithm form, the results show whether the housing measures and the explanatory variables are proportionally related – for example, if shale development employment increased 1%, what is the corresponding expected percentage increase in the Fair Market Rent. We also estimate models of the percent change in the dependent and explanatory variables.

Panel Data Analysis

The two-way fixed-effects regressions used data from 1997-2011 – the years for which data covering all variables was available, providing a balanced dataset of 2,160 observations across the 144 counties in the sample.

Panel regression:

$$X = \alpha + \beta_1 * \eta + \beta_2 * \eta^2 + \delta * \Phi + \rho * \Lambda + \tau * \Theta + \sigma * \Omega + \varepsilon$$

where:

- X: *The measure of housing availability or affordability under consideration (ie: population, Fair Market Rent, or residential building permits approved).*
- η, η^2: *The shale development metric of interest (ie: the number of shale wells drilled or jobs associated with shale development). The squared value is used as an additional explanatory variable because of possible non-linear effects.*
- Φ: *A set of additional explanatory variables controlling for the effects of population, per-capita income, percent of the population in poverty, and expected economic growth based on industry composition. For the regressions using the natural logarithms or the percentage growth of housing measures as dependent variables, the population and per-capita income were also used with the same transformation. The poverty and economic growth variables were not altered as they are already in percentage format.*
- Λ: *A set of dummy variables controlling for whether the county is in a Metropolitan Statistical Area or is part of the Appalachian region.*
- Θ: *A set of dummy variables controlling for time fixed effects.*
- Ω: *A set of dummy variables controlling for county-specific fixed effects.*
- ε: *The regression error term.*
- α, β_1, β_2, δ, ρ, τ, σ: *The regression constant and linear regression parameters to be estimated.*

Appendix 1: Statistical Methodology

Difference-in-Difference Analysis

Difference-in-difference (DiD) estimators are useful in situations where the data arise from a natural experiment. They also have the advantage of differencing out unmeasured fixed effects that could affect growth in a county. In our case, the shale gas boom occurred very rapidly in areas that contained shale gas reserves. The time period just prior to the boom provides a good estimate of housing market behavior in counties with shale drilling to compare to housing market behavior after the boom, providing us with a test of whether changes in the housing market are influenced by shale gas drilling. The mathematical implementation of the DID estimator is as follows:

DiD: $FMR_{DiD} = \{FMR_{2011} - FMR_{2007}\} - \{FMR_{2007} - FMR_{2003}\}$

The FMR_{DiD} value for a county represents the difference in the change in FMR between 2003-2007 (the pre-shale development period) and 2007-2011 (the period during which most Pennsylvania shale wells were drilled). This method uses a single observation for each county in the dataset, limiting our analysis to 144 observations. Despite this, DiD is very good at controlling for several different kinds of statistical concerns from unobservable factors that could possibly affect our results. The natural logarithm of the dependent and explanatory variables and their relevant proportional changes were also analyzed. The structure of these equations is as follows:

DiD_{log}: $FMR_{DiDlog} = \{\log(FMR_{2011}) - \log(FMR_{2007})\} - \{\log(FMR_{2007}) - \log(FMR_{2003})\}$

$DiD_{\%\Delta}$: $FMR_{DiD\%\Delta} = \{\%\Delta FMR_{2007\text{-}2011}\} - \{\%\Delta FMR_{2003\text{-}2007}\}$

where,

$$\%\Delta FMR_{2007\text{-}2011} = \{FMR_{2011} - FMR_{2007}\} / FMR_{2007} * 100\%$$

The DiD estimator is described by the follow equation:

$$X = \alpha + \beta_1*\eta + \beta_2*\eta^2 + \delta*\Phi + \rho*\Lambda + \gamma*\Psi + \varepsilon$$

where:

- X: *The DiD, DiD_{log}, or $DiD_{\%\Delta}$ measure of housing availability or affordability under consideration (ie: population, Fair Market Rent and residential building permits approved).*
- η, η^2: *The DiD, DiD_{log}, or $DiD_{\%\Delta}$ in shale development-related employment. We only consider shale wells drilled during 2007-2011for the difference-in-difference analyses so this metric is kept in level form rather than using its log or percent change for the DiD_{log} and $DiD_{\%\Delta}$ regressions. Also, this value is squared and used as an additional explanatory variable because of possible non-linear effects.*
- Φ: *A set of additional explanatory variables controlling for the differenced effects of population, per-capita income, poverty and expected economic growth based on the county's initial industry composition. For the regressions using the DiD_{log} or $DiD_{\%\Delta}$ housing measures as dependent variables the population and per-capita income were also used in DiD_{log} and $DiD_{\%\Delta}$ format. The poverty and economic growth variables were not altered as they are already in percentage format.*
- Λ: *A set of dummy variables controlling for whether the county is in a Metropolitan Statistical Area or is part of the Appalachian region.*
- Ψ: *A set of explanatory variables controlling for initial values in the year 2000 (logged values of the dependent variable, population, and per-capita income, as well as the percent of population in poverty).*
- ε: *The regression error term.*

Appendix 1: Statistical Methodology

$\alpha, \beta_1, \beta_2, \delta, \rho, \gamma$:	*The regression constant and linear regression parameters to be estimated.*

First-difference Analysis

Our regressions involving U.S. Census-specific data were limited to using observations from the 2000 Census and 2011 ACS 5-Year Moving Average Estimates. The metrics for shale development utilized were the total number of shale wells drilled in each county from 2007-2011 and the increase in shale development employment between 2006 and 2011.[12] Differencing between the year 2011 and year 2000 observations was used to control for county-specific effects. This differencing makes this analysis similar to the difference-in-difference analysis, but because of the data limitations there is no way to compare the 'before' and 'after' effects of shale development on a county – only the 'between-county' effects can be estimated. Differencing in this way limits the analysis to one observation for each county. We also use the first-difference in the natural logarithm and the percent change in the relevant measures in supplemental regressions. The following is an example of the structure of the variables used in the first-difference regressions:

Differenced: $MedianRent_{Diff} = MedianRent_{2011} - MedianRent_{2000}$

$Diff_{log}$: $MedianRent_{logDiff} = log(MedianRent_{2011}) - log(MedianRent_{2000})$

$Diff_{\%\Delta}$: $MedianRent_{\%\Delta Diff} = \%\Delta MedianRent_{2000\text{-}2011}$

where,

$$\%\Delta MedianRent_{2000\text{-}2011} = \{MedianRent_{2011} - MedianRent_{2000}\} / MedianRent_{2000} * 100\%$$

Our first-difference regression utilized the following structure:

$$X = \alpha + \beta_1 * \eta + \beta_2 * \eta^2 + \delta * \Phi + \rho * \Lambda + \gamma * \Psi + \varepsilon$$

where:

- X: *The differenced, $Diff_{log}$, or $Diff_{\%\Delta}$ measure of housing availability or affordability under consideration (ie: Median Rent, Median Home Value or Vacancy Rate).*
- η, η^2: *The difference, $Diff_{log}$, or $Diff_{\%\Delta}$ in shale development-related employment between 2006-2011. We only considered shale wells drilled during 2007-2011for the difference analyses so this metric is kept in level form rather than using its log or percent change for the $Diff_{log}$ and $Diff_{\%\Delta}$ regressions. Also, this value is squared and used as an additional explanatory variable because of possible non-linear effects.*
- Φ: *A set of additional explanatory variables controlling for the differenced effects of population, per-capita income, poverty and expected economic growth on the housing measure studied. For the regressions using the $Diff_{log}$ or $Diff_{\%\Delta}$ housing measures as dependent variables, the population and median per-capita income were also used in $Diff_{log}$ and $Diff_{\%\Delta}$ form. The poverty and economic growth variables were not altered as they are already in percentage format.*
- Λ: *A set of dummy variables controlling for whether the county is in a Metropolitan Statistical Area or is part of the Appalachian region.*
- Ψ: *A set of explanatory variables controlling for initial values in the year 2000 (logged values of the population, per-capita income, median rent and median home value, as well as the percent of population in poverty and the vacancy rate).*

12. By using 2006 as the base year, the increase in shale development jobs between 2006-2007 is incorporated into the regression, making the time period of the employment analysis equivalent to that of the wells analysis.

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ε: The regression error term.

$\alpha, \beta_1, \beta_2, \delta, \rho, \gamma$: The regression constant and linear regression parameters to be estimated.

The results of these regressions with robust standard errors are provided in the following tables. In general, the number of shale wells drilled provided stronger and more significant results than changes in oil and gas employment. In the two-way fixed effects models we analyzed both the wells drilled in the current year as well as the wells drilled in the previous year to determine if there were different lagging effects than contemporary effects on housing measures. Our results show that the lagged wells drilled variable had nearly the same effect as the contemporaneous wells drilled variable, although this could be simply due to the structure of the data.[13] We are most confident in the results obtained from the DiD models and the two-way fixed effects models.

Table 1: Two-Way Fixed Effects Regression; Shale Development Employment (Levels)

Explanatory Variables [1]	Res. Bldg. Permits (1 Units)	Res. Bldg. Permits (2 Units)	Res. Bldg. Permits (3-4 Units)	Res. Bldg. Permits (5+ Units)
Shale Dev. Empl.	.1331 (.0805)	-5.3e-04 (.0023)	.0034 (.0033)	.0048 (.0038)
Shale Dev. Empl. Squared	1.1e-06 (8.2e-06)	5.7e-08 (8.8e-08)	-2.1e-08 (2.3e-07)	-7.9e-08 (3.5e-07)
R-squared	0.382	0.040	0.118	0.075
Adjusted R-squared	0.376	0.031	0.109	0.067
F	12.77	3.360	3.068	3.895
Observations	2160	2160	2160	2160

Table 2: Two-Way Fixed Effects Regression; Shale Wells Drilled (Levels)

Explanatory Variables [1]	Res. Bldg. Permits (1 Units)	Res. Bldg. Permits (2 Units)	Res. Bldg. Permits (3-4 Units)	Res. Bldg. Permits (5+ Units)
Shale Wells Drilled	2.529*** (.956)	.0239 (.0296)	.0073 (.0204)	.0085 (.026)
Shale Wells Drilled Squared	-.0057** (.0027)	-5.7e-05 (7.9e-05)	-1.5e-05 (5.3e-05)	-1.4e-05 (6.4e-05)
R-squared	0.359	0.039	0.104	0.066
Adjusted R-squared	0.353	0.030	0.096	0.057
F	10.52	3.381	2.742	3.382
Observations	2160	2160	2160	2160

Table 3: Two-Way Fixed Effects Regression; Prev. Year Shale Wells Drilled (Levels)

Explanatory Variables [1]	Res. Bldg. Permits (1 Units)	Res. Bldg. Permits (2 Units)	Res. Bldg. Permits (3-4 Units)	Res. Bldg. Permits (5+ Units)
Prev. Year Shale Wells Drilled	2.728** (1.119)	.0185 (.0281)	.0032 (.0232)	-.0021 (.0372)
Prev. Year Shale Wells Drilled Squared	-.0062** (.0031)	-4.6e-05 (7.5e-05)	-8.9e-07 (6.2e-05)	1.4e-05 (9.5e-05)
R-squared	0.384	0.033	0.093	0.090
Adjusted R-squared	0.378	0.024	0.085	0.081
F	11.49	3.148	2.827	3.489
Observations	2016	2016	2016	2016

__Notes:__ Each column denotes a single regression. Each value listed denotes the coefficient estimate for the explanatory variable at the left for the dependent variable listed above. Robust standard errors of coefficient estimates are shown in parentheses. We also control for the effects of each county's population, median per-capita income, poverty rate, and expected employment growth based the county's industry composition. We include dummy variables to control for urbanization if the county is part of a MSA (Metropolitan Statistical Area) and geographical/cultural effects if it is part of the Appalachian region.

* - Denotes statistical significance of 10% or better. (p-value < 0.10); ** - Denotes statistical significance of 5% or better. (p-value < 0.05); *** - Denotes statistical significance of 1% or better. (p-value < 0.01)

[1] - Shale Dev. Empl. denotes NAICS (North American Industry Classification System) industry codes which are connected with shale development employment. The specific NAICS codes we utilized to capture shale development employment effects are: 2111-Oil and Gas Extraction; 2131-Support Activities for Mining; 5413 –Architectural, Engineering, and Related Services; 2389–Other Specialty Trade Contractors; 3331–Agriculture, Construction, and Mining Machinery Manufacturing; 4862–Pipeline Transportation of Natural Gas; 2371–Utility System Construction

13. Since the number of wells drilled per year per county only increases in most of the cases from 2007-2011, we are not able to determine the effect on housing measures when drilling activity slumps after the peak of the boom.

Table 4: Two-Way Fixed Effects Regression; Shale Development Employment (Logs)

Explanatory Variables[1]	log(Population)	log(FMR) (0 Bedrooms)	log(FMR) (1 Bedrooms)	log(FMR) (2 Bedrooms)	log(FMR) (3 Bedrooms)	log(FMR) (4 Bedrooms)
log(Shale Dev. Empl.)	.0477 (.0933)	-.00266 (.122)	.185** (.0845)	.114 (.071)	.0821 (.0757)	.111 (.103)
log(Shale Dev. Empl.) Squared	-.00087 (.00695)	.00035 (.0094)	-.0137** (.00642)	-.00879 (.00552)	-.00724 (.00589)	-.0106 (.00769)
R-squared	0.202	0.890	0.893	0.888	0.865	0.793
Adjusted R-squared	0.195	0.889	0.892	0.887	0.864	0.791
F	3.651	612.9	811.8	1011.7	859.6	545.6
Observations	2175	2175	2175	2175	2175	2175

Table 5: Two-Way Fixed Effects Regression; Shale Wells Drilled (Logs)

Explanatory Variables[1]	log(Population)	log(FMR) (0 Bedrooms)	log(FMR) (1 Bedrooms)	log(FMR) (2 Bedrooms)	log(FMR) (3 Bedrooms)	log(FMR) (4 Bedrooms)
Shale Wells Drilled	-.00019 (.00017)	-3.2e-06 (.00031)	-.00026 (.00021)	-.00041** (.0002)	-.00052** (.00022)	-.00082*** (.00031)
Shale Wells Drilled Squared	6.1e-07 (4.5e-07)	-4.4e-07 (7.6e-07)	8.1e-07 (5.8e-07)	1.0e-06* (5.5e-07)	1.3e-06* (6.5e-07)	2.4e-06*** (9.0e-07)
R-squared	0.174	0.897	0.898	0.894	0.871	0.798
Adjusted R-squared	0.167	0.896	0.897	0.893	0.870	0.796
F	3.786	973.6	1585.2	1934.1	1417.9	913.3
Observations	2160	2160	2160	2160	2160	2160

Table 6: Two-Way Fixed Effects Regression; Prev. Year Shale Wells Drilled (Logs)

Explanatory Variables[1]	log(Population)	log(FMR) (0 Bedrooms)	log(FMR) (1 Bedrooms)	log(FMR) (2 Bedrooms)	log(FMR) (3 Bedrooms)	log(FMR) (4 Bedrooms)
Prev. Year Shale Wells Drilled	-.0001 (.00019)	-.00031 (.00035)	-.0004 (.00029)	-.00061** (.00026)	-.00074*** (.00026)	-.001*** (.00033)
Prev. Year Shale Wells Drilled Squared	5.1e-07 (5.4e-07)	3.8e-07 (8.4e-07)	1.2e-06 (7.9e-07)	1.5e-06** (7.2e-07)	1.9e-06** (7.3e-07)	3.0e-06*** (9.7e-07)
R-squared	0.186	0.890	0.892	0.887	0.863	0.784
Adjusted R-squared	0.179	0.889	0.891	0.886	0.862	0.782
F	4.077	960.4	1677.2	1793.0	1376.3	897.0
Observations	2016	2016	2016	2016	2016	2016

__Notes:__ Each column denotes a single regression. Each value listed denotes the coefficient estimate for the explanatory variable at the left for the dependent variable listed above. Robust standard errors of coefficient estimates are shown in parentheses. We also control for the effects of each county's population, median per-capita income, poverty rate, and expected employment growth based the county's industry composition. We include dummy variables to control for urbanization if the county is part of a MSA (Metropolitan Statistical Area) and geographical/cultural effects if it is part of the Appalachian region.

* - Denotes statistical significance of 10% or better. (p-value < 0.10); ** - Denotes statistical significance of 5% or better. (p-value < 0.05); *** - Denotes statistical significance of 1% or better. (p-value < 0.01)

[1] - Shale Dev. Empl. denotes NAICS (North American Industry Classification System) industry codes which are connected with shale development employment. The specific NAICS codes we utilized to capture shale development employment effects are: 2111-Oil and Gas Extraction; 2131-Support Activities for Mining; 5413 –Architectural, Engineering, and Related Services; 2389–Other Specialty Trade Contractors; 3331–Agriculture, Construction, and Mining Machinery Manufacturing; 4862–Pipeline Transportation of Natural Gas; 2371–Utility System Construction

Table 7: Two-Way Fixed Effects Regression; Shale Development Employment (Percent Change)

Explanatory Variables[1]	Percent Increase in Population	Percent Increase in FMR (0 Bedrooms)	Percent Increase in FMR (1 Bedrooms)	Percent Increase in FMR (2 Bedrooms)	Percent Increase in FMR (3 Bedrooms)	Percent Increase in FMR (4 Bedrooms)
Percent Increase in Shale Dev. Empl.	.021 (.042)	-.276*** (.084)	-.12 (.074)	-.084 (.079)	-.156* (.092)	-.077 (.115)
Percent Increase in Shale Dev. Empl. Squared	1.5e-03 (3.2e-03)	-.04*** (4.9e-03)	-.017*** (5.2e-03)	-.017*** (6.2e-03)	-.027*** (5.4e-03)	-.01 (8.8e-03)
R-squared	0.081	0.434	0.212	0.197	0.189	0.193
Adjusted R-squared	0.073	0.429	0.205	0.190	0.181	0.185
F	8.102	212.5	212.2	215.3	179.2	168.9
Observations	2175	2160	2160	2160	2160	2160

Table 8: Two-Way Fixed Effects Regression; Shale Wells Drilled (Percent Change)

Explanatory Variables[1]	Percent Increase in Population	Percent Increase in FMR (0 Bedrooms)	Percent Increase in FMR (1 Bedrooms)	Percent Increase in FMR (2 Bedrooms)	Percent Increase in FMR (3 Bedrooms)	Percent Increase in FMR (4 Bedrooms)
Shale Wells Drilled	5.2e-03*** (1.9e-03)	-.032** (.014)	-.025** (.013)	-.025* (.013)	-.025* (.014)	-.022 (.015)
Shale Wells Drilled Squared	-6.8e-06 (4.3e-06)	9.4e-05** (4.1e-05)	7.1e-05* (3.7e-05)	7.2e-05* (3.9e-05)	7.0e-05* (4.1e-05)	6.0e-05 (4.3e-05)
R-squared	0.087	0.435	0.214	0.199	0.190	0.194
Adjusted R-squared	0.079	0.429	0.207	0.192	0.183	0.186
F	10.71	215.5	199.6	194.9	166.8	159.8
Observations	2160	2160	2160	2160	2160	2160

Table 9: Two-Way Fixed Effects Regression; Prev. Year Shale Wells Drilled (Percent Change)

Explanatory Variables[1]	Percent Increase in Population	Percent Increase in FMR (0 Bedrooms)	Percent Increase in FMR (1 Bedrooms)	Percent Increase in FMR (2 Bedrooms)	Percent Increase in FMR (3 Bedrooms)	Percent Increase in FMR (4 Bedrooms)
Prev. Year Shale Wells Drilled	6.2e-03*** (2.2e-03)	-.033** (.015)	-.026* (.014)	-.026* (.014)	-.026* (.015)	-.024 (.016)
Prev. Year Shale Wells Drilled Squared	-9.2e-06 (6.0e-06)	9.8e-05** (4.3e-05)	7.2e-05* (3.9e-05)	7.5e-05* (4.0e-05)	7.4e-05* (4.3e-05)	6.5e-05 (4.4e-05)
R-squared	0.097	0.432	0.211	0.196	0.188	0.194
Adjusted R-squared	0.089	0.426	0.203	0.189	0.181	0.186
F	7.739	223.2	194.3	190.1	160.1	147.2
Observations	2016	2016	2016	2016	2016	2016

__Notes:__ Each column denotes a single regression. Each value listed denotes the coefficient estimate for the explanatory variable at the left for the dependent variable listed above. Robust standard errors of coefficient estimates are shown in parentheses. We also control for the effects of each county's population, median per-capita income, poverty rate, and expected employment growth based the county's industry composition. We include dummy variables to control for urbanization if the county is part of a MSA (Metropolitan Statistical Area) and geographical/cultural effects if it is part of the Appalachian region.

* - Denotes statistical significance of 10% or better. (p-value < 0.10); ** - Denotes statistical significance of 5% or better. (p-value < 0.05); *** - Denotes statistical significance of 1% or better. (p-value < 0.01)

[1] - Shale Dev. Empl. denotes NAICS (North American Industry Classification System) industry codes which are connected with shale development employment. The specific NAICS codes we utilized to capture shale development employment effects are: 2111-Oil and Gas Extraction; 2131-Support Activities for Mining; 5413 –Architectural, Engineering, and Related Services; 2389–Other Specialty Trade Contractors; 3331–Agriculture, Construction, and Mining Machinery Manufacturing; 4862–Pipeline Transportation of Natural Gas; 2371–Utility System Construction

Table 10: Difference-in-Difference Regression; Shale Development Employment (Levels)

Explanatory Variables[1]	Difference in Avg. Annual Res. Bldg. Permits (1 Units)	Difference in Avg. Annual Res. Bldg. Permits (2 Units)	Difference in Avg. Annual Res. Bldg. Permits (3-4 Units)	Difference in Avg. Annual Res. Bldg. Permits (5+ Units)
DiD Shale Dev. Empl.	.4353 (.2898)	-4.0e-04 (.006)	.0059 (.0062)	.0061* (.0036)
DiD Shale Dev. Empl. Squared	-1.1e-04 (1.5e-04)	1.6e-06 (3.6e-06)	-1.2e-06 (2.7e-06)	-8.3e-07 (3.7e-06)
R-squared	0.573	0.353	0.379	0.476
Adjusted R-squared	0.531	0.289	0.316	0.424
F	15.89	4.076	2.873	2.982
Observations	144	144	144	144

Table 11: Difference-in-Difference Regression; Shale Wells Drilled (Levels)

Explanatory Variables[1]	Difference in Avg. Annual Res. Bldg. Permits (1 Units)	Difference in Avg. Annual Res. Bldg. Permits (2 Units)	Difference in Avg. Annual Res. Bldg. Permits (3-4 Units)	Difference in Avg. Annual Res. Bldg. Permits (5+ Units)
Shale Wells Drilled 2007-2011	2.304** (1.013)	.0189 (.0273)	-.0144 (.024)	-.0102 (.0195)
Shale Wells Drilled 2007-2011 Squared	-.002* (.0011)	-1.5e-05 (3.2e-05)	1.4e-05 (2.8e-05)	1.3e-05 (2.2e-05)
R-squared	0.534	0.350	0.367	0.454
Adjusted R-squared	0.488	0.285	0.304	0.399
F	10.19	3.850	2.869	2.106
Observations	144	144	144	144

Notes: Each column denotes a single regression. Each value listed denotes the coefficient estimate for the explanatory variable at the left for the dependent variable listed above. Robust standard errors of coefficient estimates are shown in parentheses. We also control for the effects of each county's population, median per-capita income, poverty rate, and expected employment growth based the county's industry composition. We include dummy variables to control for urbanization if the county is part of a MSA (Metropolitan Statistical Area) and geographical/cultural effects if it is part of the Appalachian region. We use the logged Year 2000 values of population, median per-capita income and the dependent variable and the Year 2000 values of poverty rate and expected employment growth to control for initial levels.

* - Denotes statistical significance of 10% or better. (p-value < 0.10); ** - Denotes statistical significance of 5% or better. (p-value < 0.05); *** - Denotes statistical significance of 1% or better. (p-value < 0.01)

[1] - Shale Dev. Empl. denotes NAICS (North American Industry Classification System) industry codes which are connected with shale development employment. The specific NAICS codes we utilized to capture shale development employment effects are: 2111-Oil and Gas Extraction; 2131-Support Activities for Mining; 5413 –Architectural, Engineering, and Related Services; 2389–Other Specialty Trade Contractors; 3331–Agriculture, Construction, and Mining Machinery Manufacturing; 4862–Pipeline Transportation of Natural Gas; 2371–Utility System Construction

Table 12: Difference-in-Difference Regression; Shale Development Employment (Logs)

Explanatory Variables[1]	DiD log(Population)	DiD log(FMR) (0 Bedrooms)	DiD log(FMR) (1 Bedrooms)	DiD log(FMR) (2 Bedrooms)	DiD log(FMR) (3 Bedrooms)	DiD log(FMR) (4 Bedrooms)
DiD log(Shale Dev. Empl.)	.0204** (.00987)	-.0497 (.0415)	.00718 (.0239)	.0181 (.02)	.013 (.0248)	.0102 (.0328)
DiD log(Shale Dev. Empl.) Squared	-.00684 (.0128)	-.0139 (.0504)	-.054* (.0292)	-.00814 (.023)	-.0151 (.0305)	-.0198 (.0562)
R-squared	0.381	0.148	0.185	0.221	0.289	0.307
Adjusted R-squared	0.329	0.063	0.104	0.143	0.218	0.237
F	5.115	2.978	2.987	3.834	6.153	7.140
Observations	144	144	144	144	144	144

Table 13: Difference-in-Difference Regression; Shale Wells Drilled (Logs)

Explanatory Variables[1]	DiD log(Population)	DiD log(FMR) (0 Bedrooms)	DiD log(FMR) (1 Bedrooms)	DiD log(FMR) (2 Bedrooms)	DiD log(FMR) (3 Bedrooms)	DiD log(FMR) (4 Bedrooms)
Shale Wells Drilled 2007-2011	1.4e-05 (4.9e-05)	-.00095*** (.00031)	-.00061** (.00025)	-.0006** (.00025)	-.00062** (.00028)	-.0004 (.00034)
Shale Wells Drilled 2007-2011 Squared	2.5e-08 (5.5e-08)	1.2e-06*** (3.3e-07)	6.6e-07** (2.8e-07)	6.8e-07** (2.8e-07)	7.2e-07** (3.1e-07)	3.8e-07 (3.8e-07)
R-squared	0.349	0.230	0.242	0.282	0.342	0.331
Adjusted R-squared	0.295	0.153	0.166	0.210	0.276	0.264
F	4.413	4.625	3.005	3.980	6.992	7.258
Observations	144	144	144	144	144	144

Notes: Each column denotes a single regression. Each value listed denotes the coefficient estimate for the explanatory variable at the left for the dependent variable listed above. Robust standard errors of coefficient estimates are shown in parentheses. We also control for the effects of each county's population, median per-capita income, poverty rate, and expected employment growth based the county's industry composition. We include dummy variables to control for urbanization if the county is part of a MSA (Metropolitan Statistical Area) and geographical/cultural effects if it is part of the Appalachian region. We use the logged Year 2000 values of population, median per-capita income and the dependent variable and the Year 2000 values of poverty rate and expected employment growth to control for initial levels.

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[1] - Shale Dev. Empl. denotes NAICS (North American Industry Classification System) industry codes which are connected with shale development employment. The specific NAICS codes we utilized to capture shale development employment effects are: 2111-Oil and Gas Extraction; 2131-Support Activities for Mining; 5413 –Architectural, Engineering, and Related Services; 2389–Other Specialty Trade Contractors; 3331–Agriculture, Construction, and Mining Machinery Manufacturing; 4862–Pipeline Transportation of Natural Gas; 2371–Utility System Construction

Table 14: Difference-in-Difference Regression; Shale Development Employment (Percent Change)

Explanatory Variables[1]	Difference in Percent Increase in Population	Difference in Percent Increase in FMR (0 Bedrooms)	Difference in Percent Increase in FMR (1 Bedrooms)	Difference in Percent Increase in FMR (2 Bedrooms)	Difference in Percent Increase in FMR (3 Bedrooms)	Difference in Percent Increase in FMR (4 Bedrooms)
Difference in Percent Increase in Shale Dev. Empl.	.497** (.221)	-1.58 (1)	.199 (.725)	.358 (.523)	.418 (.645)	.636 (.943)
Difference in Percent Increase in Shale Dev. Empl. Squared	6.4e-03 (.011)	-8.3e-03 (.062)	.03 (.04)	.041 (.031)	.051 (.035)	.041 (.05)
R-squared	0.395	0.167	0.176	0.222	0.293	0.301
Adjusted R-squared	0.345	0.084	0.093	0.144	0.222	0.231
F	8.972	4.941	2.426	3.366	5.693	6.591
Observations	144	144	144	144	144	144

Table 15: Difference-in-Difference Regression; Shale Wells Drilled (Percent Change)

Explanatory Variables[1]	Difference in Percent Increase in Population	Difference in Percent Increase in FMR (0 Bedrooms)	Difference in Percent Increase in FMR (1 Bedrooms)	Difference in Percent Increase in FMR (2 Bedrooms)	Difference in Percent Increase in FMR (3 Bedrooms)	Difference in Percent Increase in FMR (4 Bedrooms)
Shale Wells Drilled 2007-2011	1.5e-03 (5.2e-03)	-.112*** (.037)	-.067** (.028)	-.065** (.027)	-.067** (.031)	-.043 (.036)
Shale Wells Drilled 2007-2011 Squared	2.7e-06 (5.8e-06)	1.4e-04*** (3.8e-05)	7.1e-05** (3.0e-05)	7.4e-05** (3.0e-05)	7.8e-05** (3.3e-05)	4.1e-05 (4.0e-05)
R-squared	0.350	0.226	0.237	0.279	0.340	0.322
Adjusted R-squared	0.296	0.149	0.161	0.206	0.274	0.254
F	4.253	4.613	2.963	3.935	6.550	6.885
Observations	144	144	144	144	144	144

__Notes:__ Each column denotes a single regression. Each value listed denotes the coefficient estimate for the explanatory variable at the left for the dependent variable listed above. Robust standard errors of coefficient estimates are shown in parentheses. We also control for the effects of each county's population, median per-capita income, poverty rate, and expected employment growth based the county's industry composition. We include dummy variables to control for urbanization if the county is part of a MSA (Metropolitan Statistical Area) and geographical/cultural effects if it is part of the Appalachian region. We use the logged Year 2000 values of population, median per-capita income and the dependent variable and the Year 2000 values of poverty rate and expected employment growth to control for initial levels.

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[1] - Shale Dev. Empl. denotes NAICS (North American Industry Classification System) industry codes which are connected with shale development employment. The specific NAICS codes we utilized to capture shale development employment effects are: 2111-Oil and Gas Extraction; 2131-Support Activities for Mining; 5413 –Architectural, Engineering, and Related Services; 2389–Other Specialty Trade Contractors; 3331–Agriculture, Construction, and Mining Machinery Manufacturing; 4862–Pipeline Transportation of Natural Gas; 2371–Utility System Construction

Table 16: First-Differenced Regression; Shale Development Employment (Logs)

Explanatory Variables[1]	Change in Vacancy Rate (%) 2000-2011	Change in log(Median Home Value) 2000-2011	Change in log(Median Rent) 2000-2011
Change in log(Shale Dev. Empl. 2006-2011)	-.628 (.852)	-.106* (.0572)	-.0211 (.0159)
Change in log(Shale Dev. Empl. 2006-2011) Squared	1.07 (1.17)	.171** (.0675)	.0234 (.0208)
R-squared	0.427	0.484	0.190
Adjusted R-squared	0.360	0.421	0.095
F	7.040	9.319	2.195
Observations	144	138	144

Table 17: First-Differenced Regression; Shale Wells Drilled (Logs)

Explanatory Variables[1]	Change in Vacancy Rate (%) 2000-2011	Change in log(Median Home Value) 2000-2011	Change in log(Median Rent) 2000-2011
Shale Wells Drilled 2007-2011	-.00071 (.00276)	8.9e-05 (.00013)	.00017*** (6.3e-05)
Shale Wells Drilled 2007-2011 Squared	1.2e-06 (3.2e-06)	-7.1e-08 (1.4e-07)	-2.1e-07*** (6.7e-08)
R-squared	0.418	0.439	0.197
Adjusted R-squared	0.350	0.370	0.103
F	7.158	9.219	2.570
Observations	144	138	144

__Notes:__ Each column denotes a single regression. Each value listed denotes the coefficient estimate for the explanatory variable at the left for the dependent variable listed above. Robust standard errors of coefficient estimates are shown in parentheses. We also control for the effects of each county's population, median per-capita income, poverty rate, and expected employment growth based the county's industry composition. We include dummy variables to control for urbanization if the county is part of a MSA (Metropolitan Statistical Area) and geographical/cultural effects if it is part of the Appalachian region. We use the logged Year 2000 values of population, median per-capita income, median rent and median home value and the Year 2000 values of the poverty rate, expected employment growth and vacancy rate to control for initial levels.

* - Denotes statistical significance of 10% or better. (p-value < 0.10); ** - Denotes statistical significance of 5% or better. (p-value < 0.05); *** - Denotes statistical significance of 1% or better. (p-value < 0.01)

[1] - Shale Dev. Empl. denotes NAICS (North American Industry Classification System) industry codes which are connected with shale development employment. The specific NAICS codes we utilized to capture shale development employment effects are: 2111-Oil and Gas Extraction; 2131-Support Activities for Mining; 5413 –Architectural, Engineering, and Related Services; 2389–Other Specialty Trade Contractors; 3331–Agriculture, Construction, and Mining Machinery Manufacturing; 4862–Pipeline Transportation of Natural Gas; 2371–Utility System Construction

Table 18: First-Differenced Regression; Shale Development Employment (Percent Change)

Explanatory Variables[1]	Change in Vacancy Rate (%) 2000-2011	Percent Increase in Median Home Value 2000-2011	Percent Increase in Median Rent 2000-2011
Percent Increase in Shale Dev. Empl. Share 2006-2011	-.029 (.081)	-1.66** (.691)	-.19 (.318)
Percent Increase in Shale Dev. Empl. Share 2006-2011 Squared	-.016* (9.2e-03)	.463*** (.087)	.064 (.046)
R-squared	0.418	0.494	0.175
Adjusted R-squared	0.350	0.432	0.078
F	7.175	18.11	2.789
Observations	144	138	144

Table 19: First-Differenced Regression; Shale Wells Drilled (Percent Change)

Explanatory Variables[1]	Change in Vacancy Rate (%) 2000-2011	Percent Increase in Median Home Value 2000-2011	Percent Increase in Median Rent 2000-2011
Shale Wells Drilled 2007-2011	-9.3e-04 (2.7e-03)	1.0e-02 (.019)	.025*** (8.9e-03)
Shale Wells Drilled 2007-2011 Squared	1.4e-06 (3.1e-06)	-7.3e-06 (2.1e-05)	-3.0e-05*** (9.6e-06)
R-squared	0.411	0.422	0.182
Adjusted R-squared	0.342	0.351	0.086
F	6.248	8.175	2.474
Observations	144	138	144

__Notes:__ Each column denotes a single regression. Each value listed denotes the coefficient estimate for the explanatory variable at the left for the dependent variable listed above. Robust standard errors of coefficient estimates are shown in parentheses. We also control for the effects of each county's population, median per-capita income, poverty rate, and expected employment growth based the county's industry composition. We include dummy variables to control for urbanization if the county is part of a MSA (Metropolitan Statistical Area) and geographical/cultural effects if it is part of the Appalachian region. We use the logged Year 2000 values of population, median per-capita income, median rent and median home value and the Year 2000 values of the poverty rate, expected employment growth and vacancy rate to control for initial levels.

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[1] - Shale Dev. Empl. denotes NAICS (North American Industry Classification System) industry codes which are connected with shale development employment. The specific NAICS codes we utilized to capture shale development employment effects are: 2111-Oil and Gas Extraction; 2131-Support Activities for Mining; 5413 –Architectural, Engineering, and Related Services; 2389–Other Specialty Trade Contractors; 3331–Agriculture, Construction, and Mining Machinery Manufacturing; 4862–Pipeline Transportation of Natural Gas; 2371–Utility System Construction

Appendix 2: Additional Figures

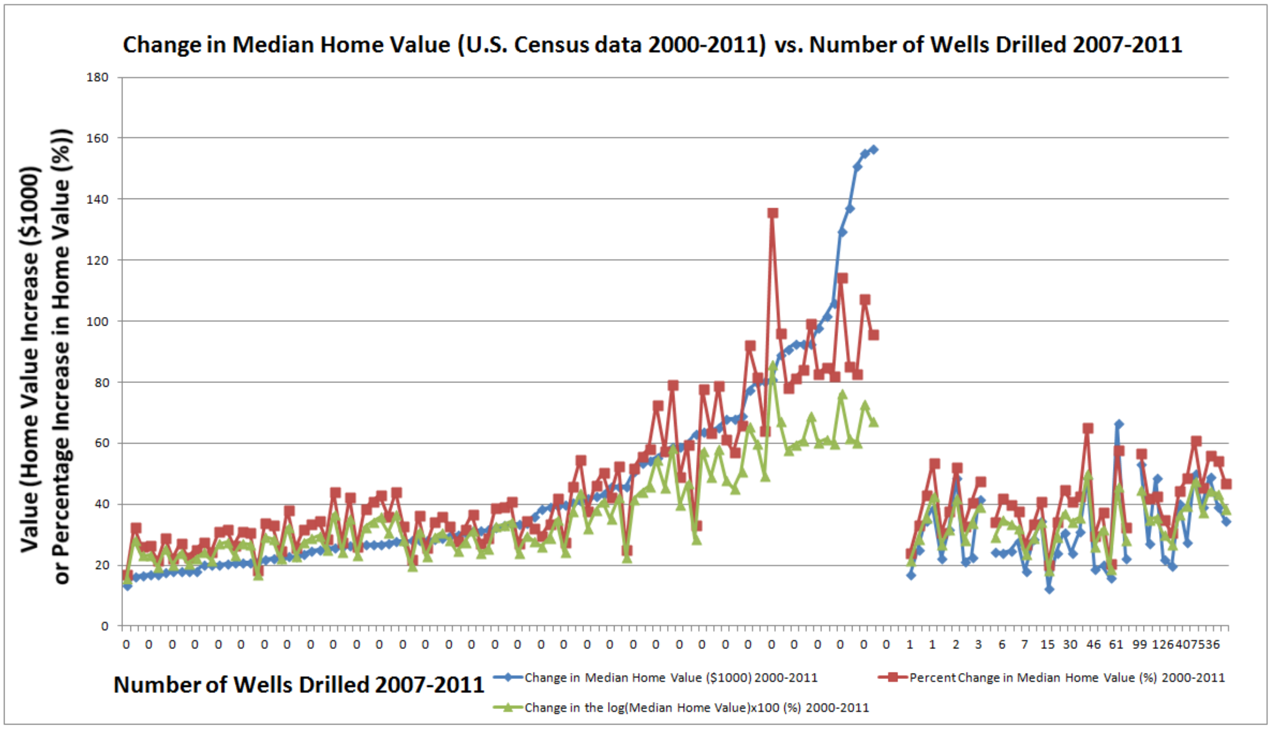

Figure 20: Illustration of the Scattered Nature of the Census Median Home Value Data

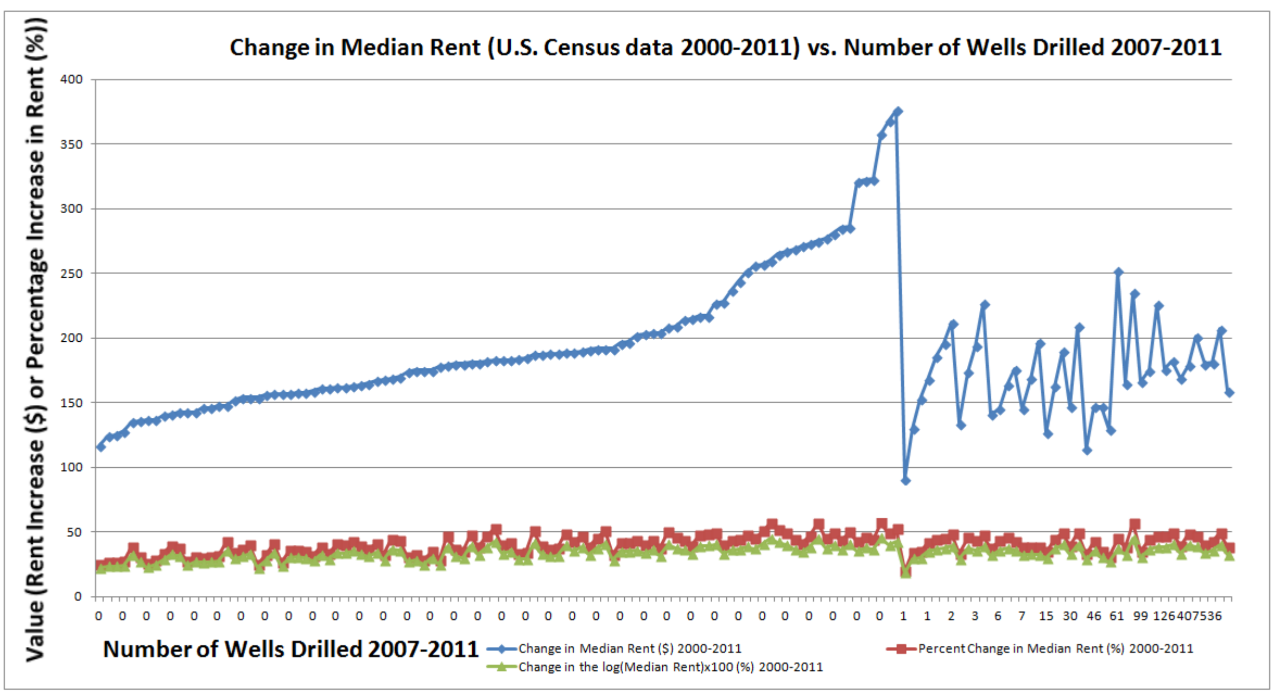

Figure 21: Illustration of the Scattered Nature of the Census Median Rent Data

Appendix 2: Additional Figures

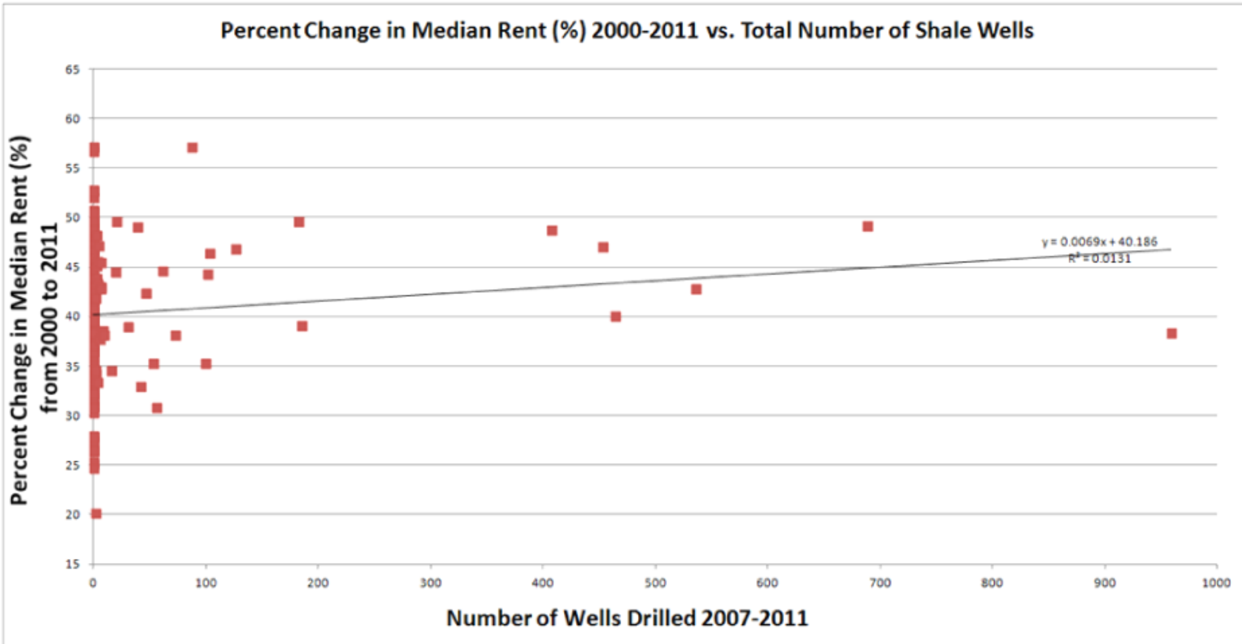

Figure 22: Relationship between the Percent Change in Median Rent and the Number of Shale Gas Wells Drilled

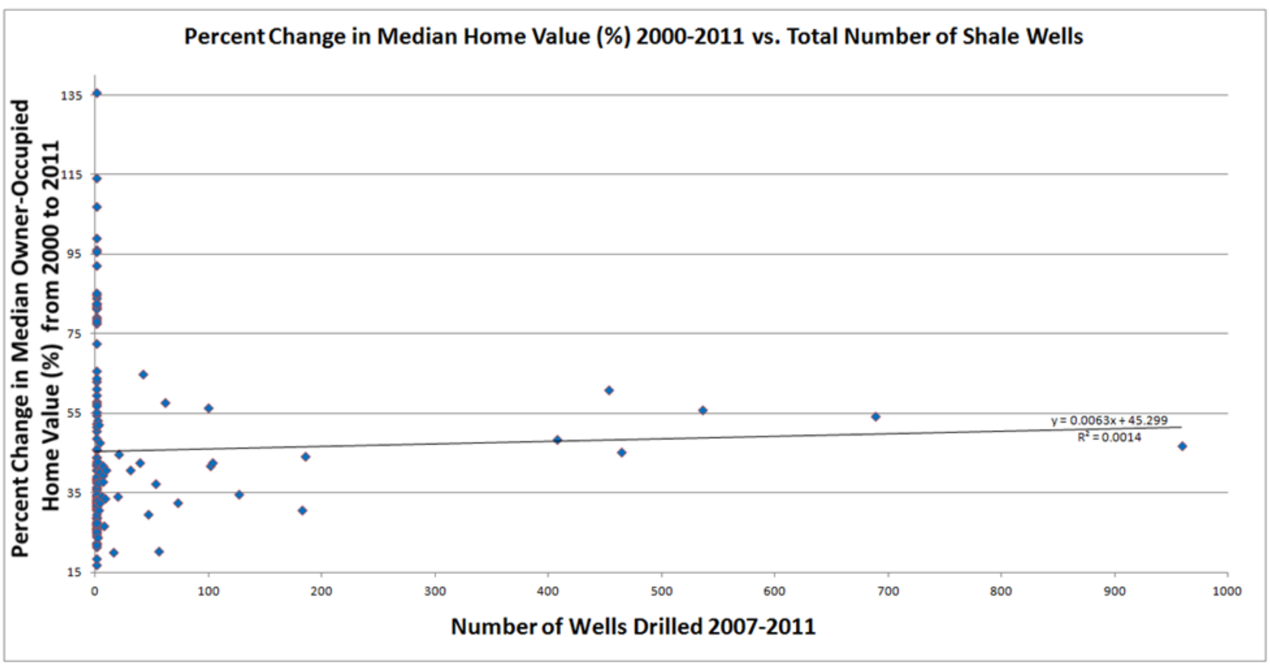

Figure 23: Relationship between Percent Change in Median Home Value and the Number of Shale Gas Wells Drilled