RFF REPORT

Housing Market Impacts of Unconventional Oil and Gas Development

Alan J. Krupnick and Isabel Echarte

This report was produced as part of **The Community Impacts of Shale Gas and Oil Development***, an RFF initiative.*

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RESOURCES FOR THE FUTURE

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Summary

Changes in housing prices as a result of unconventional oil and gas development are useful indicators of community perceptions about the benefits and damages of such development, as they aggregate and monetize preferences of home buyers and sellers. In this report, we review 16 studies of the housing market impacts of unconventional oil and gas development, focusing our discussion on the studies that use hedonic analysis, assessing changes in home prices related to proximity to unconventional oil and gas development. A few studies reviewed also focus on lease clauses, rental rates, farm values, and tax base changes. The largest number of studies (six) use data from Pennsylvania, with two of these comparing Pennsylvania housing prices with those of New York, exploiting the moratorium on drilling in New York. Two focus on Tarrant County, Texas, and one looks at the Barnett shale region in Texas, and two analyze data for Weld County, Colorado. A few examine multiple regions.

As a whole, we consider the literature on the housing market impacts of nearby unconventional oil and gas development to be reasonably conclusive, meaning several high quality studies report comparable findings, though the effects of split estates and temporal variation in these impacts are less studied.

The studies show strong evidence for decreases in value, up to –$33,843, or –26.6 percent, for groundwater-dependent homes within 2 kilometers (km) of a well pad, though this number varies by distance to a well or well pad and across studies. The studies also show strong evidence for increases in housing value for those close-in homes with piped water, up to $4,802, or 3.4 percent, again dependent on distance to well or well pad and study (Muehlenbachs, Spiller, and Timmins 2015). This range reflects anxieties about the potential for groundwater contamination. A few studies find smaller magnitude impacts, with one study finding none.

Almost all of these studies are unable to account for mineral rights ownership (which would lead to an underestimate of housing price discounts from groundwater-dependent homes), though one study is able to analyze the effects of unconventional oil and gas development near Weld County homes with split estates. Boslett et al. (2016a) found a decrease of over $60,000, or 35 percent of average home value, for homes without mineral rights.

The findings of these studies vary in terms of the persistence of these effects (the temporal nature of these impacts) as well as the relationship between these impacts and specific phases of drilling.

Community Risk-Benefit Matrix

The Community Risk-Benefit Matrix identifies specific areas of concern related to impacts addressed by the team's literature review (left column of the matrix below), as well as impacts for which RFF experts have conducted original research and analysis. (See page 3 for the section of the matrix related to this review, on the housing impacts of unconventional oil and gas development.)

The matrix indicates the quality of the literature for each impact, judged subjectively with the color indicating whether we find the studies analyzing an impact to be, on average, of a certain quality. Impacts may be assessed by multiple low-quality studies and a medium-quality study, for example, and we would consider this body of literature to be low quality. A high-quality classification indicates that we trust the results of such studies, including the accuracy, magnitude, and direction of the results—meaning, in a practical sense, that it has no serious or fatal flaws (such as inadequate methodologies) that would lead us to question the results. A study is considered low quality if we believe we cannot trust the results because the study has multiple, serious flaws (e.g., methodology, data, focus, or study design are inadequate to reliably estimate outcomes). A study is considered medium quality if it does not fit in the other two categories. A study is therefore medium quality if it has any such major flaw or if either the methodology, data, focus, or study design lead to questionable results for a number of reasons. Generally, we find the magnitude and direction of these results to be informative, but question the precision.

Lastly, we summarize the findings reported by the literature for each impact—whether the studies as a whole report increases, decreases, or no relationship between the impact and an increase in unconventional oil and gas development. The "heterogeneous" classification indicates that the literature reports different outcomes across areas. The "inconsistent" classification indicates that the literature reports contradictory results (i.e., two studies find an increase or decrease for a certain impact in the same context).

View or download the entire matrix, including all sections that correspond with each of the literature reviews by topic produced as part of this initiative:

WHIMBY (What's Happening in My Backyard?): A Community Risk-Benefit Matrix of Unconventional Gas and Oil Development

Community Risk-Benefit Matrix Literature Review: Housing Market Impacts of Unconventional Oil and Gas Development

Property Values

Impact	Findings	Results
Homes near wells, piped water	↑	Several studies find modest increases in value (depending on distance to unconventional oil and gas development as well as other factors).
Homes near wells, groundwater	↓	Several studies find large decreases in value (depending on distance to unconventional oil and gas development as well as other factors).
Homes without mineral rights	↓	One study finds that homes without mineral rights see large, negative decreases in their price from nearby unconventional oil and gas development.

Key

(green)	Higher quality: The majority of studies reviewed for an impact are of higher quality. Where there is one study of higher quality, it is marked as such.
(blue)	Medium quality: The majority of studies reviewed for an impact are of medium quality. Where there is one study of medium quality, it is marked as such.
(orange)	Lower quality: The majority of studies reviewed for an impact are of lower quality. Where there is one study of lower quality, it is marked as such.
(grey)	Not reviewed: Research on an impact was not reviewed.
↑	Increase: Studies show a positive, robust association with an impact (an increase in incidence or magnitude).
↓	Decrease: Studies show a negative, robust association with an impact (a decrease in incidence or magnitude).
↑↓	Heterogeneous: Across regions or areas, studies report robust results that differ.
Ø	No association: Studies report results that showed no association.
~	Inconsistent: Studies report differing (contradictory) results.

1. Introduction

The impact of oil and gas development on the US housing market accounts for the perceptions, experiences, fears, and expectations of a large number of people who buy and sell properties over a given period. Changes in housing prices for homes near unconventional oil and gas development—if they can be disentangled from more general demographic and economic trends—therefore offer a window into the value that the public places on the net impacts of such development in a community or region. These values reflect both actual and perceived risks and benefits as well as very local and broader spatial scales.

Oil and gas development in a community tends to affect housing values through its size, spatial pattern, and intensity, which change with the boom and bust cycle. During a boom, rental housing prices and even residential housing prices (particularly those away from the development itself) are likely to increase with demand for living quarters and overall economic opportunity and development. The opposite occurs during a bust. At the same time, for housing located close to booming developments, housing values could diminish, to the extent that home buyers and/or sellers perceive negative externalities from oil and gas operations. These effects could be mitigated or reversed if a property earns royalties and those transfer with the sale. The negative effects on prices could be expected to vary with how close the housing is to development, but the positive effects would end at some distance reflecting when a property line is within or outside the boundary of horizontal drilling activity.

Table 1 lists the studies we reviewed on housing market impacts, along with a variety of their attributes and findings. Six studies focus on Pennsylvania—with two comparing Pennsylvania with New York, highlighting the moratorium on drilling in New York. Two focus on Tarrant County, Texas, and one looks at the Barnett shale region in Texas. Two focus on Weld County, Colorado. A few examine multiple regions.

The literature related to the housing market impacts of unconventional oil and gas development has largely focused on changes in home values from nearby shale gas or tight oil development. A handful of studies differ in their focus: one study looks at the effect of the New York fracking moratorium on home prices in three New York counties compared to Pennsylvania counties (Boslett et al. 2016), and another looks at the relationship between unconventional oil and gas development on housing construction (Farren 2014). Weber et al. (2014) analyzes the impact of shale gas–related changes in the tax base on home values. Timmins and Vissing (2015) is the only study in our review to directly assess the impact of lease clauses on home values. Muehlenbachs et al. (2015), James and James (2014), Farren et al. (2013) and Jacobsen (2015) are the only studies to address rental rates. It is important to note that all of these studies analyze housing markets during a boom period of shale development, and therefore do not analyze how these effects might change during a downturn.

Where unconventional oil and gas development is concerned, it is important to note that findings of temporal variation in impacts on communities might be particularly revealing, especially for policymaking purposes. For example, evidence of persistent negative effects on home prices, occurring beyond the short-term construction and drilling phases of wells and well pads, would indicate potentially serious, perceived long-term impacts, as the initial drilling and construction phases are often the most disturbing in terms of noise, light pollution, truck traffic, and local air pollution.

TABLE 1. SUMMARY OF STUDIES REVIEWED

Study	Location	Dates	Focus
Balthrop and Hawley (2017)	Tarrant County, TX	2005–2011	Shale gas and home prices
Bennett and Loomis (2015)	Weld County, CO	2009–2012	Unconventional oil and gas development and home prices
Boslett et al. (2016a)	Garfield, Mesa, and Rio Blanco Counties, CO	2000–2014	Unconventional oil and gas development, mineral rights, and home prices
Boslett et al. (2016b)	PA, NY	2006–2012	Shale gas and moratorium impact
Delgado et al. (2014)	Lycoming and Bradford Counties, PA	2004–2013	Shale gas and home prices
Farren et al. (2013)	Pennsylvania and West Virginia	2003–2011	Shale and housing effects
Farren (2014)	Multiple areas	1997–2011	Unconventional oil and gas development and housing boom
Gopalakrishnan and Klaiber (2014)	Washington County, PA	2008–mid-2010	Shale gas and home prices
Jacobsen (2015)	US counties	2006–2014	Unconventional oil and gas development
James and James (2014)	Weld County, CO	2012	Oil and gas and home prices
Muehlenbachs, Spiller, and Timmins (2013)	Washington County, PA	2004–2009	Shale gas and home prices
Muehlenbachs, Spiller, and Timmins (2015)	Pennsylvania	1995–2012	Shale gas and home prices
Muehlenbachs et al. (2015)	PA, NY	2008–2012	Shale gas and rental rates
Timmins and Vissing (2015)	Tarrant County, TX	2003–2013	Shale gas lease clauses and home prices
Weber and Hitaj (2015)	TX, PA, NY	1992–2012	Shale gas development and farm values
Weber et al. (2014)	Barnett Shale, TX	1997–2013	Shale gas, tax base changes, and home prices

Throughout the literature, findings vary regarding the persistence or temporal nature of certain effects. For example, for homes with piped water, Muehlenbachs, Spiller, and Timmins (2015) found positive effects on prices for homes near older wellbores and statistically insignificant, negative price impacts for homes near newer wellbores. Balthrop and Hawley (2017) found negative effects even after well construction is completed, potentially owing to visual disamenities (such as the view of a rig or light pollution) or the risk of spills and other forms of pollution.

Additionally, comparing the results for permitted wells versus producing wells (or spudded wells, i.e., wells where drilling has just begun) might further differentiate the types of negative impacts reflected by decreases in home prices. For a well that is permitted only, the impacts on housing prices are likely to reflect expectations about the future negative and positive externalities. For a spudded well, the effects on housing prices likely indicate impacts from the more intrusive construction and drilling phases, whereas any effects of a producing well indicate longer-term concerns. We note these differences as we discuss the findings of the various studies in our review, and cover the literature on how overall housing prices respond to gas and oil development at the end of this report.

As a whole, the literature on the nearby housing market impacts of unconventional oil and gas development is relatively conclusive, particularly when compared to other community impact literatures covered in our reivews.[1] Homes that have access to publicly supplied water (i.e., not groundwater) generally see appreciation with nearby unconventional oil and gas development, while groundwater-dependent homes experience large negative impacts, often depending on the distance of the home from the development. For homes without mineral rights, Boslett et al. (2016a) found even larger negative impacts. These results are discussed in more detail below.

The majority of the studies we review rely on a form of analysis called hedonic property valuation, in which changes or variation in housing prices are explained statistically with by comparing characteristics of the homes (such as where drinking water comes from, distance of the home from the well, or number of wells within a certain distance of the home). Bennett and Loomis (2015) describe the intuition behind this method:

"High-amenity areas are both desirable places to live and scarce in supply. Those properties with access to these desirable attributes find their house prices bid up by competing buyers willing to pay more to live near high environmental amenities. Likewise, in order to get households to accept living near a less desirable environment (e.g., oil/gas well), households have to be compensated by lower house prices" (1169–1170).

The studies employing this method analyze variation in housing prices, using econometric methods to isolate the impact of oil and gas development from all of the other factors that affect housing prices (such as the features of the house, the size of the lot, its location relative to other structures, the town center, road networks, mass transit, and the like—as well as broader socioeconomic and demographic changes). Additionally, studies might analyze the housing price effects from nearby shale development (the effect of proximity, or whether or not there is a well pad within a certain distance), or the intensity of shale development (the number of wells or well pads within a certain distance, or the effect of an additional well). We analyze these studies below, beginning first with a discussion of the hedonic studies that assess the housing price effects from nearby shale development.

2. Hedonic Models and Nearby Shale Development

For the most part, the hedonic price studies report comparable results, despite different study areas, time periods, and methodologies, indicating that these results are likely an accurate reflection of the perceived costs or benefits of extraction (see Table 2). Variation in these results, as shown in Figure 1, largely result from differing analyses, but it is important to note that three studies use comparable methods in Pennsylvania and find similar results, as is apparent in Figure 1 below. The studies report results in both percentage changes in price and the dollar value (or absolute) price change—the former is important in that it provides context for the magnitude of the price change, while the latter estimates the willingness to pay to reduce or increase, respectively, a

[1] See all the literature reviews conducted as part of this initiative: [WHIMBY (What's Happening in My Backyard?): A Community Risk-Benefit Matrix of Unconventional Gas and Oil Development]

disamenity or an amenity. The willingness to pay estimates are functions of homebuyers' perceived amenities or disamenities. For example, these measures do not reflect quantified changes to air quality or increases in noise.

Generally, the studies show that homes near unconventional oil and gas development with piped or publicly-supplied water (i.e., not groundwater) see appreciation associated with shale development, while groundwater-dependent homes near unconventional oil and gas development see large decreases in home prices. The estimated increases range from $715 (or 0.5 percent) for homes with publicly supplied water within 3.22 km of a well in Washington County, Pennsylvania (Gopalakrishnan and Klaiber 2014), to $4,802 (or 3 percent) for homes with publicly supplied water within 1.5 km of a well in Pennsylvania (Muehlenbachs, Spiller, and Timmins 2015). Groundwater-dependent homes see lower prices, with estimates ranging from a 16 percent decrease in Pennsylvania (Muehlenbachs, Spiller, and Timmins 2015) to a 20–25 percent decrease in Washington County (Golapakrishnan and Klaiber 2014). The properties could see increases in value because of payments for mineral rights that are going to the property owners. The studies above did not have data on mineral rights, but Boslett et al. (2016a) analyzed homes (in Colorado) without mineral rights located within 1 mile (or 1.61 km) of a well, finding large negative impacts—over $63,000, or 34.8 percent. Their study, however, has no information on water supply. Most of the studies find positive effects on prices when homes are farther away from wells, but still within a plausible range for receiving royalty payments, even for groundwater dependent homes.

An important issue in measuring the costs or benefits of unconventional oil and gas development to homeowners is disentangling the positive and negative effects. All of the studies but one, Boslett et al. (2016a), are unable to separate the positive effects of royalty payments from the negative externalities. Thus, the observed price effects in other studies, if negative, are likely to underestimate the negative externality effects.

FIGURE 1. WILLINGNESS TO PAY ESTIMATES FOR WELLS OR WELL PADS WITHIN X KM OF A HOME

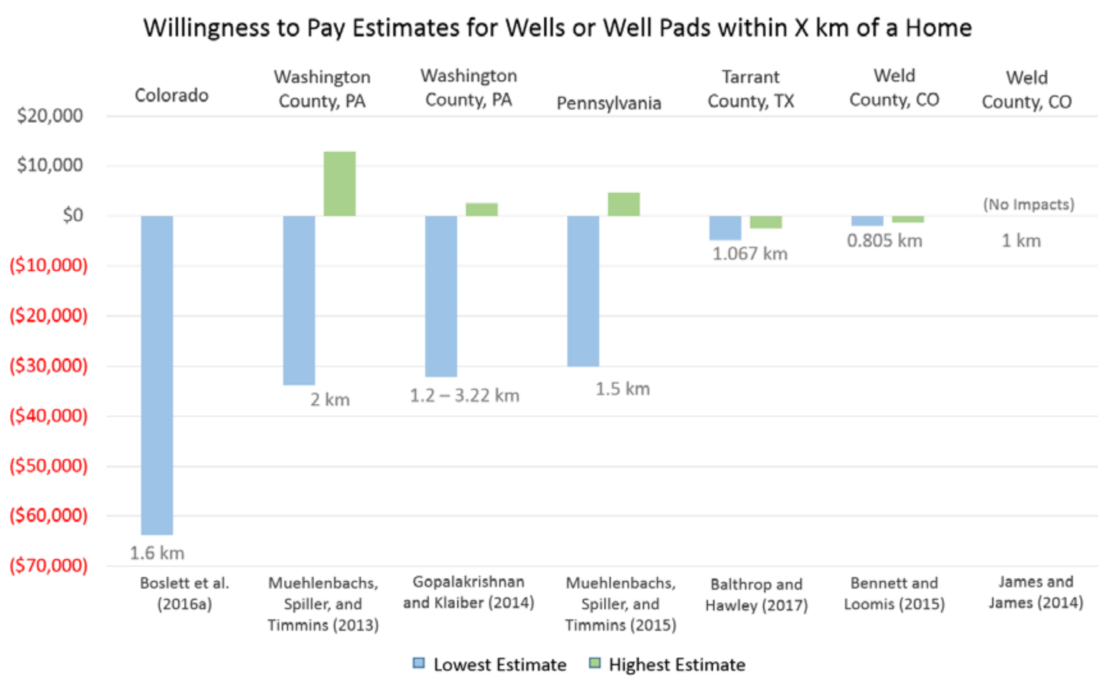


TABLE 2. SUMMARY OF HEDONIC STUDY RESULTS FOR IMPACTS OF NEARBY UNCONVENTIONAL OIL AND GAS DEVELOPMENT ON HOME PRICES

Study	Focus	Location	Dates	Distance	Price Impacts, %	Price Impacts, Avg. Home Price
Balthrop and Hawley (2017)	Shale gas	Tarrant County, TX	2005–2011	One or more wells within 1.067 km	-2.9% to -1.5%	-$4,889 to -$2,529
Bennett and Loomis (2015)	Unconventional oil and gas development	Weld County, CO	2009–2012	0.805 km	-1% for each additional well	-$1,342 to -$1,936
				Decreasing a home's distance to nearest producing well by 1 meter decreases value by $12.		
Boslett et al. (2016a)	Unconventional oil and gas development	Rio Blanco, Mesa, and Garfield Counties, CO	2000–2014	A well within 1.609 km of a home without mineral rights	-34.8%	-$63,788
Delgado et al. (2014)	Shale gas	Lycoming and Bradford Counties, PA	2004–2013	An additional well within 3.2 to 4.8 km	-0.45% to -0.3% in Bradford	-$535 to -$357 in Bradford
				Property sales within 60 days of the issuance of a well permit within 3.2 to 4.8 km	-4.45% to -1.56%	-$695.38 to -$2,409.85
Gopalakrishnan and Klaiber (2014)	Shale gas	Washington County, PA	2008 to mid-2010	1.2 km to well permitted 6 months prior to home sale and drilled	-21.7% to -1.4%	-$32,198 to -$2,013
				1.609 km to permitted well	-5.6% to 1.1%	-$8,288 to +$1,576
				3.22 km to permitted well	+0.5% to +1.8%	+$715 to $2,609
James and James (2014)	Oil and gas	Weld County, CO	2012	One or more wells within 1 km	Statistically insignificant results	Statistically insignificant results
				Decreasing a home's distance to nearest producing well by 1 meter decreases value by $15.		
Muehlenbachs, Spiller, and Timmins (2013)	Shale gas	Washington County, PA	2004–2009	2 km to well pad	- 26.6% for a groundwater-dependent home +10.1%, for public water-serviced homes.	-$33,843 for groundwater dependent homes +$12,851 for public water-serviced homes
Muehlenbachs, Spiller, and Timmins (2015)	Shale gas	Pennsylvania	1995–2012	1 to 1.5 km to well pad	-16.5 to -6.5% for groundwater-dependent homes; insignificant or +3.4% for public-water serviced homes	-$30,167 for groundwater-dependent homes; +$4,802 for public water-serviced homes

Boslett et al. (2016a) makes this separation by exploiting the legacy of a 1916 law, the Stock-Raising Homestead Act, in which the government disbursed land to homesteaders but kept the mineral rights for itself. Much of this land is in Garfield, Mesa, and Rio Blanco Counties in Colorado, where a recent boom in unconventional oil and gas development has occurred. The study, analyzing 871 transactions from 2000 to 2014 for homes completely contained within this federal mineral ownership area, found that homes within 1 mile of a well sold for 34.8 percent (or $63,788) less than comparable properties, even when analyzing repeated sales or using matching models. Furthermore, when analyzing the effect of an additional well for properties with unclear mineral rights ownership (i.e., where the property is partly on the boundary of federal ownership), this effect is statistically insignificant—suggesting that royalty payments can largely offset negative externalities of development as perceived by homebuyers and sellers.

Compared to the other studies we review, Muehlenbachs, Spiller, and Timmins (2015) is perhaps the most comprehensive, assessing the net costs and benefits of unconventional oil and gas development to homeowners, because it analyzes the entire shale region of Pennsylvania (36 counties from 1995 to 2012) and also includes a large number of repeated home sales, which allows the authors to control for time-invariant unobservable characteristics. All of the other hedonic analysis studies assessing the effect of nearby development look at one to two counties.

Muehlenbachs, Spiller, and Timmins (2015) analyze "vicinity effects," or price impacts felt by homes within 20 km of a well pad from traffic congestion and local employment; "adjacency effects" felt within 1-2 km that include light pollution, visual disamenities, noise, and royalty and lease payments; and lastly, the risk of groundwater contamination. The property value response to a groundwater risk is not based on measured groundwater damage but rather, these results reflect the willingness to pay of a homebuyer to reduce their perceived (potentially incorrect) risk of a disamenity due to proximity to a shale gas well.

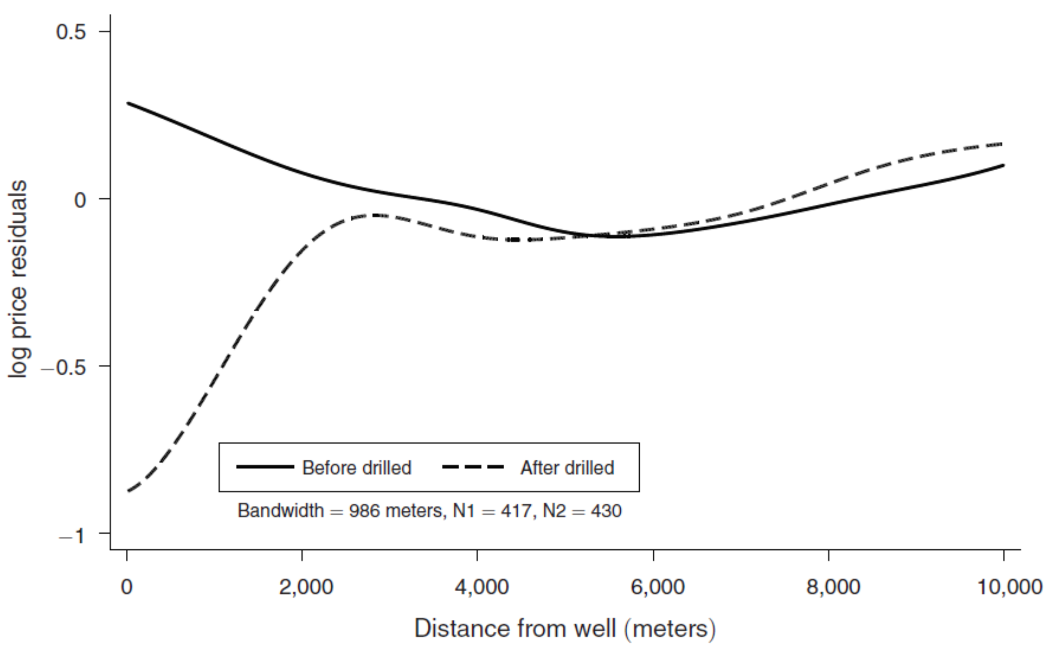
The study found that within 1 km, groundwater-dependent homes saw large negative impacts (decreases in home prices of 16.5 percent). Moving farther from a well pad, the negative impacts for groundwater-dependent homes decrease; at 2 km, the study found that there are no longer significant negative impacts. Homes with publicly supplied water saw an increase in property values when not too close to a well (i.e., a 3 percent increase when 1.5 km from a well). The increase then becomes smaller the farther a home is from a well (i.e., 1.6 percent when 2 km from a well), likely due to the decreased potential for royalty or lease payments. The study does not include data on property boundaries, so the authors assume that beyond 2 km it is less likely that a well pad will be within the boundary of a property. Figure 2 shows that the estimated price difference is substantial for a groundwater-dependent home sold before the well was drilled compared to after the well was drilled within 2 km—but beyond 2 km, the price is about the same after the well is drilled.

Additionally, the study found temporal variation, with the positive impacts on homes with publicly-supplied water coming from older wellbores, and newer wellbores resulting in a statistically insignificant negative impact. This result indicates that the disruptions from the drilling and fracking process (which often have greater local impacts, such as noise and truck traffic) may reduce or outweigh the benefits of royalty and lease payments. The results of this study imply that the perceived risk of groundwater contamination from shale development is large: groundwater-dependent homes within 1.5 km of wells see an average loss of $30,167 after the wells are drilled, while properties with public water service see an average increase of $4,802 after wells are drilled within 1.5 km, for an overall differential of around $35,000.

An earlier study by Muehlenbachs, Spiller, and Timmins (2013) and a study by Gopalakrishnan and Klaiber (2014), both focused on Washington County, Pennsylvania. Muehlenbachs, Spiller, and Timmins (2013) report similar, though larger, results compared to the state-wide study of Muehlenbachs, Spiller, and Timmins (2015). Gopalakrishnan and Klaiber (2014) found similar impacts to Muehlenbachs, Spiller, and Timmins (2013), though they also analyzed the effect of proximate farm land on home prices. Because they each analyzed a single county, neither study can control for the effects of county-wide changes that might result from shale development.

Muehlenbachs, Spiller, and Timmins (2013) analyzed home sales in Washington County, Pennsylvania, from 2004 to 2009 and conducted a similar analysis as Muehlenbachs, Spiller, and Timmins (2015), looking at the effect of proximity to shale gas well pads. The study finds a decrease of 26.6 percent (or an average of $33,843) for a groundwater-dependent home and an increase of 10.1 percent (or an average of $12,851) for proximity to a well pad for homes with publicly supplied water within 2 km of a well pad. Both the costs and benefits reported in this study are much larger than those in Muehlenbachs, Spiller, and Timmins (2015). Because the study looks at only a single county, these results indicate “who benefits and who loses from this unconventional form of natural gas extraction *relative* to the overall change in economic activity throughout the county” (Muehlenbachs, Spiller, and Timmins 2013, 30), assessing the net of these effects, as well as how one specific risk (the perceived potential for groundwater contamination) affects home prices.

Figure 2. Price Gradient of Distance from Future/Current Well, Using Groundwater-Dependent Areas



Source: Muehlenbachs, Spiller, and Timmins (2015).

Gopalakrishnan and Klaiber (2014) analyzed fewer years (2008 to mid-2010), but their analysis covers most of the period of the state's shale boom, which became far more intense beginning in 2008. This paper is also the only study to look at variation in prices for areas with different amounts of agricultural development. The authors found large variation in the impacts of an additional well, permitted within six months of the sale date and drilled within 0.75 to 2 miles (or 1.2 to 3.22 km). The authors found that wells are, on average, drilled between three and four months following permitting, so the authors hypothesize that this dependent variable would include the most visible activity.

In terms of proximity, within 0.75 miles, the authors found all impacts to be negative, with the impacts on groundwater-dependent homes an order of a magnitude larger than those for homes with publicly supplied water. The negative impacts are over $30,000 for groundwater-dependent homes and range from $2,000 to just under $4,000 for homes with public water service. Within 1 mile, homes with low surrounding agricultural land and piped water have a modest positive impact of 1.1 percent (or $1,576). Homes with high levels (greater than 80 percent) of surrounding agricultural land face larger negative impacts and homes with well water also face larger negative impacts. Homes with both attributes face the largest negative impact of $8,288. Additional wells within 2 miles was related to positive effects on home prices. Most notably, homes with wells within 2 miles that also had a high share of surrounding agricultural lands (greater than 80 percent) experienced the largest positive price effects. This analysis makes clear that wells permitted within six months of a sale can have highly varying impacts, even for homes dependent on groundwater or with varying levels of nearby agricultural activity. These impacts were largely found to be short term in the analysis. Additionally, homes near major roadways—which are used heavily during shale development—face negative price impacts that persist for longer time periods.

The study likewise found that the intensity of shale development had larger impacts than distance to the closest well: an additional permitted well within 1 mile of a home decreased value by $3,596, whereas a home 100 feet farther from a permitted well was estimated to gain $377 in value.

One issue with this study, however, is that it does not account for well pads with multiple wells drilled or permitted. Rather, the study accounts for intensity by measuring the active well count (for wells permitted within six months of a home sale) within these varying distances. This analysis may therefore overstate the impacts, as two wells on two different well pads within a certain distance might be more intrusive then a second well on the same well pad. In fact, Muehlenbachs, Spiller, and Timmins (2013) found that only 25 percent of well pads had only one wellbore in Washington County. Gopalakrishnan and Klaiber (2014) additionally state that using the spud date of the well as opposed to using the earlier permit date made their results insignificant. This permit date dependent variable may be able to capture expectations about future drilling operations on the part of homeowners, though it differs from the methodology used by other studies, namely, Muehlenbachs, Spiller, and Timmins (2013; 2015). Another issue with the study is that it does not compare changes in the price of the same property over time—meaning that the study compares two different homes (with and without nearby wells), which may bias the results as these homes may differ on average in ways not related to shale wells. Nonetheless, the study's findings are comparable to those reported in other studies.

Balthrop and Hawley (2017) is the only study to analyze the impact of proximity to shale development on home prices in an urban area, covering Dallas, Fort Worth, and Arlington in Tarrant County, Texas. Analyzing an urban area has a number of implications for both the analysis and the impacts that might be felt by homeowners. Urban areas have higher densities and smaller plot sizes, meaning that more people might be exposed to negative externalities of oil and gas development with smaller benefits of royalty payments. Additionally, the study uses a larger number of sales than studies of more rural areas, providing greater precision to the statistical estimates.

The study found that, for the average home, the existence of one or more shale gas wells within 3,500 feet (or 1.067 km) of a home reduced home values by 1.5 to 2.9 percent (or $2,529 to $4,889). These impacts become statistically insignificant beyond 3,500 feet. When differentiating the impacts of well construction versus more long-term effects once a well is completed, Balthrop and Hawley (2017), unlike Gopalakrishnan and Klaiber (2014), found that the impacts from completed wells were larger than those from wells under construction, though both had statistically significant results. The authors note that this persistence might be the result of negative externalities (such as visual disamenities) or perceived risks of the potential for spills or other forms of pollution, as well as potential development activity in the future (as multiple wells can be drilled on one well pad).

The study attempts to control for well pads by constructing variables for 1 to 6 wells, 7 to 12 wells, and 13 or more wells, though the results on these categories are largely mixed. Ranges, rather than continuous or binary variables, are not used in any other study covered in this review. These range variables may be less useful in analyzing the impacts of well pads or multiple wells than calculating whether wells are on the same well pad based on distance, as in Muehlenbachs, Spiller, and Timmins (2013; 2015). This measure might therefore present issues.

Interestingly, when comparing repeat sales for homes that never have a well within 6,500 feet during the study period and homes that featured a well within 6,500 feet during the study period, the authors find that the two groups of homes have different characteristics. This finding indicates that the placement of wells within 6,500 feet of a home might not be random (i.e., that an operator might seek to put a well within 6,500 feet of a certain type of home). Such a finding could bias results of many of the hedonic analyses, a finding that has implications for the literature as a whole. However, the authors of this particular study use a matching technique to minimize the potential for any bias arising from this finding.

Bennett and Loomis (2015) use hedonic analysis to assess the impacts of shale development in Weld County, Colorado, from 2009 to 2012. The study found that an additional well being drilled within a half-mile of a home at the time of purchase decreases its value between $1,342 to $1,936 (or about 1 percent). The study did not find statistically significant results for development intensity (i.e., the number of producing wells). These results are more similar to Gopalakrishnan and Klaiber (2014) and contrast with the results of Balthrop and Hawley (2017). When analyzing differences between urban and rural areas, the study found that increasing the distance of wells being drilled from homes in rural areas increases housing prices, whereas in urban areas this increased distance decreases housing prices. The decrease in prices in the urban areas (which likely have smaller plots) could be due to homeowners suffering negative externalities without receiving royalty payments, whereas rural homes (with likely larger plots) face fewer disamenities but might still receive royalty payments. Testing this hypothesis would require data on leases and mineral rights ownership.

James and James (2014) also analyzed the impact of the distance of unconventional oil and gas wells on home sale prices in Weld County in 2012, finding no statistically significant difference in the effect for homes within 1 km of a well versus homes farther than 1 km from a well. Increasing a home's distance to the nearest well by 1 meter, however results in an increase of home prices of $10 to $15. This number is comparable to the finding of Bennet and Loomis (2015) that for rural areas, being farther from a well increases home prices by $12 per meter—though the fact that the James and James study does not find any statistically significant effects for a well within 1 km is odd given the consistency of this finding throughout the literature. The study does find that homes with a horizontal well intersecting the property boundary have a large, positive impact of $10,000 to $11,000, indicating a royalty payment effect (though this is only significant at the 10 percent level). One concern with this analysis is that the well data are from 2013, while the housing sale data are from 2012—although the authors argue that the number of wells likely didn't change much from 2012 to 2013. Additionally, the study does not control for well pad effects (as opposed to well effects).

The paper also compared home prices in counties that lie above a shale play to home prices in counties that do not, finding that home prices in shale counties, other things equal, decreased between $225 and $525 between the 2000 census and the 2005–2009 census data. This analysis also found that shale counties experienced a 0.3 percent to 0.4 percent faster annual average growth in rental rates. These effects could reflect concerns about negative impacts from future development, but averaging over large areas such as counties (compared to analyzing individual home prices) does not control as well for variation in many factors that can occur within a county. Additionally, there could be unobserved differences in shale counties and non-shale counties that vary over time, affecting home prices for reasons other than shale development. Lastly, the study period ends before the shale boom largely occurred, particularly in areas such as the Marcellus shale in Pennsylvania.

Delgado et al. (2014) analyzed the effects of shale gas wells on housing prices in Pennsylvania's Bradford and Lycoming Counties, finding "little evidence that negative environmental externalities of natural gas extraction are manifested in nearby property values," but also "some evidence that negative environmental effects may have been capitalized into property values in the earliest years of unconventional natural gas extraction" (1). The authors analyzed the two counties separately, which means they cannot control for county-wide changes. The results for Bradford County are mostly insignificant, though initial results for well counts within 2 miles and 3 miles of a home showed a $535 to $357 decrease in home values per additional well. These results are small compared to other studies, and also showed positive impacts of wells for homes with groundwater, which is counterintuitive and the opposite of the results from the analyses by Muehlenbachs, Spiller, and Timmins (2013; 2015). Results for wells permitted within 60 days of the sale of a home showed decreases in value of $695 to $2,409 for an additional well within 2 or 3 miles, respectively. The results are all insignificant for Lycoming County, save for when the study analyzed the effect of well pads, which were correlated with higher home values, except for groundwater-dependent properties. Overall, the study found low impacts of shale development. The largest price impact ($2,409) was due to the short-term effect of being close to a permitted well.

With the exception of Delgado et al. (2014), the majority of the hedonic analyses found large impacts on home prices due to unconventional oil and gas development. Most importantly, they found largely heterogeneous impacts—particularly for groundwater-dependent homes or homes surrounded by agricultural land—which has direct implications for policy meant to mitigate the actual and perceived impacts of unconventional oil and gas development.

3. Lease Clauses and Hedonic Analysis

Oil and gas companies or surrogates must hold leases with mineral rights owners and sometimes with surface owners before they drill. Timmins and Vissing (2015) conducted the only study in this review of how different lease clauses (in which requirements for oil and gas operators might be implemented) affect home prices, though it should be noted that an updated version of this paper is in progress. This study looked at Tarrant County, Texas, from 2003 to 2013 using hedonic analysis but we consider it in a separate category due to its focus on lease clauses, rather than oil and gas development activity. The study found that leases for split estates (where the mineral rights are and surface rights are held by different people) were less likely to include clauses that reduce noise and other environmental impacts, as well as "restrictions on surface access, indemnity clauses, and clauses ascribing future attorney fees to the lessor." Lease clauses that benefit homeowners were positively correlated with annualized appraised values, whereas lease clauses that do not benefit homeowners (such as longer lease terms, which give companies more time to start producing and, therefore, delay royalty payments) were negatively correlated with annualized appraised values. Having compressor stations on the property increased the home value by $1,907, and ascribing attorney fees to the lessor positively impacted value by $849. Reducing a lease by 36 months reduced its value by $457 per year. This study shows the importance of negotiating lease clauses on the part of homeowners. It additionally shows how homeowners without mineral rights might be negatively impacted by a lack of beneficial lease clauses.

4. Farmland Values and Hedonic Analysis

Weber and Hitaj (2015) estimated the appreciation of land prices on farms in shale versus non-shale areas in Texas and Pennsylvania. Though the study only had quinquennial self-reported data on farm values (making controlling for unobserved factors that don't vary over time more difficult), the authors observed greater appreciation in Pennsylvania, likely related to greater mineral rights ownership. Farms in shale areas generally saw greater appreciation, nearly 50 percent more, than farms in non-shale areas. The study also reports evidence that greater appreciation occurred when land was leased and not when the booms actually occurred, which could reflect declining revenue as the productivity of wells falls after the first few years of drilling. The study found some variation in appreciation across different types of farms, with residential farms seeing greater appreciation than livestock farms, though these findings are not conclusive given the small sample size. A decline in land values below the pre-development levels could indicate a long-term externality, so updating this analysis for the more recent shale bust would help clarify these impacts. According to the authors, these results provide indirect evidence that split estates are more common in Texas than in Pennsylvania, which means it may be less likely it is that a homeowner or landowner might experience the positive effects of shale development (royalty revenue) in Texas than in Pennsylvania.

5. New York Moratorium

Boslett et al. (2016b) compared three New York counties and two Pennsylvania shale counties to estimate the impact of the fracking moratorium in New York. Analyzing properties within 5 miles of the border from 2006 to 2012 (during which the state announced a moratorium on fracking), the authors found a 23 percent drop in housing prices following the announcement of the moratorium. The authors argue that this large result reflects a change in expectations of the potential for income from shale leases and royalties following the moratorium. Another interpretation of their finding is that the control counties (i.e., the counties in Pennsylvania without the moratorium) increased in value. In other words, when comparing home prices in the two states, prices may have either decreased in New York, or increased in Pennsylvania. If home prices were gradually increasing following the discovery of shale in these counties in New York, however, and prices dropped following the announcement, the interpretation that prices in New York decreased might be plausible. Additionally, the 23 percent figure might be biased upward if the moratorium in New York caused more development in Pennsylvania—or biased downward if New York counties experienced benefits from drilling in Pennsylvania (e.g., nearby jobs or increased economic activity).

6. Rental Prices

A few studies discussed in this review conduct some analysis of housing rental rates as part of a broader assessment, but Muehlenbachs et al. (2015) is the only study we review that focused on changes in rental prices. The study constructed quantiles of shale activity to account for heterogeneous impacts and analyzed rent changes for census tracts in Pennsylvania between 2008 and 2012. The study found that the estimated effect of unconventional oil and gas development on rent was an increase of $100 per month, with an increase of more than $250 per month occurring at the highest quantiles. This study improves upon the James and James (2014) analysis (which found that shale counties experienced a 0.3 percent to 0.4 percent faster annual average growth in rental rates than other counties) because it analyzed changes between census tracts and also used a more robust econometric technique; the results are less intuitive, however, as they are reported in quantiles.

Farren et al. (2013), though not a peer reviewed study, analyzed several impacts of shale development on housing in Pennsylvania. In its analysis of Fair Market Rent (FMR)[2] data calculated by the US Department of Housing and Urban Development, the study found no strong statistical link between drilling activity and fair market rent. The method of analysis used for these results, however, is not very robust, as it compares the county's fair market rent in 2003–2007 (before shale development) to that from 2007–2011 (after shale development). Shale development could have heterogeneous impacts depending on the timing of the drilling, the drilling intensity, and other factors throughout a period of four years. Additionally, this analysis included only 144 observations (one for each county), a sample size that might be too small to detect differences; additionally, it did not control for within-county variation.

Lastly, Jacobsen (2015), analyzing the effect of the recent boom on housing prices and wages, found a modest increase in rental rates of 5 percent (and a larger increase of 12 percent in home prices) from 2007 to 2012 for "boom" non-metropolitan areas (those that experienced an increase in oil and gas

[2] The US Department of Housing and Urban Development defines the FMR as: "the 40th percentile of gross rents for typical, non-substandard rental units occupied by recent movers in a local housing market."

extraction of $500 million or more between 2006 and 2011) compared to non-boom, non-metropolitan areas. Non-boom, non-metropolitan areas are not an ideal counterfactual, as areas with less or no shale development might differ in ways that affect wage rates, housing, and rental rates for reasons not related to shale development. Furthermore, non-metropolitan areas are quite large, with 12 counties per area, on average. Analyzing such large areas does not control for or analyze variation in the impacts of energy production (which can vary substantially even between two similar homes, as much of this literature demonstrates). Furthermore, only 17 of the 160 non-metropolitan areas in the study are categorized as “boom” areas, which is quite a small sample size.

7. Tax Base Changes and Housing Prices

Weber et al. (2014), studying the Barnett shale region in Texas from 1997 to 2013, analyzes the effects on property values that result from an expansion of the property tax base associated with the increase value of oil and gas following the shale boom. The supposition is that an expansion in the tax base per capita would increase property values as the local government provides more public services or lower tax rates (or both). The change in property values would also reflect expectations about how long this tax base expansion will last, the extent of negative externalities associated with the shale development, and how effectively the local government spends this money.

The authors found that zip codes in areas with shale development had housing prices that appreciated more than zip codes in areas with no shale development, noting that “appreciation closely followed changes in the oil and gas property tax base [...] The expansion of the tax base, in turn, was associated with lower property taxes and more school revenues” (Weber et al. 2014, 3). The study did find that nearby wells drilled in the year or two before sale were associated with decreased housing values. The authors attributed the higher housing prices in zip codes with shale development to taxation of gas production because increased income from royalties is unlikely (less than 10 percent of homeowners own subsurface rights) and the large housing market in the area as well as the econometric analysis likely control for differences in levels of economic activity. The comparison across zip codes could bias the results, as zip codes with shale development might differ from those without in a way the data cannot observe, though the authors also addressed the density of drilling to help control for this issue.

8. Housing Boom

Farren (2014) is the only study in our review to assess the impacts of shale gas development on housing supply. The study covered the Marcellus shale region (in Pennsylvania, West Virginia, Ohio, and New York), the Bakken region (in North Dakota and Montana), and the Fayetteville region (in Arkansas) from 1997 to 2011. The author found that each Marcellus well, for example, is associated with 1.7 housing permits (with this value decreasing as the numbers of wells increased). The study found larger impacts in North Dakota than in Pennsylvania, with 100 wells associated with a 30 percent increase in housing construction in the Marcellus shale region and a 126 percent increase in North Dakota. Due to its methodology, the study cannot control for spillover effects from neighboring areas and, like other studies in this review, cannot differentiate among various effects related to shale development, such as increases in demand for housing from workers and decreases in demand related to disamenities.

9. Conclusion

Overall, the literature employs robust methodologies to assess the housing price impacts of shale gas development, particularly in addressing nearby development impacts. Using hedonic analysis, a number of studies are able to assess the net of the benefits (royalty and lease payments, employment, etc.) and costs (environmental disamenities, truck traffic, etc.) as perceived or anticipated by home buyers and sellers. Only one study, Boslett et al. (2016a) accounted for mineral rights ownership, finding, as expected, a much larger negative impact for homeowners without mineral rights (although the study covered Colorado, whereas most others looked at for Pennsylvania). This finding highlights the need for future research to take into account mineral rights ownership, which would enable the disentangling of the positive and negative impacts on housing prices from royalty payments and externalities, respectively. These studies are successful in analyzing the heterogeneity of these impacts (particularly for groundwater-dependent homes) and are largely conclusive in terms of how different homeowners might be affected by unconventional oil and gas developmental. Further study is needed in areas such as the changes in housing supply, rental rate changes, and impacts on different types of land.

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