United States Department of Agriculture

Unconventional Shale Gas Development and Agriculture in the Appalachian Basin Marcellus Play: Exploratory Analysis of the 2012 Census of Agriculture

Office of Energy Policy and New Uses

Office of the Chief Economist
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Abstract

This report investigates whether the recent expansion of unconventional shale gas drilling in the Marcellus play might be impacting the agricultural sector of the region. By analyzing data on nine main agricultural indicators from the 2007 and 2012 USDA National Agricultural Statistics Service (NASS) Census of Agriculture, we find a varied set of relationships between shale gas drilling and agriculture. Shale development coincides with higher farmland and farm losses as well as increases in the median farm size in shale counties, which provides some evidence of farm consolidation in shale areas. It also coincides with lower average percentage changes in hired labor and larger average percentage decreases in the number of beef farms. Counties with drilling activity have a higher average percentage increase in market value of machinery and equipment and higher average percentage changes in the market value of land and buildings per acre during the leasing period, which is only slightly eroded during the drilling period. However, patterns that emerge across all counties of the Marcellus region do not necessarily hold for individual States or Land Resource Regions. For example, the farm size in Pennsylvania is not different between drilling and non-drilling counties. In some cases, the disaggregate analysis provides more clarity. For example, a negative relationship between drilling and dairy farming is revealed at the regional level, but the phase out from dairy to beef farming can only be explained by the trends in Ohio, Northern Atlantic and, potentially, Northern regions. Our study highlights the diversity of impacts among regions, as drilling and agricultural production depend upon a multitude of individual and collective decisions, as well as such factors as climate and geography.

I. Introduction

Unconventional gas development is changing the energy landscape of the United States and is having pronounced effects in rural and remote local communities. Among the productive shale gas plays in the United States, the Marcellus Shale Natural Gas play is the largest producing basin as of 2013, with over 34.5 percent of the U.S. shale gas production (US EIA, 2016). The Marcellus play also accounts for the largest share of shale gas reserves, totaling 43.5 percent of U.S. recoverable reserves (US EIA, 2015). It is located in the Appalachian Basin and primarily overlays New York, Ohio, Pennsylvania, and West Virginia.

Due to the transformative nature of the unconventional gas industry, particularly in rural regions where agriculture can be a key economic sector, and the considerable number of wells drilled on agricultural land, it is important to determine if and how unconventional gas development is changing agriculture. Characteristically, Drohan et al. (2012) showed that 54 percent of permitted well pads in Pennsylvania until 2011 were on agricultural land, and around 41percent were on private forest land, which showcases the link of farming to shale development. Due to the recent increases of gas drilling and production in the Marcellus, and most importantly the long-term potential of the play, the shale gas industry has the potential to have a lasting influence on agricultural activity in the Marcellus region.

The four States in the Marcellus region —New York, Ohio, Pennsylvania, and West Virginia— comprise a small but diverse subsection of the national agriculture sector. Agriculture in the region accounts for a significant share of total output, and it is a major source of local foods for northeast markets and an important source of household livelihood. The four States accounted for 9.09 percent of the 2,109,303 farms in the United States in 2012, and produced 6 percent of the total U.S. market value of agricultural products sold, with 5.54 percent and 6.54 percent of crops and livestock respectively (NASS, 2012). Among the States in the Marcellus region, farming varies by size, scale, and type. Ohio ranks 13th in terms of total market value of products sold, New York and Pennsylvania rank in the mid-20s, and West Virginia ranks lowest at 41st. Ohio and Pennsylvania have the largest number of farms. New York and Pennsylvania receive the largest share of market value of products sold from cow's milk, Ohio from grains, and West Virginia from poultry and eggs.

Shale gas drilling and production may affect agriculture through many channels and throughout different stages of development. Drilling sites require acreage clearing for well pads, access roads, and pipelines (Adams and Kelsey, 2012; Glenna et al., 2014), and farms might see up to a 5-year decline in production or yields after infrastructure installation (Seachrist, 2011). According to Drohan et al. (2012), at least 1,600 to 2,600 acres of agricultural land and 1,300 to 2,200 acres of forest land were removed for wells that were permitted in Pennsylvania until 2011. Flowback from unconventional drilling creates a potential risk of contaminated runoff (Olmstead et al., 2012). Additionally, wells drilled in inappropriate locations can disrupt the land, obstruct farm operations, or alter how water flows through fields. While farmers who own gas rights might influence infrastructure placement, those without gas rights or farmers who lease land often cannot influence it (Drohan et al., 2012).

Farmers who own the gas rights on their farms also have the possibility of receiving leasing payments from energy companies, as well as royalty payments if drilling occurs, providing supplemental income during the stages of exploration, drilling, and production. Anecdotes from the farm community in these States suggest that some farmers are using this supplemental income to pay off farm loans, expand their operations, buy or repair equipment, or erect new farm buildings (Seachrist, 2011, Brasier et al., 2014).

High water needs for hydraulic fracturing can lead to competition for water with agriculture. However, unlike water-scarce regions such as Texas and Oklahoma, such pressures are less of a concern in the water-rich Marcellus region. Agriculture can face increased competition for other inputs as well, like hay and labor. Glenna et al. (2014) noted shortages in some farm inputs (e.g., lime) and difficulty of retaining farm labor due to Marcellus development. Farmers are considered good candidates for employment in the Marcellus natural gas and supporting industry (Seachrist, 2011). In the Bakken region, local farm labor has become hard to find, and farmers are increasingly relying on foreign labor under H-2A visas (Deede, 2014).

The shale development can also impact how the types of agriculture and economic activity evolve. For example, dairy farms may switch from milk cows to types of agriculture that are less demanding, or farmers might decide to not plant and instead invest funds in other ways (Seachrist, 2011). Concerns about preserved air and water pollution on animal health or certain types of agriculture (e.g., organic) can also affect farmer choices. Most importantly, future expectations about farming can affect the long-run composition of activity as the new generation of farmers contemplates options in the changing economic environment of the Marcellus region.

We evaluate the impacts of unconventional gas development on farming for the Marcellus region (New York, Ohio, Pennsylvania, and West Virginia) during the main period of unconventional shale gas development (2007-2012). Specifically, we characterize the relationship between unconventional gas drilling activity and nine agricultural indices in the Marcellus region using data from the two most recent Censuses editions of the U.S. Department of Agriculture, National Agricultural Statistics Service (NASS) Census of Agriculture and well-spud data from the Ohio Department of Natural Resources (ODNR), Pennsylvania Department of Environmental Protection (PA DEP), and West Virginia Geological & Economic Survey (WV GES) covering the period from 2002 through 2012. While wells are spudded when drilling starts, not all spudded wells come online. The indicators examined include the number of farms, the market value of agricultural products sold, land in farms, the median size of farms, the number of dairy farms, the number of beef farms, the hired labor, the market value of land and building per acre, and the market value of machinery and equipment per farm. Farming and drilling varies across the Marcellus region, and the impacts of unconventional shale gas development will also vary due to local factors. To this effect, the impacts of unconventional shale gas development are examined for different levels of drilling activity and different spatial outlays.

II. Study Approach

To evaluate the impact of unconventional shale gas development on agriculture, changes in key indicators of agricultural activity between 2007 and 2012 are assessed in relation to the level of Marcellus Shale drilling. These changes are examined across the region as a whole, across States, and across Land Resource Regions. Examining these changes over time, in relation to differing levels of activity and for multiple groupings, allows the analysis to consider multiple influences on farming and farm owners.

Non-drilling counties are compared to counties with drilling (at least one well drilled) and counties with considerable drilling (more than 20 wells drilled). Disaggregated categories of counties with drilling are also explored. To account for the effects of drilling intensity, drilling counties were categorized into one of three types based on the number of unconventional gas wells drilled between 2002 and 2012. The categories are loosely based upon the quartiles of unconventional wells drilled when considering only counties with wells drilled (Table 1). The categories include: (1) counties with 1 to 20 wells (median well count, rounded up); (2) counties with 21 to 80 wells (median to third quartile); and (3) counties with 81 or more wells drilled between 2002 and 2012 (third quartile to max). We can also think of the drilling categories as describing drilling exposure. The first category is comprised of counties with limited drilling, for example where some test wells were drilled but were not further developed, or have just recently started drilling. The second category is comprised of counties that have moderate levels of drilling, while the last category covers counties with extensive amounts of drilling. All else equal, one might expect the counties with the most drilling to be the most likely to see significant changes in agriculture due to shale gas development.

Table 1. Marcellus Region Summary of Unconventional Drilling (2002-2012)

	All Counties	Counties With Drilling
Number of Counties	272	103
Average Wells Drilled per County	32.1	84.8
Standard Deviation	119.0	182.0
Minimum	0	1
First Quartile	0	3
Median	0	18
Third Quartile	6	78.5
Maximum	1,121	1,121

Analysis of the counties was conducted from three spatial perspectives: (1) for the whole region; (2) by State, to reflect State-level differences in agriculture, energy development, and policies affecting unconventional gas development; and (3) by Land Resource Region (LRR), to capture significant geographic and agronomic differences across the land and to reflect topological differences in agriculture and industry composition.

We focus on county-level data from the 2007 and 2012 Census of Agriculture data to compare various indicators of agricultural activity before and after the onset of drilling activity. These 2 years were selected because they represent the most recent census data collection years and the 5-year time span corresponding to increased shale gas drilling activity in the Marcellus region. To compare outcomes from 2007 and 2012, we calculate the percentage changes (e.g., "5%") in outcomes for every county and then average the county-level percentages for each study region. The analysis of average percentage changes helps demonstrate the magnitude of the changes and allows the comparison of multiple agricultural outcomes in different regions with a common denominator (e.g., number of farms and land in farms).

The period 2007-2012 we examine throughout the study corresponds to the period of intense drilling. However, for the market value of land and buildings per acre, we also evaluate changes between 2002 and 2007, which corresponds to the leasing period during which Weber and Hitaj (2014) identified that most of the appreciation occurred.

Of the 272 counties in the study region, 103 (37.87 percent) counties have at least one spudded unconventional well (Table 1). Through the end of 2012, 8,738 unconventional wells were drilled. The average number of wells among counties with drilling is almost 85, while the median number of wells was 18. The largest number of wells in a single county was 1,121 wells drilled in Bradford County, Pennsylvania. The breakdown of counties in each State and LRR by drilling activity appears in Tables 2 and 3 respectively.

Table 2. Counties by Drilling Activity, by State (2002 – 2012)

Number of Wells	All States		New York		Ohio		Pennsylvania		West Virginia	
0	161	(61%)	55	(100%)	69	(78%)	27	(41%)	10	(18%)
1-20	54	(20%)	0	(0%)	16	(18%)	15	(23%)	23	(42%)
21-80	23	(9%)	0	(0%)	2	(2%)	11	(17%)	10	(18%)
81+	26	(10%)	0	(0%)	1	(1%)	13	(20%)	12	(22%)
All Counties	264	(100%)	55	(100%)	88	(100%)	66	(100%)	55	(100%)

Table 3. Counties by Drilling Activity, by Land Resource Region (2002 – 2012)

Number of Wells	All Regions		Central Feed Grains and Livestock		East and Central Farming and Forest		Lake State Fruit, Truck Crop and Dairy		Northeastern Forage and Forest		Northern Atlantic Slope Diversified Farming	
Location			*W- OH*		*SE- OH W- PA WV*		*Mid NY N- OH*		*NY N- OH N- PA*		*E- PA NE- WV*	
0	161	(61%)	37	(95%)	19	(20%)	25	(100%)	49	(73%)	31	(78%)
1-20	54	(20%)	2	(5%)	33	(35%)	0	(0%)	11	(16%)	8	(20%)
21-80	23	(9%)	0	(0%)	20	(22%)	0	(0%)	2	(3%)	1	(3%)
81+	26	(10%)	0	(0%)	21	(23%)	0	(0%)	5	(7%)	0	(0%)
All Counties	264	(100%)	39	(100%)	93	(100%)	25	(100%)	67	(100%)	40	(100%)

Only in the 2 regions with the most drilling activity is there more than 1 county with more than 81 wells. In Ohio, 3 counties have over 20 wells and 1 county had over 80 wells. Two counties in the Central Feed Region had up to 20 wells drilled, and 1 county in the Northern Atlantic Slope Region had over 20 wells. Due to these limited observations, caution must be exercised when interpreting results relative to these categories. While the results for these categories are noted in light gray in the tables, no further discussion for these categories is offered.

Counties with a limited number of farms were excluded from the study, since small changes in these counties can result in large percentage changes (e.g., a county with four farms, where one of those farms stops operating, experiences a 25-percent loss in the number of farms). The excluded counties had no unconventional gas wells drilled and fewer than 25 farms for either 2007 or 2012; they consisted of 7 counties in New York (Bronx, Hamilton, Kings, New York, Queens, Richmond, and Rockland) and 1 county in Pennsylvania (Philadelphia). Most of these counties lay within the large Metropolitan areas near New York City and Philadelphia. Hamilton is the only county in a non-metropolitan area.

III. Variables Studied

We examine nine indicators of agricultural activity, including the number of farms, the market value of agricultural products sold, the market value of agricultural products sold per farm, land in farms, the median size of farms, the number of dairy farms, the number of beef farms, hired labor, the market value of land and building per acre, and the market value of machinery and equipment per farm. For individual indicators, we also compare the market value of agricultural products sold to the market value of agricultural products sold per farm, the hired labor to hired labor per farm, and the market value of machinery and equipment per farm to the total market value of machinery and equipment (Table 4).

Land in farms (*land*) represents how much land within a county is dedicated to agriculture and serves as an overall indicator of agricultural activity within a county. The number of farms (*farms*) serves as an overall indicator of agricultural activity, and the market value of agricultural products sold (*mvps*) also measures the size of the overall farm economy within a county. The market value of agricultural product sold per farm (*mvps/f*) clarifies if changes are due to changes in farms or changes in products sold. The median size of farms (*size*) captures the size in acres of the median farm (the middle farm if farms are ordered from smallest to largest). Changes in median farm size could indicate that farming is becoming either larger scale or more industrialized if the median size increases (such as if large farms are buying more land, or smaller farmers are going out of business), or smaller scale if the median size decreases.

The number of dairy farms (*dairy*) is evaluated given that dairy farming is an important agricultural sector for New York and Pennsylvania. Both States receive the largest share of market value of agricultural products sold from milk and products from cows. Because dairy farming is particularly labor and time intensive, dairy farmers who receive supplemental income from natural gas extraction may be more likely than other famers to change primary products or end production all together. Adams and Kelsey (2012) found that intensity of gas drilling and decline in dairy cow numbers seem to be associated. Finkel et al. (2013) found that milk production and milk cows decreased more in 5 counties with over 100 wells compared to 6

adjacent counties with fewer than 100 wells drilled from 2007 through 2011 (coinciding with the rapid expansion in unconventional drilling). While beef farming is not a prominent agricultural sector in the Marcellus region, prior research by Glenna et al. (2014) suggests that dairy farmers who consider either downsizing their operations or leaving dairy farming altogether first convert to beef farms as a common practice prior to any further changes. Due to the importance of dairy farming in New York and Pennsylvania, examining the trends in the numbers of beef farms (*beef*) allows us to consider if this "phasing-out" process is occurring at the county level.

We also examine changes in the number of hired labor on farms (*labor*); since drilling can be labor intensive, it is possible that this could create frictions in local labor markets. The natural gas industry can affect local wage rates as it competes to hire skilled workers, making it difficult for farmers and others to retain their workforce (Hitaj et al., 2014). In addition, some farmers may want to hire additional employees but are unable to compete with the higher wages offered by the gas industry. Hired labor per farm (*labor/f*) clarifies whether changes are due to changes in the number of farms or changes in hired labor.

Table 4. Study Variables

Variable	Abbreviation
Land in farms	land
Number of farms	farms
Market value of agricultural products sold	mvps
Market value of agricultural product sold per farm	mvps/f
Median size of farms	size
Number of dairy farms	dairy
Number of hired laborers	labor
Number of hired laborers per farm	labor/f
Market value of land and building per acre (for 2007-2012)	mvlb/a
Market value of land and building per acre (for 2002-2007)	mvlb/a (02-07)
Market value of machinery and equipment per farm	mvme/f

All variables are examined for 2007-2012.
The market value of land and building per acre is also examined for 2002-2007.
Source: 2002, 2007, 2012 Census editions of the U.S. Department of Agriculture, National Agricultural Statistics Service (NASS), Census of Agriculture.

Finally, we examine the market value of land and building per acre (*mvlb/a*) and the market value of machinery and equipment per farm (*mvme/f*), because increased farm wealth from shale development can lead to investments in the form of building additions or improvements and purchases of farm machinery and equipment. Most importantly, if a farmer owns the mineral rights on his or her property, the farmer could capitalize those mineral rights into the property value, increasing the market value of land and buildings. However, mineral rights can also be severed from the land, in which case the farmer who owns the land would receive no benefits in the way of lease and royalty payments. Furthermore, land fractionation and other externalities can possibly decrease property values. These influences will differ by geography and jurisdiction based on topography, farm production, and mineral rights history. For example, a history of prior gas and oil development could indicate a higher probability of severed mineral rights; thus,

changes in the East and Central region, where mining has been a central activity for decades, will likely differ from changes in the Northeastern region, where mineral rights are not typically severed from surface rights. The period 2007-2012 that we examine throughout the study corresponds to the period of intense drilling; however, Weber and Hitaj (2014) examined four drilling counties in Pennsylvania and identified that most of the appreciation occurred during the leasing period which corresponds more closely to 2002-2007. Hence, for this variable we examine both periods (*mvlb/a* for 2007-2012 and *mvlb/a (02-07)* for 2002-2007).

We exclude the property taxes paid from our analysis; although Ohio and West Virginia levy a property tax on gas and oil, Pennsylvania does not. Additionally, we do not explore acres irrigated. Despite the large water needs of hydraulic fracturing, irrigation is not a significant part of agriculture in the Marcellus region.

IV. Study Region

Our study focuses on four States —New York, Ohio, Pennsylvania, and West Virginia —for the period 2007-2012. Although exploratory wells were drilled shortly after 2002, it was not until around 2007 that drilling reached significant levels. West Virginia was the first State to have a sizeable number of spudded wells, followed closely by Pennsylvania (West Virginia surpassed 80 cumulative spuds in 2005, while Pennsylvania passed this threshold during 2007). Ohio lagged behind the other two States in drilling, surpassing 80 cumulative spuds during 2012. Although New York had some exploratory unconventional drilling in counties along its southern border with Pennsylvania, the moratorium placed on hydraulic fracturing effectively stopped unconventional gas development in New York, and our analysis assumes no production-oriented unconventional drilling has occurred within the State.[1]

Pennsylvania has the most unconventional drilling activity, accounting for about 71 % of all such drilling in the four-State region (Table 4). West Virginia had about 25 percent of all unconventional wells, while Ohio had about 3 percent of the total share of unconventional gas wells. The region produced 2,395 billion cubic feet of natural gas from shale in 2012 (U.S. EIA, 2016). Pennsylvania produced about 85 percent of total regional output, West Virginia slightly over 14 percent, and Ohio less than 0.01 percent. Table 4 summarizes the number of wells by county. In terms of counties in each State affected by the industry, West Virginia had a larger share of counties with unconventional wells (82 percent) than Pennsylvania (52 percent) and Ohio (22 percent). A detailed exposition for each State is available in Appendix A.

Figure 1 shows the number of unconventional wells drilled across the study region between 2002 and 2012. The counties shaded the darkest purple had at least 81 wells drilled during the study period, while the medium purple had 21 to 80 and the lighter purple had 1 to 20 wells drilled. Most of the unconventional gas wells are spudded in an arc from southern West Virginia through southwestern Pennsylvania to the northern tier of Pennsylvania. Within individual States, the majority of wells drilled are concentrated in a relatively small number of counties, rather than

[1] Due to public health and water concerns associated with unconventional drilling, New York placed a hold moratorium on unconventional drilling development in 2009 and subsequently formally banned hydraulic fracturing during late 2014.

being evenly distributed across the State. This results in counties with extensive unconventional drilling being clustered together.

Table 5. State Summary of Unconventional Drilling (2002 – 2012)					
	All States	New York	Ohio	Pennsylvania	West Virginia
Drilling Counties	103	0	19	39	45
Non-Drilling Counties	169	62	69	28	10
Total Counties	272	62	88	67	55
Drilling Counties %	37.9%	0%	21.6%	58.2%	81.8%
Total Wells Drilled	8,738	0	238	6,230	2,270
Total Wells Drilled %	100%	0%	2.7%	71.3%	26.0%
Year of Drilling Onset*	2005	-	2012	2007	2005

*Defined as the year when cumulative unconventional wells drilled is greater than 80.
Sources: Ohio Department of Natural Resources; Pennsylvania Department of Environmental Protection; West Virginia Geological & Economic Survey

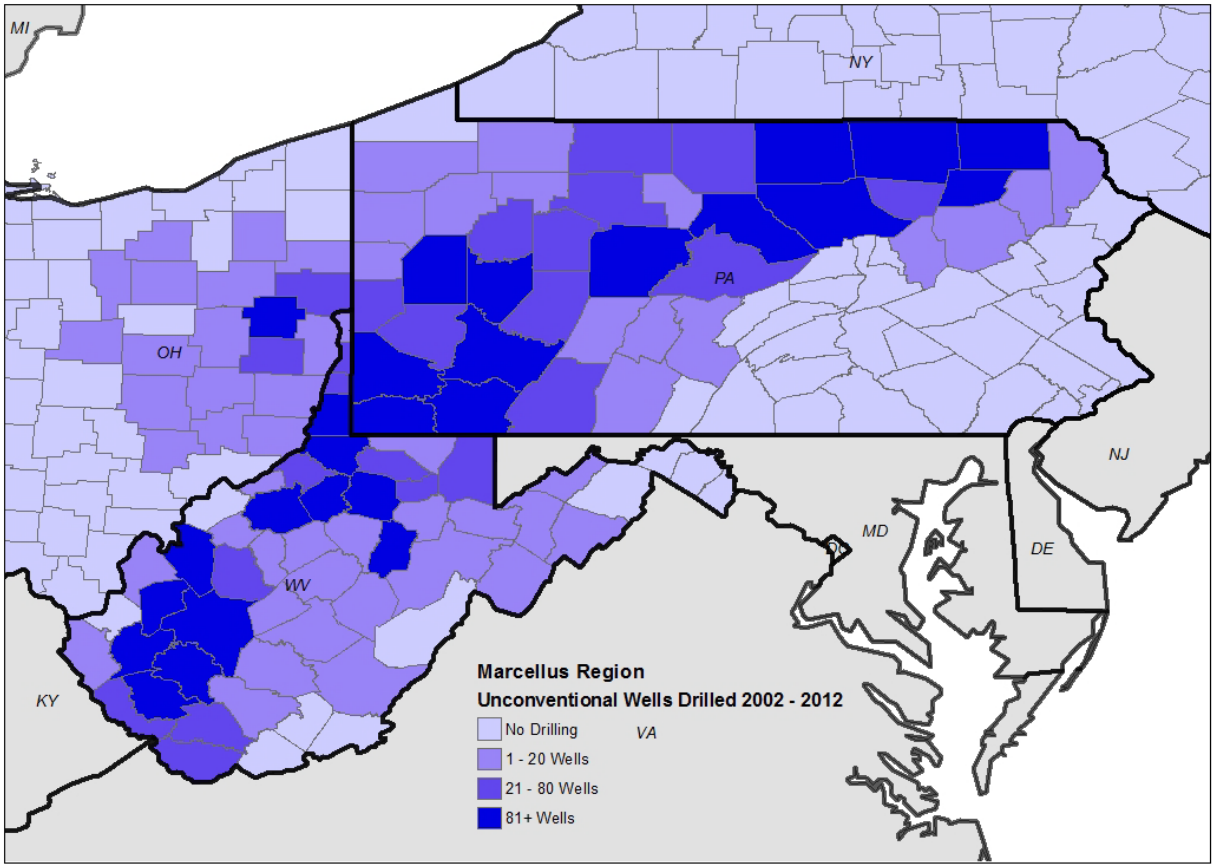

Figure 1. Unconventional Shale Gas Wells Drilled by County (2002-2012). Sources: Ohio Department of Natural Resources; Pennsylvania Department of Environmental Protection; West Virginia Geological & Economic Survey.

The Marcellus region features varied terrains, soil types, and climates. These ecological variations result in distinct patterns of agricultural production. Such differences are not confined to State boundaries, so we also consider the five LRRs that span the Marcellus region (Figure 2). The LRR classifications were developed by the USDA's Natural Resources Conservation Service and recognize key agro-ecological differences in topography, farm size, farm type, and production. Table 5 summarizes the key features of the Land Resources Regions in the Marcellus region.

Nearly all of the unconventional wells drilled in the Marcellus region have been in two LRRs, the East and Central Farming and Forest Region and the Northeastern Forage and Forest Region, with 59 percent and 40 percent of total wells drilled, respectively (Table 6). This encompasses Southeastern Ohio, Western Pennsylvania, and most of West Virginia, as well as Northeastern Ohio, Northern Pennsylvania, and most of New York. Only a relatively small number of wells have been drilled in the other LRRs, spread among a relatively small number of counties.

Table 6. Descriptions of Land Resource Regions

	Land Resource Region				
Characteristics	**Central Feed Grains and Livestock Region**	**East and Central Farming and Forest Region**	**Lake State Fruit, Truck Crop, and Dairy Region**	**Northern Forage and Forest Region**	**Northern Atlantic Slope Diversified Farming Region**
Geographic Region	Western Ohio	Southeastern Ohio, Western Pennsylvania, most of West Virginia	Northern Ohio, Mid New York	Northeastern Ohio, Northern Pennsylvania, most of New York	Eastern Pennsylvania, Northeastern West Virginia
Land type and Elevation	Nearly level to gently sloping	Varied: steep Appalachian Mountains to gently rolling plateaus	Gently sloping	Plateaus, plains, and mountains	Piedmont, ridges and valleys
Agricultural Climate	Favoring agriculture	Hardwood forests: 75% of area	Favoring agriculture	Much of the land is forested	Favoring Agriculture
Types of Agriculture	Corn, soybean, and feed grain	Forestry important, farm income largely from beef and dairy farming, supported by hay and pasture	Dairy important, fruits, wine grapes	West: Feed grains (corn and soybeans) and forage for dairy cattle. East: hay, pasture, grain for dairy cattle	Farming is highly diversified with many large-scale farms

Source: Regional descriptions are adapted from USDA, 2006

Table 7. Land Resource Region Summary of Unconventional Drilling (2002-2012)						
	Land Resource Regions					
	All Regions	Central Feed Grains and Livestock	East and Central Farming and Forest	Lake State Fruit, Truck Crop and Dairy	Northeastern Forage and Forest	Northern Atlantic Slope Diversified Farming
Geographic Location		W- OH	SE- OH W- PA WV	Mid NY N- OH	NY N- OH N- PA	E- PA NE- WV
Drilling Counties	103	2	74	0	18	9
Non-Drilling Counties	169	37	19	25	53	35
Total Counties	272	39	93	25	71	44
Drilling Counties %	37.9%	5.1%	79.6%	0%	25.4%	20.5%
Total Wells Drilled	8,738	2	5157	0	3,499	80
Total Wells Drilled %	100%	0.02%	59%	0%	40%	1%
Year of Drilling Onset*	2005	-	2005	-	2008	2012

*Defined as the year when the number of cumulative unconventional wells drilled is greater than 80.
Sources: Ohio Department of Natural Resources; Pennsylvania Department of Environmental Protection; West Virginia Geological & Economic Survey

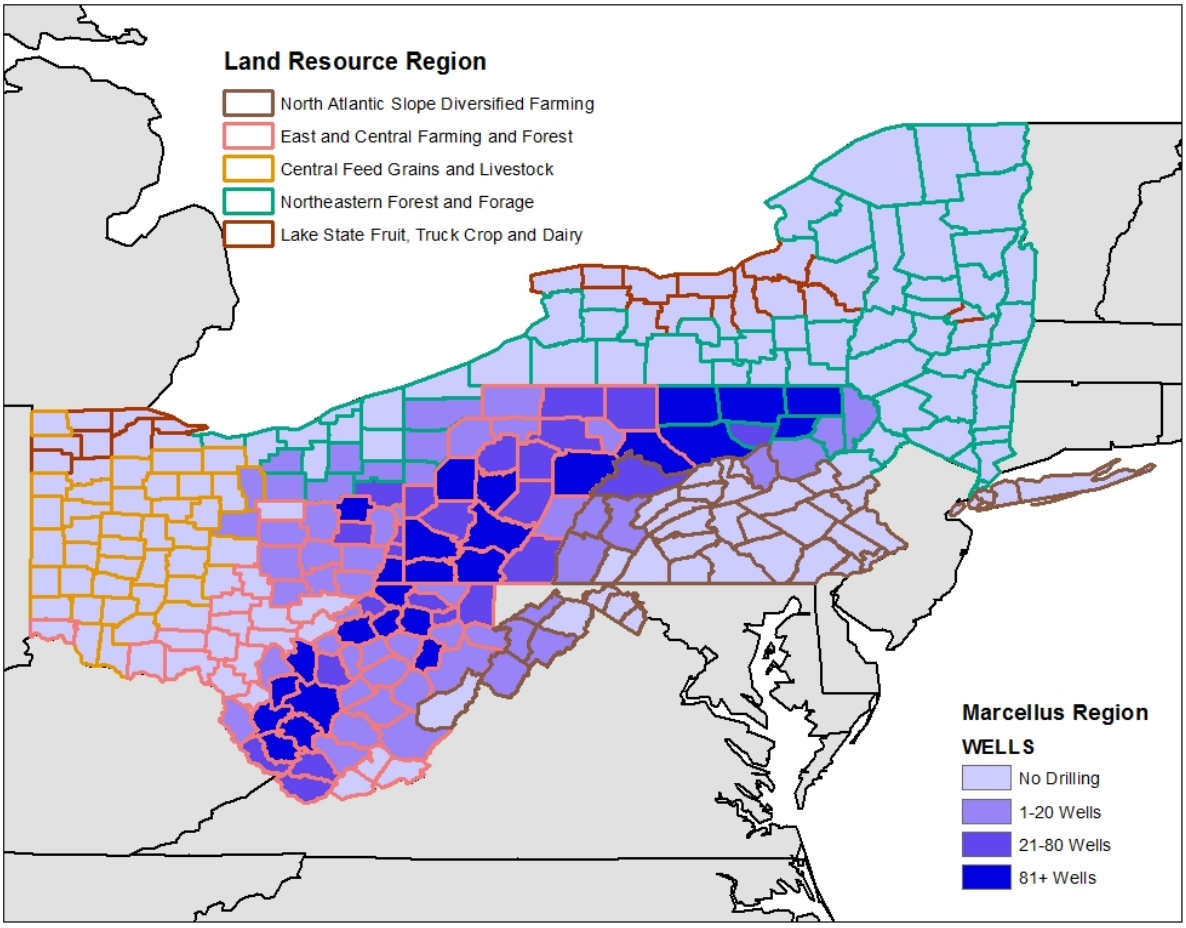

Figure 2. USDA Land Resource Regions. Source: USDA's Natural Resources Conservation Service.

V. Results Summary and Implications

A number of relationships emerge between agriculture and shale gas development from the comparative analysis of counties without drilling to different categories of counties with drilling. Summary results are discussed below, while the detailed analysis is presented for each indicator of agricultural activity in Appendix B. The examination across all counties in the Marcellus region is summarized in Figures 3 and 4: Figure 3 shows differences between counties with and without unconventional shale gas[2] activity, while Figure 4 details how the impact relates to drilling intensity. For the disaggregate State and LRR analysis, comparative graphics are displayed only for the States and regions with the most wells. Figures 5 and 6 present the respective results in terms of drilling and drilling intensity for Pennsylvania (6,230 wells) and

[2] Counties without drilling are compared to counties with any amount of drilling (1+ wells) and to counties with considerable drilling (21+ wells).

West Virginia (2270 wells), and Figures 7 and 8 present the same results for the Central (5,157 wells) and Northeastern (3,499 wells) regions.

Across all counties in the Marcellus region, the loss in farms is greater in regions with more drilling. While land in farms is increasing for counties without drilling, it is decreasing for counties with drilling (Figure 3). The percentage decreases in both farms and farmland are larger in counties with more wells drilled (Figure 4). The median farm size, on the other hand, shows a comparatively higher average increase in drilling counties. The higher increase in the median farm size, combined with the higher decrease in the number of farms may suggest that smaller farms are particularly disproportionately exiting agriculture or that consolidation is occurring in the agricultural sector —as some farms are exiting agriculture, remaining farms are likely buying farmland from their neighbors. Counties with no unconventional drilling activity experienced, on average, larger percentage increases in the value of agricultural sales than counties with drilling (Figure 3). However, no distinction emerged for the per farm value of agricultural sales between drilling and non-drilling counties, suggesting that, in general, reductions in the market value of agricultural sales stem from farm decreases, not reductions in per farm sales. For drilling counties, no distinct differences emerged based on the intensity of drilling activity (Figure 4).

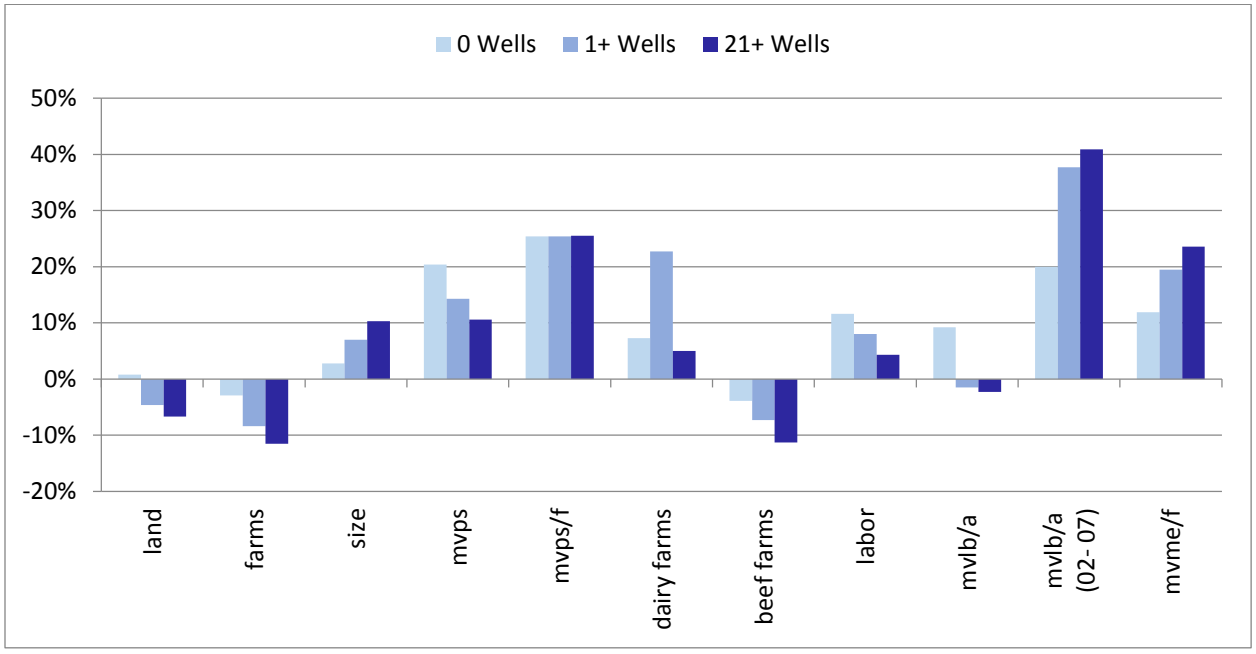

Figure 3. Shale and Non-Shale County Comparisons of Agricultural Index Changes Across the Marcellus Region (2007-2012). Table 4 expands on variable names.

This analysis finds no evidence that farmers across the Marcellus region are shifting from dairy farming to beef farming. Drilling counties experienced larger average percentage decreases in the number of beef farms. No clear pattern was revealed between changes in dairy farm numbers and drilling activity, probably due to the large percentage changes in West Virginia (Figure 5). Counties with drilling are also shown to have lower average percentage changes in hired labor and hired labor per farm. The study finally finds that drilling activity is associated with increases in land values and capital investments for drilling counties. Counties with drilling activity have a

higher average percentage increase in market value of machinery and equipment compared to counties without drilling. In addition to increased capital investments on farms, this could also point to the fact that, among drilling counties, smaller farms are ceasing operation, while surviving operations are larger and more capital-intensive operations. Similarly to Hitaj and Weber (2014), the study finds that for most of the Marcellus region, counties with more drilling had higher average percentage changes in the market value of land and buildings per acre over the leasing period (2002-2007), with 20 percent for non-drilling counties versus 41 percent for counties with over 80 wells. This impact is slightly eroded during the drilling period (2007-2012), during which counties with no drilling saw an average increase of 9.2 percent, while counties with higher levels of drilling saw an average percentage decrease of 1.5 percent.

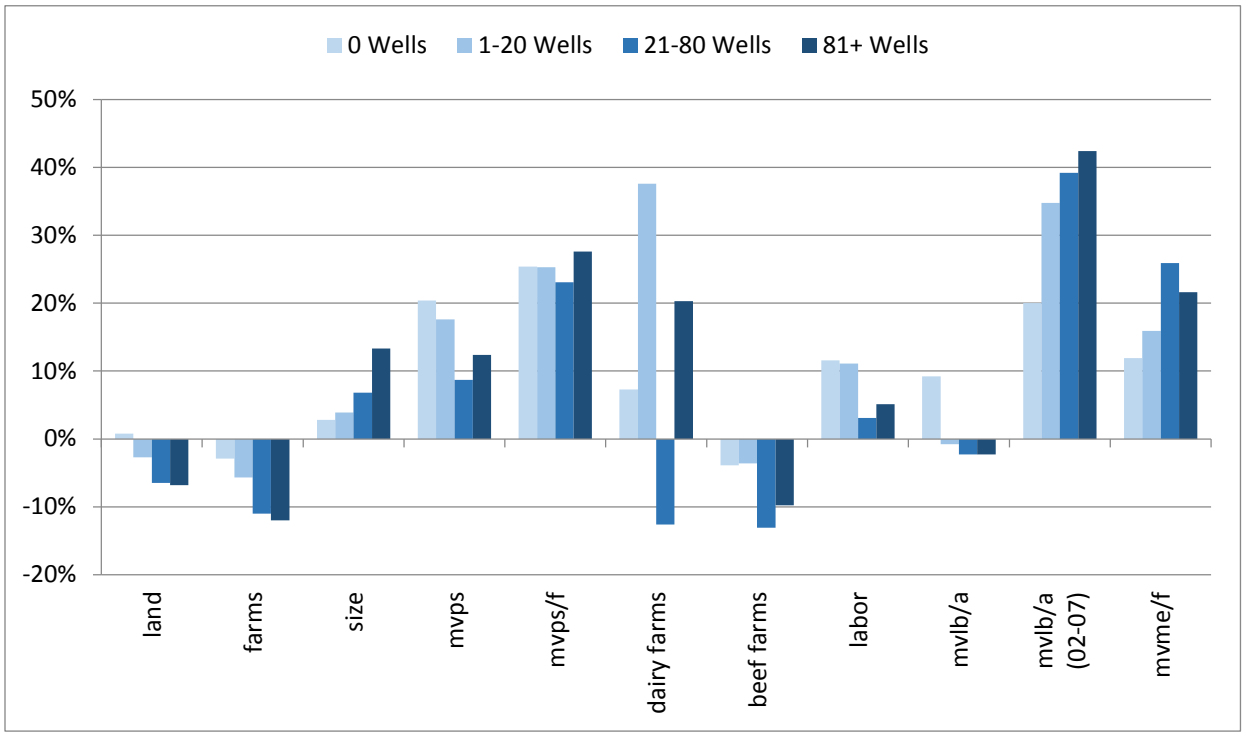

Figure 4. Comparisons of Agricultural Index Changes Across the Marcellus Region by Drilling Intensity (2007-2012). Table 4 expands on variable names.

A disaggregated analysis at the State and LRR levels provides more insights. Distinct trends are identified in at least one State or LRR in most cases. Indeed, only in the case of land and the total market value of agricultural products are trends similar across all three States, and only in the case of the per farm value of machinery and the per acre value of land for 2002-2007 are trends similar to the above general trends across every LLR. District characteristics in shale development, relevant policies, agriculture, topology, and history can lead to distinct patterns in States and LRRs. While Hitaj, Boslett, and Weber evaluate the shale development of oil and gas in agriculture across all counties in south-central United States and the western Plains, they accept that impacts can vary substantially at the regional, local, and even farm levels.

Pennsylvania had the most unconventional shale gas wells through 2012 (6,230). In addition to wells drilled, Pennsylvania produced the most shale gas, leading to the potential for large lease

and royalty payments that could accrue to farmers. In West Virginia, the number of wells drilled was approximately a third of those in Pennsylvania. Considering the fact that overall agricultural output is much smaller in West Virginia, drilling could have more extreme impacts in the State versus the Marcellus region as a whole. The onset of drilling came much later in Ohio (2011), and as of 2012 we may have not yet fully seen the effects of shale gas development there. Additionally, there are only few counties with extensive drilling in Ohio, and the potential amount of drilling activity near farms is limited.

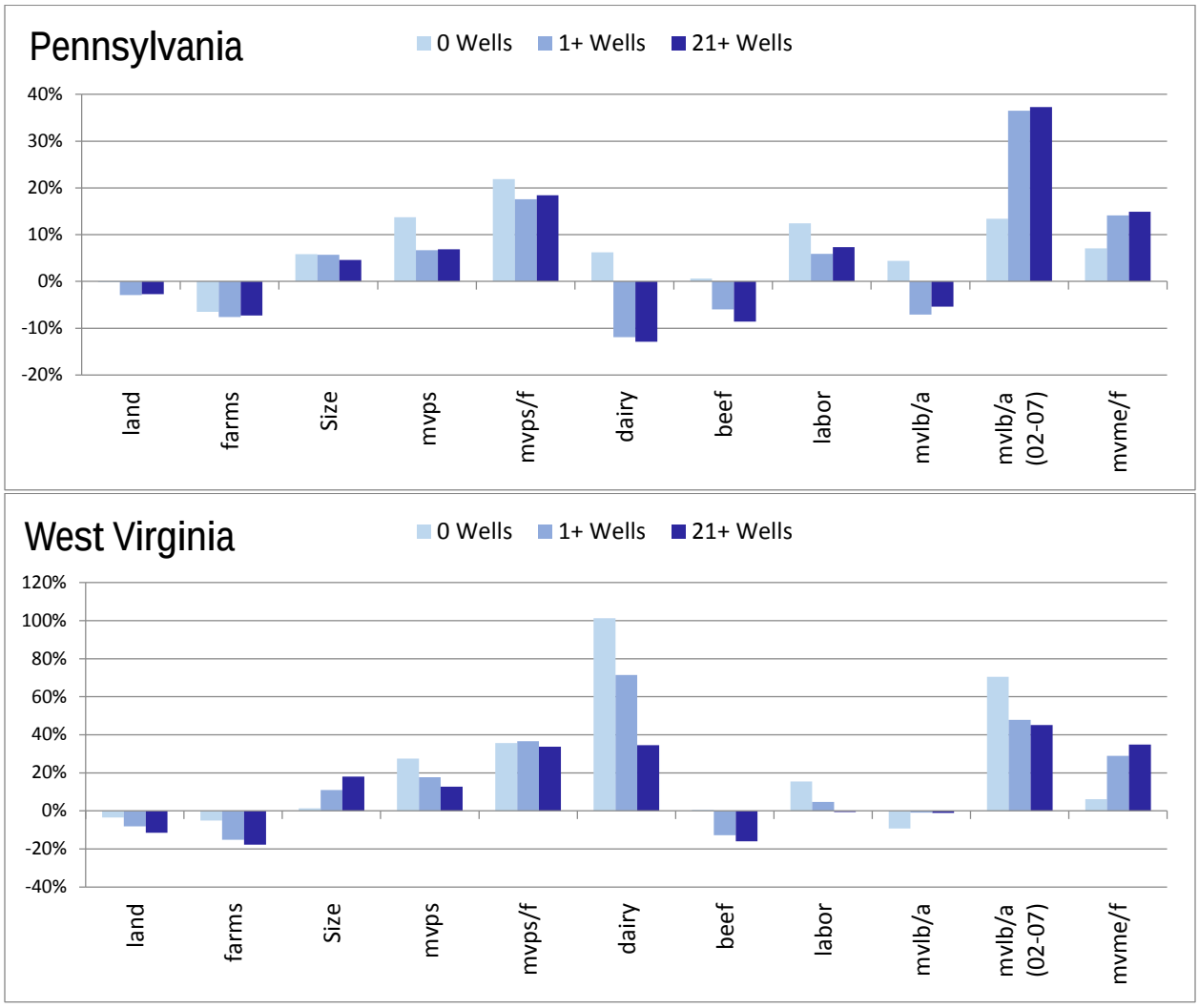

Figure 5. Shale and Non-Shale County Comparisons of Agricultural Index Changes for Pennsylvania and West Virginia (2007-2012). Table 4 expands on variable names.

The East and Central region, where farm income is predominately from beef and dairy farming and forestry is important, had the most unconventional gas wells drilled in the Marcellus region at 5,157 and the longest exposure to drilling activity. This region has had conventional gas and oil drilling, as well as coal production, in the past and likely a history of severed mineral and surface rights. The Northeastern region, with agricultural activities in hay, forage, and feed for dairy cattle, had 3,499 wells drilled through 2012, the second highest for the LRRs. There was no

large-scale conventional gas and oil drilling in the Northeastern region prior to Marcellus shale development. This increases the likelihood that mineral rights remained under the ownership of landowners. Consequently, there could be large lease and royalty payments to farmers within this region, possible having significant influence on agricultural decisions. Additionally, owners with intact subsurface rights might influence infrastructure placement, but those without those rights often cannot (Drohan et al., 2012). The Northern Atlantic region, which favors agriculture, had 80 wells drilled, with the majority of those wells being in one county and the remaining distributed among eight counties.

In the case of dairy and beef farms, the disaggregate analysis provides for a more informative evaluation. Although a simple examination across all counties determined no clear pattern between changes in dairy farm numbers and drilling activity, at the State level, a negative relationship between drilling and dairy farming is revealed for Ohio and Pennsylvania (this relationship becomes stronger for higher levels of drilling). The LLR examination also confirms this negative relationship with the exception of the Northern Atlantic region. Average percentage changes are positive for non-drilling counties in every State and LRR except New York, Lake State region, and Northeastern region.

Additionally, the analysis across all counties is unable to support a phase out from dairy to beef farming. However, in Ohio and the Northeastern region, trends of higher decreases of dairies in drilling counties are accompanied by sequential increases in beef farms. As suggested by Glenna et al. (2014), phasing out of dairy farming may begin with conversion to beef farming. In the Northeastern region, drilling counties show lower increases in dairy farms and average increases in beef farms in most drilling counties, which can also be explained by such a phasing-out process.

In the case of the per farm market value of agricultural products sold, the State and LRR examinations further confirm the absence of a consistent relationship with drilling activity. Increases are similar between drilling and non-drilling counties across all counties in the region. At the disaggregate level, the average increase is higher in non-drilling counties for the Northeastern region and Ohio; the reverse is true for the Northern Atlantic, East and Central regions and West Virginia.

Ohio exhibits distinct trends, in most cases, relative to the Marcellus region, Pennsylvania, and West Virginia for farms, median farm size, beef farms, labor, market value of machinery per farm, and market value of land per acre for 2002-2007. Drilling in Ohio is more recent (2011 onset) and compares to just one-tenth of drilling in West Virginia. The Northern Atlantic region, where drilling remained very limited since it started in 2010, also has distinct trends relative to the above general trends in the Marcellus region in every case except for the per farm value of machinery and the per acre value of land for 2002-2007 (similar for every region) and for labor. Nonetheless, trends are similar to the Northeastern region for farm land and the east and Central region for the per farm market value and the market value of land for 2007-2012.

Pennsylvania and West Virginia follow the general trends in most cases (Figure 5). Only in the case of per farm market value and the number of dairy farms, Pennsylvania and West Virginia have distinct trends relative to those across all counties. Additionally, in terms of farm size, no distinct pattern emerges for Pennsylvania, while in West Virginia and across the Marcellus

region, the average increase in the median size is higher for drilling counties relative to non-drilling counties. In West Virginia, the trends are also distinct in the case of land values per acre. Across the region and in Pennsylvania, the average value of land and buildings per acre increased more in drilling counties relative to non-drilling counties during 2002-2007, while in 2007-2012, it decreased for drilling counties and increased for counties without drilling. The trends in West Virginia are exactly the opposite. The increases are lower in drilling counties during 2002-2007, and decreases are lower in 2007-2012 compared to counties without drilling. For every other indicator, the trends between Pennsylvania and West Virginia are similar (Figure 5).

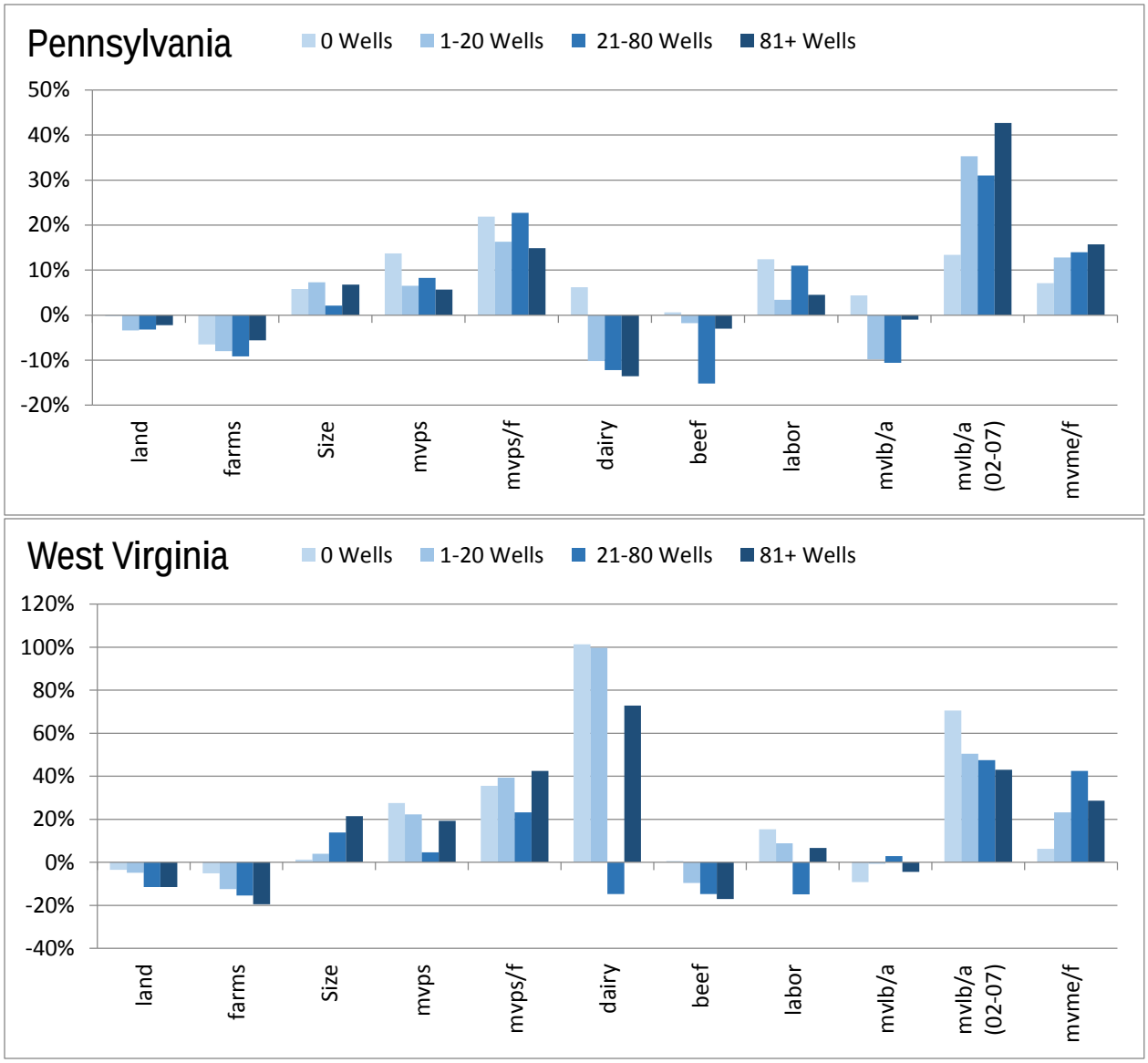

Figure 6. Comparisons of Agricultural Index Changes for Pennsylvania and West Virginia by Drilling Intensity (2007-2012). Table 4 expands on variable names.

Some differences can exist in terms of drilling intensity, like in the case of farm number changes and increases in the market value of agricultural products sold (Figure 6). Decreases in the number of farms were higher for higher levels of drilling intensity across all counties and in West Virginia but not in Pennsylvania. Similarly, increases in total market value of agricultural products sold were lower for drilling counties in Pennsylvania; however, across all counties and in West Virginia, increases were also higher for higher levels of drilling intensity. West Virginia follows the trend for the whole region of higher farm sizes as drilling increases, but in the case of farm land, decreases did not escalate for higher drilling levels either in Pennsylvania or West Virginia (Figure 6).

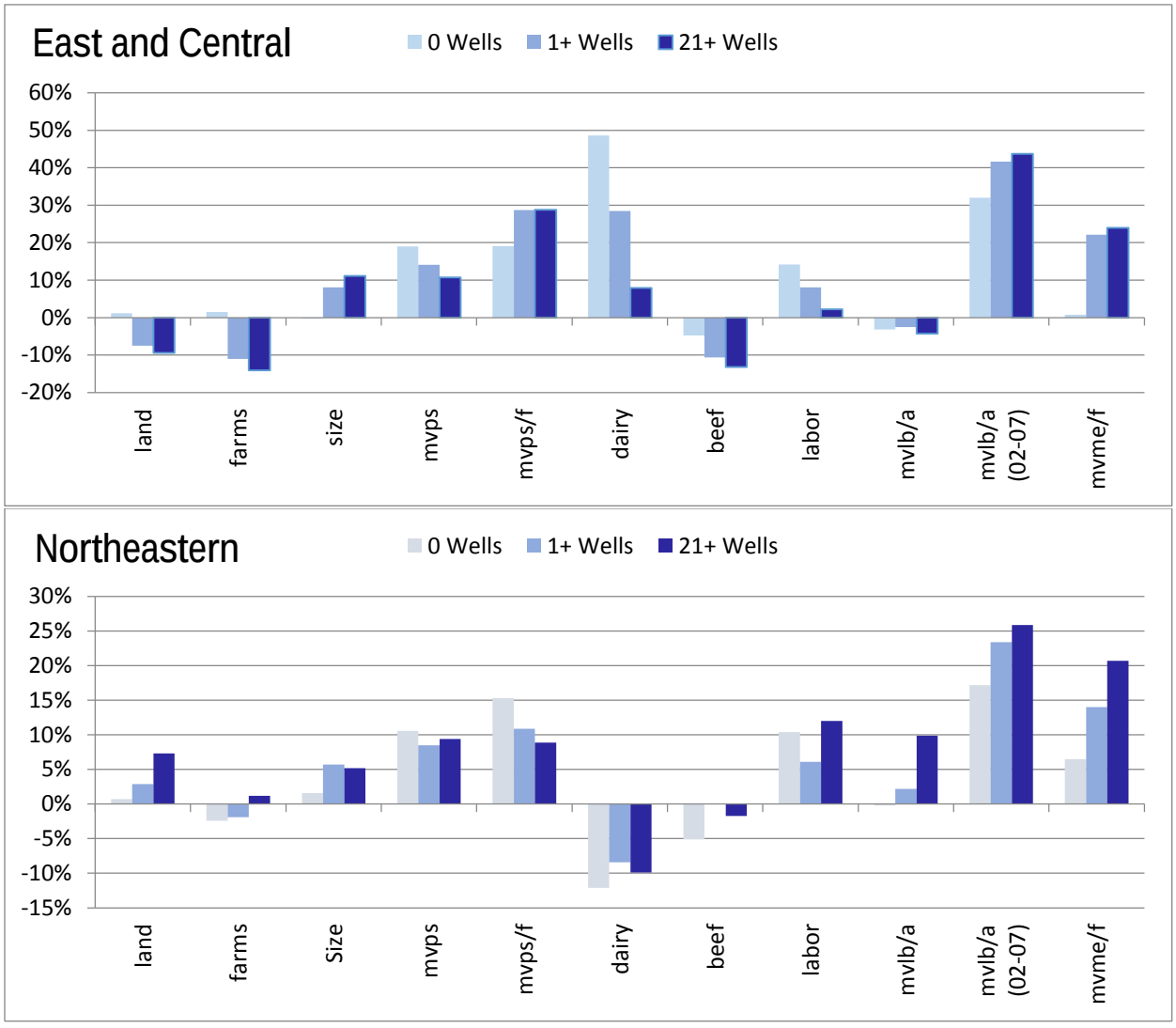

Figure 7. Shale and Non-Shale County Comparisons of Agricultural Index Changes for East and Central and Northeast (2007-2012). Table 4 expands on variable names.

The East and Central region is commonly associated with the Marcellus development in West Virginia and Pennsylvania and follows similar trends with these States and for the region as a whole for farmland, farms in agriculture, market value of agriculture, beef farms, labor, and

market value of machinery. It also follows a trend similar to the region as a whole and West Virginia in the case of farm size, where drilling counties saw gradually higher size increases with intensified drilling activity, and a trend similar to the region as a whole and Pennsylvania for the higher land-value increases in drilling counties during 2002-2007 (Figure 7, Figure 8).

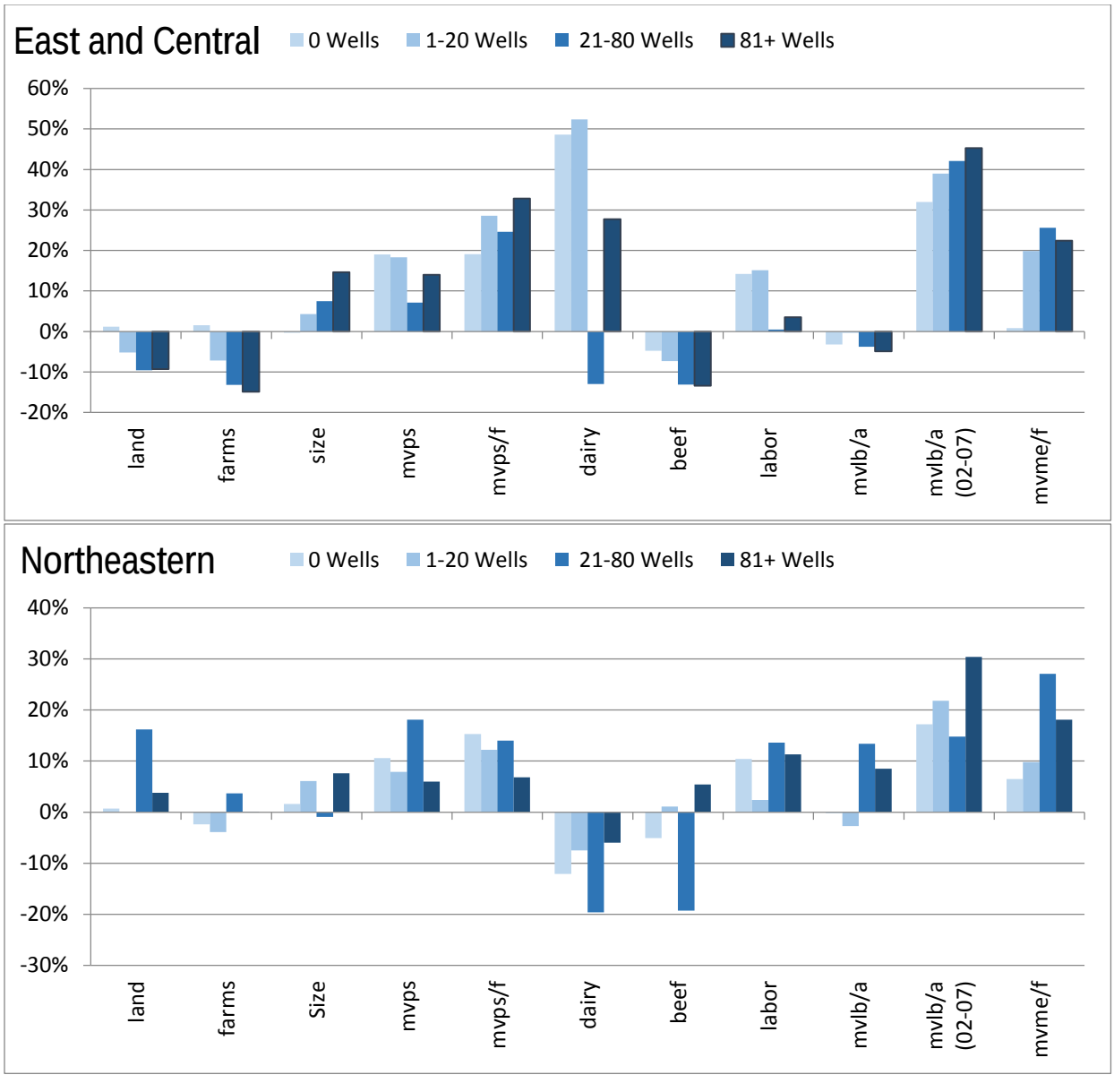

Figure 8. Comparisons of Agricultural Index Changes for Pennsylvania and West Virginia by Drilling Intensity (2007-2012). Table 4 expands on variable names.

The North Eastern region, covering Northeastern Ohio, Northern Pennsylvania, and most of New York, is a newcomer to energy production and mostly experiences distinct trends compared to the Marcellus region as a whole. In addition to the per farm value of machinery and the per acre value of land for 2002-2007, for which every LRR with drilling follows the general trends across the whole region, trends in the Northeastern region are also similar to the region as a whole and

the East and Central region only in the case of gradually higher farm size for counties with higher drilling activity and the lower market value of agricultural product sales for drilling counties (Figure 7, Figure 8).

VI. Concluding Remarks

The recent expansion of unconventional shale gas drilling in the Marcellus play has raised questions about its possible impacts on agriculture in the region. By analyzing data on nine main agricultural indicators from the 2007 and 2012 USDA, NASS Census of Agriculture, we find a varied set of relationships between shale gas drilling and agriculture. Shale development coincides with higher farmland and farm losses as well as increases in the median farm size in shale counties, which provides some evidence of farm consolidation in shale areas. It also coincides with lower average percentage changes in the number of hired labor and larger average percentage decreases in the number of beef farms. Counties with drilling activity have a higher average percentage increase in market value of machinery and equipment and higher average percentage changes in the market value of land and buildings per acre during the leasing period, which is only slightly eroded during the drilling period.

Patterns that emerge for the Marcellus region as a whole may not hold for individual States or LRRs. For example, the farm size in Pennsylvania is not different between drilling and non-drilling counties, and the larger percentage decreases in number of farms for drilling counties do not show an association with drilling intensity like they do across the region. At the regional level, a negative relationship between drilling and dairy farming is revealed, but the phase out from dairy to beef farming can only be explained from the trends in Ohio, North Atlantic, and potentially the Northern regions. Our study highlights the diversity of impacts among regions, as drilling and agricultural production depend upon a multitude of individual and collective decisions, as well as such as factors like climate and geography.

Hitaj, Boslett, and Weber's (2014) analysis of the south-central United States and the western Plains similarly find decreases in farms, and that increases in values of land and building per acre and machinery and equipment per farm in drilling areas outpace those in non-drilling areas, but do not find changes in total value of sales.

We further find evidence that the degree of change is associated with drilling intensity for farmland, the number farms, median size, and per acre land value for 2002-2007, while for total market value of agricultural sales, the number of beef farms, labor, market value for machinery, and per acre land value for 2007-2012, changes are more intense only for counties with significant drilling. Regionally, we find fewer associations of drilling intensity to the degree of change in agricultural indicators, with stronger relationships found in West Virginia, Pennsylvania, and the East and Central region.

As drilling in the Marcellus play has started more recently than other plays, the relationships seen here can and likely will change over time as farmers act and react to both drilling activity and the maturation of the shale gas industry and changes in industry composition as well as local, regional, and national farm economy forces. There are also many factors we are unable to

control for with our study approach, such as extreme weather events or changes in local credit and land markets that could cause large changes in agricultural activity. Nevertheless, it appears that Marcellus drilling is one of a multitude of factors affecting the agricultural sector in the Marcellus Shale region.

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Appendix A. State Review

Each of the four States' drilling activity and key agricultural characteristics are described in the tables below.

1. New York

Through the late 2000s, exploratory unconventional drilling took place in New York. Due to concerns over public health, many local municipalities placed a moratorium on hydraulic fracturing, effectively stopping unconventional gas development in New York[3]. Due to the moratorium, no production-oriented drilling[4] occurred in New York. Therefore, we assume that no unconventional gas wells were drilled.

From 2002 to 2012 the number of farms in New York decreased by over 1,700, and median farm size decreased by 35 acres (see Table 1A). All dollar measures of farming increased, although there was only a small increase in the market value of livestock, poultry, and their products from 2007 to 2012. Market value of total sales had the largest year-over-year increase, growing by over $1.4 billion over the study period (note all dollar figures are in terms of 2012 dollars).

Table 1A. New York Agriculture and Unconventional Drilling Activity

	2002	2007	2012
Total Unconventional Wells in State	0	0	0
Number of Farms	37,255	36,352	35,537
Median Size of Farms (acres)	128	95	93
Market Value of Total Sales ($1,000)	$ 3,979,077	$ 4,892,843	$ 5,411,236
Livestock, Poultry, and Their Products: Market Value of Total Sales ($1,000)	$ 2,530,391	$ 3,163,288	$ 3,164,664
Crops: Market Value of Total Sales ($1,000)	$ 1,448,687	$ 1,729,553	$ 2,244,228

Market values of crops sales and livestock sales do not necessarily sum to total sales due to inflation adjustment and rounding.
Sources: USDA, NASS Census of Agriculture, 2002, 2007, and 2012

2. Ohio

In addition to the Marcellus formation, the Utica-Point Pleasant formation also lies beneath Ohio. Despite only five of Ohio's shale gas wells targeting the Marcellus, for purposes of this study we are using Marcellus as a general term to encompass all unconventional shale gas wells within the State. The total number of unconventional wells exceeded 25 during 2012, much later than in Pennsylvania and West Virginia. Ohio had a total of 238 wells drilled by the end of 2012. The majority of these wells are located in 3 counties in the eastern part of the State (Figure 1A).

[3] In late 2014, hydraulic fracturing was banned.
[4] There are no available data on shale gas production for New York. (http://www.eia.gov/dnav/ng/ng_prod_shalegas_s1_a.htm)

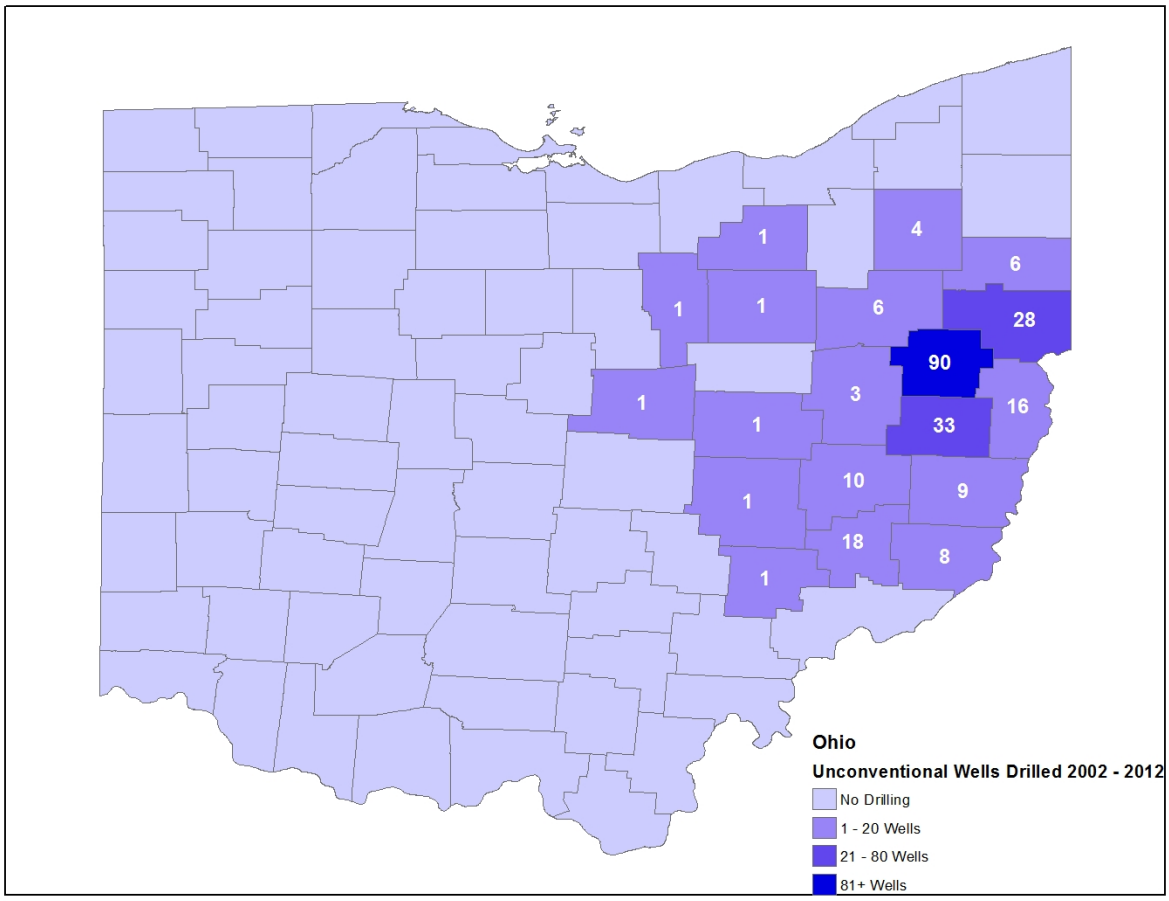

Figure 1A. Ohio Unconventional Shale Gas Wells Drilled (2002-2012). Source: Ohio Department of Natural Resources

Similar to New York, the number of farms and median farm size decreased in Ohio from 2002 to 2007 by approximately 2.3 thousand and 24 acres respectively (see Table 2A). Despite the similarity, average median farm size increased from 2007 to 2012 in Ohio. All dollar measures of farming increased, with the total value of sales almost doubling and total value of crop sales more than doubling from 2002 to 2012. Like New York, the increase in livestock, poultry, and their products had the smallest increase over the last 5 years.

Table 2A. Ohio Agriculture and Unconventional Drilling Activity			
	2002	2007	2012
Total Unconventional Wells in State	0	0	238
Number of Farms	77,797	75,861	75,462
Average Median Size of Farms (acres)	93	66	69
Market Value of Total Sales ($1,000)	$ 5,441,274	$ 7,828,989	$ 10,064,085
Livestock, Poultry, and Their Products: Market Value of Total Sales ($1,000)	$ 2,499,695	$ 3,278,211	$ 3,466,139
Crops: Market Value of Total Sales ($1,000)	$ 2,941,579	$ 4,550,778	$ 6,597,946
Market values of crops sales and livestock sales do not necessarily sum to total sales due to inflation adjustment and rounding. Sources: USDA, NASS Census of Agriculture, 2002, 2007, and 2012; Ohio Department of Natural Resources			

3. Pennsylvania

Most of the unconventional shale gas wells drilled within the Marcellus region are in Pennsylvania. Some exploration of the Utica formation occurred over our study period, but the majority of drilling in Pennsylvania is in the Marcellus play[5]. Over the study period, a total of 6,230 wells were drilled, with a rapid increase in the annual number of wells from 2009 to 2011. By 2006, the cumulative total of unconventional gas wells drilled exceeded 25. Although 38 counties have had at least 1 unconventional well drilled, 13 counties account for the majority of the drilling activity in the Commonwealth (Figure 2A).

The trend in the number of farms in Pennsylvania during the time of the study is different from New York and Ohio. There was an increase in number of farms between 2002 and 2007 followed by a decrease between 2007 and 2012 (see Table 3A). Despite the latter decrease, the overall number of farms grew by 1.2 thousand over the study period. The average median size of farms decreased from 2002 to 2007 and then rebounded slightly in 2012, leading to an overall decrease of 22 acres from 2002. All dollar measures of farming increased, with the value of total sales increasing by almost $2 billion, while crop and livestock measures increased by about $1 million from 2002 to 2012.

[5] The number of Utica permits is low versus Marcellus, 279 to 16,110 respectively, as of 2015. (http://www.fractracker.org/2015/06/utica-drilling-in-pennsylvania/)

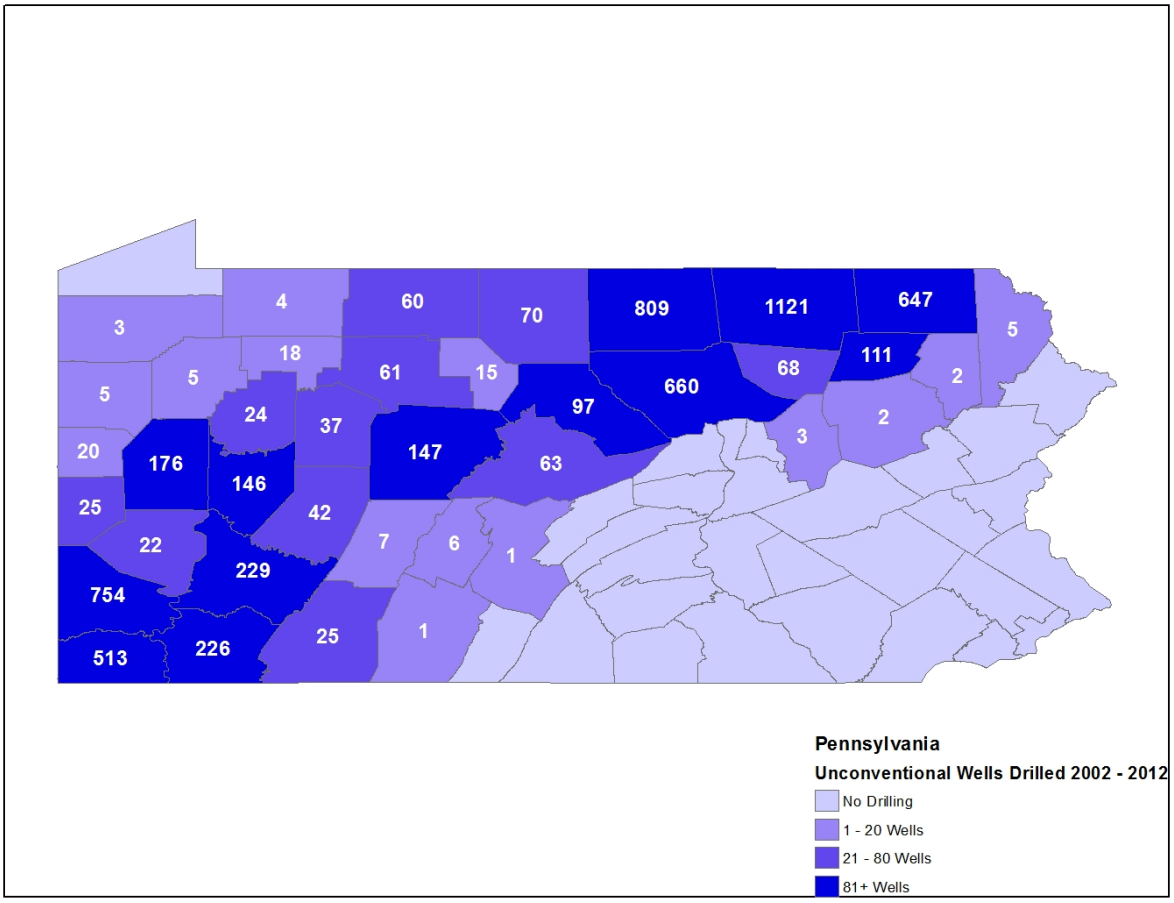

Figure 2A. Pennsylvania Unconventional Shale Gas Wells Drilled (2002-2012). Source: Pennsylvania Department of Environmental Protection

Table 3A. Pennsylvania Agriculture and Unconventional Drilling Activity

	2002	2007	2012
Total Unconventional Wells in State	1	168	6,230
Number of Farms	58,105	63,163	59,309
Average Median Size of Farms (acres)	90	65	68
Market Value of Total Sales ($1,000)	$ 5,432,864	$ 6,432,205	$ 7,400,781
Livestock, Poultry, and Their Products: Market Value of Total Sales ($1,000)	$ 3,747,072	$ 4,361,842	$ 4,617,870
Crops: Market Value of Total Sales ($1,000)	$ 1,685,792	$ 2,070,363	$ 2,782,911

Note all dollar figures are in terms of 2012 dollars.
Market values of crops sales and livestock sales do not necessarily sum to total sales due to inflation adjustment and rounding.
Sources: USDA, NASS Census of Agriculture, 2002, 2007, and 2012; Pennsylvania Department of Environmental Protection

4. West Virginia

West Virginia had the second-largest number of unconventional gas wells drilled within our study region. The total number of unconventional wells in West Virginia exceeded 25 in 2005, a year before Pennsylvania reached that milestone. Although the onset of drilling was earlier in West Virginia, its 2,270 wells are roughly a third of those drilled in Pennsylvania. The counties with the most wells drilled are concentrated in two main areas, one in the counties bordering Pennsylvania in the north and another in the southwestern part of the State (Figure 3A).

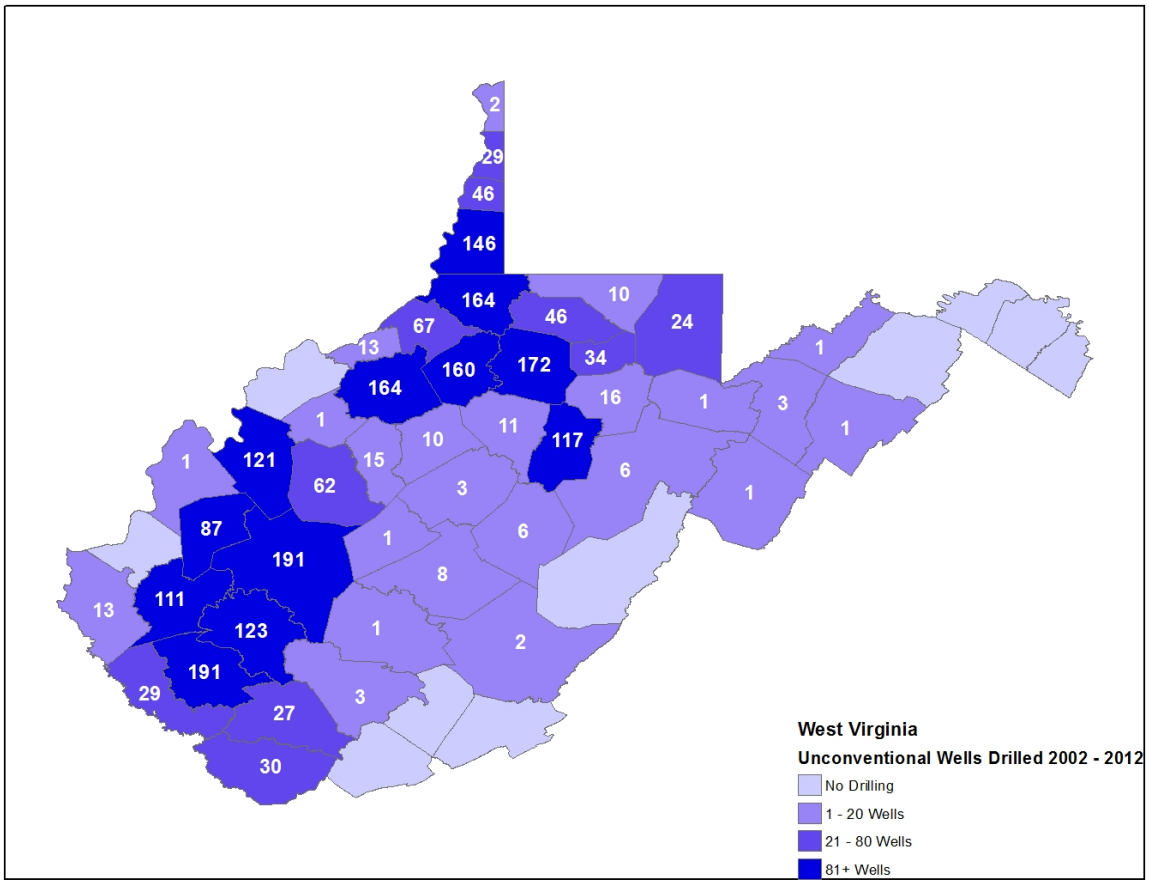

Figure 3A. West Virginia Unconventional Shale Gas Wells Drilled (2002-2012). Source: West Virginia Geological and Economic Survey

The number of farms in West Virginia increased between 2002 and 2007 and then decreased between 2007 and 2012, although the overall number of farms increased by about 650 relative to 2002 (see Table 4A). While the average median farm size increasing by 5 acres from 2007 to 2012, it decreased by about 20 acres over the full study period. The changes in farms and average median size followed the same pattern as Pennsylvania —first increasing between 2002 and 2007, and then decreasing between 2007 and 2012. The market value of total sales, livestock sales, and crop sales all increased over the study period, with total sales increasing by approximately $190 million. Unlike the other States, total crop sales value actually fell over the first 5-year period before rebounding in 2012. Note that the value of sales in West Virginia is much lower than the value of sales in the other three study States (New York, Ohio, and Pennsylvania).

Table 4A. West Virginia Agriculture and Unconventional Drilling Activity			
	2002	2007	2012
Total Unconventional Wells in State	3	824	2,270
Number of Farms	20,812	23,618	21,489
Average Median Size of Farms (acres)	115	90	95
Market Value of Total Sales ($1,000)	$ 616,182	$ 655,163	$ 806,775
Livestock, Poultry, and Their Products: Market Value of Total Sales ($1,000)	$ 527,238	$ 568,451	$667,683
Crops: Market Value of Total Sales ($1,000)	$ 88,944	$ 86,712	139,092

Note all dollar figures are in terms of 2012 dollars.
Market values of crops sales and livestock sales do not necessarily sum to total sales due to inflation adjustment and rounding.
Sources: USDA, NASS Census of Agriculture, 2002, 2007, and 2012; West Virginia Geological and Economic Survey

Appendix B: *Comparative Analysis*

The tables below present the findings for each of the indicators of agricultural activity considered. Each category represents the average percentage change across the counties that encompass it[6].

A. Land in Farms

The land in farms represents how much land within a county is dedicated to agriculture and serves as an overall indicator of agricultural activity within a county. The average percentage change of land in farms (acres) is negative at -1.3 percent across the region; States with extensive drilling all experienced farmland decreases, while the States with little or no drilling had increases (Table 1B). New York had the largest increase in land in farms, while West Virginia saw the largest average decrease of land in farms. The East and Central region, where the most wells were drilled, had an average percentage decrease in farmland, while the Northeastern region, the second-highest drilling region, saw an increase. The average change in farmlands was nearly -700 acres, while the East and Central saw the largest decrease by 2,640 acres. The largest increase in farmlands was in the Northeastern region, with the second-highest number of wells drilled.

[6] In addition to average percentage changes for each state and region, we also present average changes in real terms. It is possible for the average percentage change to be positive while the average change is negative, or vice-versa.

Table 1B. Land in Farms (Acres), by State (2007-2012)						
	Number of Wells	*New York (0 wells)*	*Ohio (238 wells)*	*Pennsylvania (6,230 wells)*	*West Virginia (2,270 wells)*	*All States (8,738 wells)*
	Average Percent Change					
All Counties		1.9%	0.8%	-1.8%	-7.2%	-1.3%
Drilling Activity	None (0)	1.9%	1.0%	-0.2%	-3.5%	0.8%
	Any (1+)	-	0.2%	-2.9%	-8.1%	-4.6%
	Significant (21+)	-	-3.1%	-2.7%	-11.5%	-6.7%
Drilling Intensity						
	Limited (1-20)	-	0.8%	-3.4%	-4.8%	-2.7%
	Medium (21-80)	-	-0.1%	-3.2%	-11.5%	-6.5%
	Extensive (81+)	-	-9.1%	-2.2%	-11.5%	-6.8%
	Average Change					
All Counties		118.7	45.9	-1,588.2	-1,653.3	-701.5

Table 2B. Land in Farms (Acres), by Land Resource Region (2007-2012)							
	Number of Wells	*Central Feed Grains and Livestock Region (2 wells)*	*East and Central Farming and Forest Region (5,157 wells)*	*Lake State Fruit, Truck Crop and Dairy Region (0 wells)*	*Northeastern Forage and Forest Region (3,499 wells)*	*Northern Atlantic Slope Diversified Farming Region (80 wells)*	*All Land Resource Regions (8,738 wells)*
	Average Percentage Change						
All Counties		0.4%	-5.7%	-1.6%	1.3%	3.2%	-1.3%
Drilling Activity	None (0)	0.6%	1.2%	-1.6%	0.7%	3.0%	0.8%
	Any (1+)	-2.3%	-7.5%	-	2.9%	3.9%	-4.6%
	Significant (21+)	-	-9.4%	-	7.3%	9.1%	-6.7%
Drilling Intensity							
	Limited (1-20)	-2.3%	-5.2%	-	0.0%	3.3%	-2.7%
	Medium (21-80)	-	-9.6%	-	16.2%	9.1%	-6.5%
	Extensive (81+)	-	-9.3%	-	3.8%	-	-6.8%
	Average Change						
All Counties		-1,063.8	-2,640.3	-3,472.6	2,177.0	1,070.3	-701.5

When considering well categories across the region, higher levels of drilling are associated with more loss of farmland. While counties without drilling had a nearly 1-percent increase in land in farms, counties with drilling saw decreases from -2.7 percent to -6.8 percent as drilling activity increased. The trend holds in West Virginia even though the non-drilling counties also experienced a farmland decrease. In Ohio, the average farmland increase in counties with 1-20 wells is just slightly lower than in counties without wells. In Pennsylvania, counties with 0 wells

saw only a slight decrease (-0.2 percent), and drilling counties experienced higher levels of farm loss than non-drilling counties. Different LRRs saw different outcomes (Table 2B). The East and Central region, where the most wells were drilled, had a similar but more pronounced trend to the one across all counties, while the Northeastern region and Northern Atlantic region increases were higher in drilling relative to non-drilling counties.

B. Number of Farms

The number of farms serves as an overall indicator of agricultural activity within a county. The average percentage change in the number of farms between 2007 and 2012 is negative both overall at -5.1 percent (27.4 farms) (Table 3B), as well as for each state and LLR individually (Table 4B).

Table 3B. Number of Farms, by State (2007-2012)

	Number of Wells	*New York (0 wells)*	*Ohio (238 wells)*	*Pennsylvania (6,230 wells)*	*West Virginia (2,270 wells)*	*All States (8,738 wells)*
	Average Percent Change					
All counties		-1.1%	-0.9%	-7.1%	-13.3%	-5.1%
Drilling Activity	None (0)	-1.1%	-2.6%	-6.5%	-5.1%	-2.9%
	Any (1+)	-	5.4%	-7.6%	-15.1%	-8.4%
	Significant (21+)	-	0.0%	-7.3%	-17.7%	-11.5%
Drilling Intensity						
	Limited (1-20)	-	6.4%	-8.0%	-12.5%	-5.7%
	Medium (21-80)	-	2.6%	-9.2%	-15.5%	-11.0%
	Extensive (81+)	-	-5.3%	-5.6%	-19.5%	-12.0%
	Average Change					
All Counties		-15.2	-4.5	-58.5	-38.7	-27.4

When considering well categories across the region, higher drilling levels were associated with greater farm loss. This overall trend also holds for West Virginia, where counties with 81 or more wells had an average percentage decrease in the number of farms of 19.5 percent. A similar pattern emerges for Pennsylvania, although counties with 21 to 80 wells saw the largest percentage decrease at 9.2 percent. The overall trend is driven in large part by the decreases in both Pennsylvania and West Virginia. Ohio does not follow the trend; a positive increase is noted for counties with 1 to 20 wells, while a decrease is noted for counties without wells. All LRRs experienced farm loss on average, but there are differences across the regions by farm typology. The East and Central region is the only area that had an average percentage increase in the number of farms in non-drilling counties, while every other category in this region saw declines at an increasing rate for more wells drilled. In contrast, in the Northeastern region, the growth in farms showed no association with the number of wells. In the Northern Atlantic region, the decrease in farms was lower for counties with 1-20 wells than for counties without drilling.

Table 4B. Number of Farms, by Land Resource Region (2007-2012)							
	Number of Wells	*Central Feed Grains and Livestock Region (2 wells)*	*East and Central Farming and Forest Region (5,157 wells)*	*Lake State Fruit, Truck Crop and Dairy Region (0 wells)*	*Northeastern Forage and Forest Region (3,499 wells)*	*Northern Atlantic Slope Diversified Farming Region (80 wells)*	*All Land Resource Regions (8,738 wells)*
	Average Percentage Change						
All Counties		-3.5%	-8.5%	-3.3%	-2.2%	-4.6%	-5.1%
Drilling Activity	None (0)	-3.8%	1.5%	-3.3%	-2.4%	-5.1%	-2.9%
	Any (1+)	3.0%	-11.0%	-	-1.9%	-2.9%	-8.4%
	Significant (21+)	-	-14.1%	-	1.2%	4.0%	-11.5%
Drilling Intensity							
	Limited (1-20)	3.0%	-7.2%	-	-3.9%	-3.7%	-5.7%
	Medium (21-80)	-	-13.2%	-	3.7%	4.0%	-11.0%
	Extensive (81+)	-	-14.9%	-	0.1%	-	-12.0%
	Average Change in the Number of Farms (2007-2012)						
All Counties		-31.4	-29.6	-24.7	-18.9	-34.1	-27.4

C. Median Size of Farms

The median size of farms captures the size in acres of the middle farm if farms are ordered from smallest to largest. Changes in median farm size could indicate that farming is becoming larger scale or more industrialized if the median size increases (such as if large farms are buying more land, or smaller farmers are going out of business), or smaller scale if the median size decreases.

Across the Marcellus region and for each State individually, the average percentage change in the median farm size was positive, averaging 4.4 percent overall (Table 5B). The largest percentage change was in West Virginia at 9.1 percent, while the other State's averages were closer to the region average (except for New York where there was a negative percentage change). The average change in median farm size amounted to 2 acres, while the two States with the most drilling, Pennsylvania and West Virginia, saw increases of 3.6 and 4.6 acres respectively.

Across the region, as drilling levels increase, the average percentage change in median farm size increases, to a high of 13.3 percent for counties with 81 or more wells. West Virginia follows the same trend as the region. The trend is reversed in Ohio, where counties with low levels of drilling had lower percentage increases than counties without drilling. In terms of drilling intensity, there is no clear pattern in Pennsylvania; however, counties with considerable drilling show lower percentage size increases than non-drilling counties. Only in New York counties had a negative percentage change (Table 5B). The East and Central region also follows the same trend as the region. In the Northeastern region, drilling counties have higher farm

increases than non-drilling counties, and the largest percentage change is in counties with 81 or more wells. Contrarily, in the Northern Atlantic region, the average percentage increase in drilling counties was lower than in non-drilling counties. Only one region, the East and Central, saw a negative percentage change of 0.3 percent for counties without drilling (Table 6B).

Table 5B. Median Size of Farms (Acres), by State (2007-2012)						
	Number of Wells	*New York (0 wells)*	*Ohio (238 wells)*	*Pennsylvania (6,230 wells)*	*West Virginia (2,270 wells)*	*All States (8,738 wells)*
	Average Percent Change					
All Counties		-1.9%	4.4%	5.7%	9.1%	4.4%
Drilling Activity	None (0)	-1.9%	5.5%	5.8%	1.3%	2.8%
	Any (1+)	-	0.3%	5.7%	10.9%	7.0%
	Significant (21+)	-	-1.6%	4.6%	18.0%	10.3%
Drilling Intensity						
	Limited (1-20)	-	0.7%	7.3%	4.0%	3.9%
	Medium (21-80)	-	-2.4%	2.1%	13.9%	6.8%
	Extensive (81+)	-	0.0%	6.8%	21.5%	13.3%
	Average Change					
All Counties		-2.9	2.4	3.6	4.6	2.0

Table 6B. Median Size of Farms (Acres), by Land Resource Region (2007-2012)							
	Number of Wells	*Central Feed Grains and Livestock Region (2 wells)*	*East and Central Farming and Forest Region (5,157 wells)*	*Lake State Fruit, Truck Crop and Dairy Region (0 wells)*	*Northeastern Forage and Forest Region (3,499 wells)*	*Northern Atlantic Slope Diversified Farming Region (80 wells)*	*All Land Resource Regions (8,738 wells)*
	Average Percentage Change						
All Counties		5.3%	6.4%	1.5%	2.7%	3.6%	4.4%
Drilling Activity	None (0)	5.5%	-0.3%	1.5%	1.6%	4.3%	2.8%
	Any (1+)	2.0%	8.1%	-	5.7%	1.1%	7.0%
	Significant (21+)	-	11.1%	-	5.2%	9.6%	10.3%
Drilling Intensity							
	Limited (1-20)	2.0%	4.3%	-	6.1%	0.0%	3.9%
	Medium (21-80)	-	7.5%	-	-0.9%	9.6%	6.8%
	Extensive (81+)	-	14.6%	-	7.6%	-	13.3%
	Average Change						
All Counties		3.9	3.4	-0.4	0.4	1.4	2.0

D. Market Value of Agricultural Product Sold

The market value of agricultural products sold serves as an overall indicator of agricultural activity within a county. The market value of agricultural products sold, on average, is positive for the entire region—increased by 18.1 percent across all counties—and for each State and LRR (Table 7B). Ohio had the largest increases in levels and percentage. West Virginia had the second-largest percentage increases, while Pennsylvania had the second-largest average increases in sale dollars (Table 7B).

Across the Appalachian basin, counties with no unconventional drilling activity on average experienced larger percentage increases in the value of agricultural sales than did counties with drilling. This pattern is evidenced in each State as well. The same holds for each resource region except for the Northern Atlantic region, where the percentage change in the value of agricultural sales is higher for drilling counties. For counties with wells, there did not seem to be any association between the number of wells and the value of sales (Table 8B).

Table 7B. Market Value of Agricultural Products Sold, by State (2007-2012)

	Number of Wells	*New York (0 wells)*	*Ohio (238 wells)*	*Pennsylvania (6,230 wells)*	*West Virginia (2,270 wells)*	*All States (8,738 wells)*
	Average Percent Change					
All Counties		7.8%	29.8%	9.6%	19.6%	18.1%
Drilling Activity	None (0)	7.8%	31.8%	13.7%	27.5%	20.4%
	Any (1+)	-	22.4%	6.7%	17.7%	14.3%
	Significant (21+)	-	26.9%	6.9%	12.7%	10.6%
Drilling Intensity						
	Limited (1-20)	-	21.5%	6.5%	22.3%	17.6%
	Medium (21-80)	-	28.8%	8.3%	4.6%	8.7%
	Extensive (81+)	-	23.2%	5.7%	19.3%	12.4%
	Average Change					
All Counties		$9,908	$25,398.9	$14,671.9	$2,913	$14,980.9

Table 8B. Market Value of Agricultural Products Sold, by Land Resource Region (2007-2012)							
	Number of Wells	*Central Feed Grains and Livestock Region (2 wells)*	*East and Central Farming and Forest Region (5,157 wells)*	*Lake State Fruit, Truck Crop and Dairy Region (0 wells)*	*Northeastern Forage and Forest Region (3,499 wells)*	*Northern Atlantic Slope Diversified Farming Region (80 wells)*	*All Land Resource Regions (8,738 wells)*
	Average Percent Change						
All Counties		36.9%	15.2%	25.0%	10.0%	15.1%	18.1%
Drilling Activity	None (0)	37.0%	19.0%	25.0%	10.6%	12.7%	20.4%
	Any (1+)	33.7%	14.1%	-	8.5%	23.2%	14.3%
	Significant (21+)	-	10.7%	-	9.4%	18.7%	10.6%
Drilling Intensity							
	Limited (1-20)	33.7%	18.3%	-	7.9%	23.8%	17.6%
	Medium (21-80)	-	7.1%	-	18.1%	18.7%	8.7%
	Extensive (81+)	-	14.0%	-	6.0%	-	12.4%
	Average Change						
All Counties		$36,641	$2,672.8	$26,054	$9,430.6	$23,654.4	$14,980.9

When looking at per farm market value of agricultural products sold, no clear pattern exists for the region as a whole, and there is no consistency between individual States or LRRs. This implies that changes in agriculture are mostly due to farm losses and consolidation, rather than reductions in the value of agricultural products sold at the farm level. In West Virginia, the per farm value is slightly higher in counties with drilling activity, while in Pennsylvania it's slightly higher for counties without drilling. In Ohio, a more distinct pattern of higher per farm market value of agricultural products emerges for counties without drilling (Table 9B). In the East and Central region, where a majority of wells were drilled, counties with drilling had a larger market value of sales increase than the counties without drilling, as was also the case in the Northern Atlantic region that had limited drilling. In the Northeastern region, which had the second-highest number of wells drilled, counties without drilling saw the highest increase in market value of sales at 14.2 percent, with the percentage increases falling to 6.8 percent for the 81-or-more wells category (Table 10B).

Table 9B. Market Value of Agricultural Products Sold per Farm, by State (2007-2012)						
	Number of Wells	*New York (0 wells)*	*Ohio (238 wells)*	*Pennsylvania (6,230 wells)*	*West Virginia (2,270 wells)*	*All States (8,738 wells)*
	Average Percent Change					
All Counties		10.5%	32.3%	19.4%	36.5%	25.4%
Drilling Activity	None (0)	10.5%	36.6%	21.9%	35.6%	25.4%
	Any (1+)	-	16.6%	17.6%	36.7%	25.4%
	Significant (21+)	-	26.9%	18.4%	33.8%	25.5%
Drilling Intensity						
	Limited (1-20)	-	14.6%	16.3%	39.3%	25.3%
	Medium (21-80)	-	25.3%	22.7%	23.2%	23.1%
	Extensive (81+)	-	30.1%	14.9%	42.5%	27.6%
	Average Change					
All Counties		$11,878.7	$32,991.4	$14,411.2	$6,616.5	$18,641

Table 10B. Market Value of Agricultural Products Sold per Farm, by Land Resource Region (2007-2012)							
	Number of Wells	*Central Feed Grains and Livestock Region (2 wells)*	*East and Central Farming and Forest Region (5,157 wells)*	*Lake State Fruit, Truck Crop and Dairy Region (0 wells)*	*Northeastern Forage and Forest Region (3,499 wells)*	*Northern Atlantic Slope Diversified Farming Region (80 wells)*	*All Land Resource Regions (8,738 wells)*
	Average Percent Change						
All Counties		42.5%	26.7%	30.0%	14.0%	21.3%	25.4%
Drilling Activity	None (0)	43.2%	19.1%	30.0%	15.3%	19.5%	25.4%
	Any (1+)	30.0%	28.7%	-	10.9%	27.6%	25.4%
	Significant (21+)	-	28.8%	-	8.9%	14.1%	25.5%
Drilling Intensity							
	Limited (1-20)	30.0%	28.6%	-	12.2%	29.3%	25.3%
	Medium (21-80)	-	24.6%	-	14.0%	14.1%	23.1%
	Extensive (81+)	-	32.8%	-	6.8%	-	27.6%
	Average Change						
All Counties		$49,578	$4,108.6	$41,137	$12,064.5	$17,802.2	$18,641

E. Number of Dairy Farms

Dairy farming is an important agricultural sector for New York and Pennsylvania. Both States receive the largest share of market value of agricultural products sold from milk and products from cows. Qualitative studies and anecdotes indicate that dairy farming may be particularly susceptible to change. Adams and Kelsey (2012) found that intensity of gas drilling and decline in dairy cow numbers seem to be associated. Finkel et al. (2013) found that milk production and milk cows decreased more in 5 counties with over 100 wells compared to 6 adjacent counties with fewer than 100 wells drilled from 2007 through 2011 (coinciding with the rapid expansion in unconventional drilling). Because dairy farming is particularly labor and time intensive, as dairy farmers receive supplemental income from natural gas extraction, they may be more likely than other famers to change primary products or end production all together. Consequently, we chose this particular type of farm for study.

The average percentage change in the number of dairy farms is positive for the region at 13.2 percent (Table 11B). Percentage changes are negative for both New York and Pennsylvania, where dairy is the dominant agricultural activity. In Ohio and West Virginia, percentage changes are positive. The average regional decrease was 1.3 dairy farms per county. Pennsylvania saw the largest average decrease in dairy farms of -7.7 per county, while Ohio had the largest increase by 4.9 farms per county. Despite the large percentage change in West Virginia, dairy farming represents a smaller share of the agricultural sector, where the average number of dairy farms increased by 1.5 farms per county. The Lake State region, where there was no drilling, saw a decrease of -5.2 percent. The Northeastern region, which had a significant amount of drilling, saw the largest percentage change at -11.1 percent (Table 12B).

Table 11B. Number of Dairy Farms, by State (2007-2012)

	Number of Wells	*New York (0 wells)*	*Ohio (238 wells)*	*Pennsylvania (6,230 wells)*	*West Virginia (2,270 wells)*	*All States (8,738 wells)*
	Average Percent Change					
All Counties		-7.6%	4.4%	-4.4%	77.4%	13.2%
Drilling Activity	None (0)	-7.6%	6.6%	6.2%	101.3%	7.3%
	Any (1+)	-	-3.1%	-11.9%	71.5%	22.7%
	Significant (21+)	-	-8.5%	-12.9%	34.5%	5.0%
Drilling Intensity						
	Limited (1-20)	-	-2.1%	-10.2%	99.7%	37.6%
	Medium (21-80)	-	-6.8%	-12.2%	-14.8%	-12.6%
	Extensive (81+)	-	-11.8%	-13.6%	72.9%	20.3%
	Average Change					
All Counties		-4.9	4.3	-7.7	1.5	-1.3

Across the Appalachian Basin and across the land regions, there is no clear pattern between changes in dairy farm numbers and drilling; however, it is hard to determine the

overall trend due to the large percentage changes in West Virginia. Within several States, a negative relationship between drilling and dairy farming is manifested. In Ohio and Pennsylvania, there is a positive percentage change in counties without drilling and a negative percentage change for counties with drilling. Additionally, higher levels of drilling activity were associated with larger percentage losses in the number of dairy farms—reaching, for example in Pennsylvania, the highest losses of 13.6 percent for counties with 81 or more wells. In West Virginia, even drilling counties witnessed gains in dairy farming (with the exception of counties with 21-80 wells). Still, the gains were highest in non-drilling counties (Table 11B). There are no clear associations at the land-resource-regional level. Due to how West Virginia's counties are located throughout the LRRs, it is hard to interpret the average percentage changes in three regions. In the East and Central region, the average percentage increase is lower in drilling counties; in the Northeastern region, the average decrease is lower in drilling counties; and in the Northern Atlantic region, the average percentage increase is higher in drilling counties (Table 12B).

Table 12B. Number of Dairy Farms, by Land Resource Region (2007-2012)

	Number of Wells	*Central Feed Grains and Livestock Region (2 wells)*	*East and Central Farming and Forest Region (5,157 wells)*	*Lake State Fruit, Truck Crop and Dairy Region (0 wells)*	*Northeastern Forage and Forest Region (3,499 wells)*	*Northern Atlantic Slope Diversified Farming Region (80 wells)*	*All Land Resource Regions (8,738 wells)*
	Average Percent Change						
All Counties		11.7%	32.8%	-5.2%	-11.1%	23.6%	13.2%
Drilling Activity	None (0)	10.8%	48.6%	-5.2%	-12.1%	17.8%	7.3%
	Any (1+)	29.0%	28.5%	-	-8.4%	42.2%	22.7%
	Significant (21+)	-	7.9%	-	-9.9%	8.4%	5.0%
Drilling Intensity							
	Limited (1-20)	29.0%	52.4%	-	-7.5%	46.4%	37.6%
	Medium (21-80)	-	-13.0%	-	-19.6%	8.4%	-12.6%
	Extensive (81+)	-	27.7%	-	-6.0%	-	20.3%
	Average Change						
All Counties		0.1	1.1	-0.9	-4.4	-3.2	-1.3

F. Number of Beef Farms

Although beef farming is not a prominent agricultural sector in the Marcellus region, prior research (Glenna et al., 2014) suggests that when dairy farmers decide to either downsize their operations or leave dairy farming altogether, it is common practice to first convert to beef farms before considering any further changes. Due to the importance of dairy farming in New York and Pennsylvania, examining the trends in beef farms allows U.S. to consider if this "phasing-out" process is occurring at the county level.

Across the Marcellus region and for each State individually, there is a negative average percentage change for the number of beef farms, -5.2 percent per county (Table 13B). The largest percentage decrease in dairy farms occurred in West Virginia at -10.4 percent, while the smallest decrease occurred in Ohio at -2.6 percent. The average change was a decrease of six beef farms per county. The average change in Ohio and Pennsylvania was close to the region's average, while the largest decrease was nine beef farms in West Virginia. Only one LRR, the Northern Atlantic, had a positive percentage change in the number of beef farms (Table 14B). The East and Central region saw the largest average decrease at -9.4 percent. The largest average farm decreases occurred in the Central and East and Central regions, both roughly double the -6.0 beef farm Marcellus region average.

Across the region, drilling counties experienced larger average percentage decreases in the number of beef farms. In Pennsylvania and West Virginia, counties without drilling saw a slight positive percentage change in the number of beef farms. In Pennsylvania, counties with drilling experienced an average percentage decrease in beef farms, while in West Virginia, higher loss of beef farms was associated with higher levels of drilling activity as well. Counties with 81 or more wells, for example, lost an average of 17.1 percent of beef farms, compared to an average 9.6 percent loss in counties with 1 to 20 wells. In Ohio, beef farms were reduced in counties with no drilling by -4.1 percent, while counties with 1-20 wells saw a positive percentage increase of 3.3 percent in the number of beef farms. This was the only average increase among drilling counties (Table 13B).

Table 13B. Number of Beef Farms, by State (2007-2012)

	Number of Wells	*New York (0 wells)*	*Ohio (238 wells)*	*Pennsylvania (6,230 wells)*	*West Virginia (2,270 wells)*	*All States (8,738 wells)*
	Average Percent Change					
All Counties		-6.7%	-2.6%	-3.3%	-10.4%	-5.2%
Drilling Activity	None (0)	-6.7%	-4.1%	0.6%	0.5%	-3.9%
	Any (1+)	-	3.0%	-6.0%	-12.8%	-7.3%
	Significant (21+)	-	1.1%	-8.6%	-16.0%	-11.3%
Drilling Intensity						
	Limited (1-20)	-	3.3%	-1.8%	-9.6%	-3.6%
	Medium (21-80)	-	7.0%	-15.2%	-14.7%	-13.1%
	Extensive (81+)	-	-10.7%	-3.0%	-17.1%	-9.8%
	Average Change					
All Counties		-4.1	-5.4	-5.7	-9.0	-6.0

In the East and Central region, the percentage decreases increase as there are more wells, reaching -13.4 percent for counties with 81 or more wells. The Northeastern region saw a positive percentage change for counties with 1-20 wells and 81 or more wells. The Northern Atlantic region was the only region where counties without drilling saw a positive percentage change in the number of beef farms (Table 14B).

Table 14B. Number of Beef Farms, by Land Resource Region (2007-2012)							
	Number of Wells	*Central Feed Grains and Livestock Region (2 wells)*	*East and Central Farming and Forest Region (5,157 wells)*	*Lake State Fruit, Truck Crop and Dairy Region (0 wells)*	*Northeastern Forage and Forest Region (3,499 wells)*	*Northern Atlantic Slope Diversified Farming Region (80 wells)*	*All Land Resource Regions (8,738 wells)*
	Average Percent Change						
All Counties		-6.9%	-9.4%	-3.7%	-3.7%	3.0%	-5.2%
Drilling Activity	None (0)	-7.3%	-4.8%	-3.7%	-5.1%	2.7%	-3.9%
	Any (1+)	-0.7%	-10.6%	-	0.0%	3.9%	-7.3%
	Significant (21+)	-	-13.2%	-	-1.7%	-0.8%	-11.3%
Drilling Intensity							
	Limited (1-20)	-0.7%	-7.3%	-	1.1%	4.4%	-3.6%
	Medium (21-80)	-	-13.1%	-	-19.3%	-0.8%	-13.1%
	Extensive (81+)	-	-13.4%	-	5.4%	-	-9.8%
	Average Change						
All Counties		-12.6	-11.4	-4.0	0.6	1.0	-6.0

G. Hired Labor on Farms

Since drilling can be labor intensive, it is possible that this could create frictions in local labor markets. The natural gas industry can affect local wage rates as it competes to hire skilled workers, making it difficult for farmers and others to retain their workforce (Hitaj et al, 2014). In addition, some farmers may want to hire additional employees but are unable to compete with the higher wages offered by the gas industry.

Across the Marcellus region, there was a positive average percentage change in the amount of hired labor on farms of 10.3 percent (Table 15B). Ohio had the largest percentage change in hired labor of 14.2 percent, while New York, Pennsylvania, and West Virginia are lower than the region's average. The average change in the hired farm labor per county was 50.5 laborers, while West Virginia had a lower increase of 9.8 employees per county. Pennsylvania had the largest average increase of 75.6 employees per county. The average percentage change in hired labor is positive for each LRR (Table 16B). Of the regions with drilling, the East and Central region saw the smallest average increase at 16.2 laborers per county. The largest average change was in the Northern Atlantic region, over three times the Marcellus region average with 157.6 workers. The Lake State region with no wells saw an average decrease by 43 laborers.

Across the region, counties with drilling have lower average percentage changes in hired labor. The percentage change is smallest for counties with 21-80 wells at 3.1 percent. This pattern holds for West Virginia, where counties with 21-80 wells even saw a negative percentage change in hired labor, and Pennsylvania, where counties with 1-20 wells had the lowest

percentage increases. Contrarily, in Ohio, non-drilling counties on average experienced lower increases than drilling counties (Table 15B). In the East and Central and Northern Atlantic regions, counties with drilling had smaller percentage increases in hired labor. The Northeastern region saw the largest percentage changes in counties with considerable drilling (Table 16B). A similar overall story emerges when considering hired labor per farm.

Table 15B. Hired Labor, by State (2007-2012)						
	Number of Wells	*New York (0 wells)*	*Ohio (238 wells)*	*Pennsylvania (6,230 wells)*	*West Virginia (2,270 wells)*	*All States (8,738 wells)*
	Average Percent Change					
All Counties		8.6%	14.2%	8.7%	7.2%	10.3%
Drilling Activity	None (0)	8.6%	13.2%	12.4%	15.4%	11.6%
	Any (1+)	-	17.9%	5.9%	4.8%	8.0%
	Significant (21+)	-	5.2%	7.3%	-0.5%	4.3%
Drilling Intensity						
	Limited (1-20)	-	20.3%	3.4%	8.8%	11.1%
	Medium (21-80)	-	8.8%	11.0%	-14.9%	3.1%
	Extensive (81+)	-	-2.0%	4.5%	6.6%	5.1%
	Average Change					
All Counties		21.2	71.8	75.6	9.8	50.5

	Table 16B. Hired Labor, by Land Resource Region (2007-2012)						
	Number of Wells	*Central Feed Grains and Livestock Region (2 wells)*	*East and Central Farming and Forest Region (5,157 wells)*	*Lake State Fruit, Truck Crop and Dairy Region (0 wells)*	*Northeastern Forage and Forest Region (3,499 wells)*	*Northern Atlantic Slope Diversified Farming Region (80 wells)*	*All Land Resource Regions (8,738 wells)*
	Average Percent Change						
All Counties		15.6%	9.6%	6.8%	9.3%	10.7%	10.3%
Drilling Activity	None (0)	15.1%	14.2%	6.8%	10.4%	11.8%	11.6%
	Any (1+)	25.0%	8.1%	-	6.1%	6.9%	8.0%
	Significant (21+)	-	2.2%	-	12.0%	18.8%	4.3%
Drilling Intensity							
	Limited (1-20)	25.0%	15.1%	-	2.4%	5.4%	11.1%
	Medium (21-80)	-	0.5%	-	13.6%	18.8%	3.1%
	Extensive (81+)	-	3.5%	-	11.3%	-	5.1%
	Average Change						
All Counties		87.2	16.2	-42.8	41.1	157.6	50.5

H. Market Value of Land and Buildings per Acre

The market value of land and buildings can be positively or negatively affected by shale gas development. Increased farm wealth from shale development can lead to investments in the form of building additions or improvements. Most importantly, if a farmer owns the mineral rights on his or her property, the farmer could capitalize those mineral rights into the property value, increasing the market value of land and buildings. However, mineral rights can also be severed from the land, in which case the farmer who owns the land would receive no benefits in the way of lease and royalty payments. Furthermore, land fractionation and other externalities can possibly decrease property values. These influences will differ by geography and jurisdiction based on topography, farm production, and mineral rights history. A history of prior gas and oil development could indicate a higher probability of severed mineral rights.

The average percentage change in market value of land and buildings per acre is positive for the Marcellus region at 5 percent, but negative for the two States with significant drilling (Table 17B). The largest increase occurred in Ohio, at 17.2 percent. Across the region, the average change was negative, at -$287.4/acre. New York saw the largest average market-value decrease, -$2,213/acre, while Ohio had a $603 decrease per acre. The average percentage change in market-value of land and buildings varies by LRR (Table 18B). Regions with no drilling (the Lake State region) and little drilling (the Central region) saw large positive increases of over 20 percent. Regions where the majority of drilling occurred saw small changes, one positive and one negative. In terms of average changes, the Northeastern region saw the largest decrease of over -$530/acre among the two major drilling regions. The largest average change occurred in the Northern Atlantic region, exceeding -$2,370/acre.

Across all counties, only counties with no drilling saw an average increase of 9.2 percent, while counties with higher levels of drilling saw an average percentage decrease of -1.5 percent. This general pattern holds for Pennsylvania. In West Virginia, counties with drilling had a lower reduction than counties without drilling. Counties without drilling in Ohio had the largest increase, at nearly 20 percent. Additionally, counties in Ohio with 1-20 wells had an average positive percentage change of 7.6 percent (Table 17B). Across drilling categories, no LRR shares the overall trend of positive changes among counties without drilling and negative changes for drilling counties. In the East and Central region, every drilling category saw a negative average percentage change, with the largest loss of -4.9 percent happening in counties with 81 or more wells. The opposite occurred in the Northeastern region, where counties with the most wells averaged an increase of 8.5 percent, although counties with low levels of drilling also saw negative percentage changes. In this region, unlike the East and Central region where mining has been a central activity for decades, the mineral rights were not typically severed from surface rights (Table 18B).

Table 17B. Market Value of Land and Buildings per Acre, by State (2007-2012)						
	Number of Wells	*New York (0 wells)*	*Ohio (238 wells)*	*Pennsylvania (6,230 wells)*	*West Virginia (2,270 wells)*	*All States (8,738 wells)*
	Average Percent Change					
All Counties		1.8%	17.2%	-2.4%	-2.4%	5.0%
Drilling Activity	None (0)	1.8%	19.6%	4.4%	-9.2%	9.2%
	Any (1+)	-	8.4%	-7.1%	-0.9%	-1.5%
	Significant (21+)	-	13.1%	-5.4%	-1.1%	-2.3%
Drilling Intensity						
	Limited (1-20)	-	7.6%	-9.8%	-0.7%	-0.8%
	Medium (21-80)	-	17.0%	-10.6%	2.9%	-2.3%
	Extensive (81+)	-	5.5%	-1.0%	-4.4%	-2.3%
	Average Change					
All Counties		-$2,213.0	$602.6	$2.7	-$134.1	-$287.4

Table 18B. Market Value of Land and Buildings per Acre Land Resource Region (2007-2012)							
	Number of Wells	*Central Feed Grains and Livestock Region (2 wells)*	*East and Central Farming and Forest Region (5,157 wells)*	*Lake State Fruit, Truck Crop and Dairy Region (0 wells)*	*Northeastern Forage and Forest Region (3,499 wells)*	*Northern Atlantic Slope Diversified Farming Region (80 wells)*	*All Land Resource Regions (8,738 wells)*
	Average Percent Change						
All Counties		27.4%	-2.7%	22.7%	0.4%	-2.4%	5.0%
Drilling Activity	None (0)	28.0%	-3.2%	22.7%	-0.2%	-1.8%	9.2%
	Any (1+)	15.9%	-2.5%	-	2.2%	-4.4%	-1.5%
	Significant (21+)	-	-4.3%	-	9.9%	-4.0%	-2.3%
Drilling Intensity							
	Limited (1-20)	15.9%	-0.3%	-	-2.7%	-4.4%	-0.8%
	Medium (21-80)	-	-3.8%	-	13.4%	-4.0%	-2.3%
	Extensive (81+)	-	-4.9%	-	8.5%	-	-2.3%
	Average Change						
All Counties		$1,117.6	-$113.4	$697.8	-$494.7	-$2,330.7	-$287.4

The period examined (2007-2012) corresponds to the period of intense drilling; however, Weber and Hitaj (2014) examined four drilling counties in Pennsylvania and found that most of the appreciation occurred during the leasing period, which corresponds more closely to 2002-2007. For this period, the average percentage change in market value of land and buildings per acre was positive for the Marcellus region, at 26.9 percent, and for each individual State and region

(Table 19B, Table 20B). The largest increase occurred in West Virginia, at 51.9 percent. Across the region, the average change was negative, at $816.9/acre. The lowest increase was in Ohio at $351/acre, and the highest increase was in New York at $1,831.5/acre. In terms of LRRs, the East and Central region had the largest average percentage increase and the Central region had the lowest. The Central region also had the lowest value increase at $343.5/acre. The largest average increase occurred in the Northern Atlantic region at $2,201/acre.

Across the region, counties with more drilling had higher average percentage changes in the market value of land and buildings per acre for 2002-2007. This pattern holds for each of the three LRRs with drilling (Table 20B). Similarly in Pennsylvania, counties with drilling experienced higher average percentage changes. However, in West Virginia, average percentage increase was lower in drilling relative to non-drilling counties. In Ohio, where considerable drilling occurred only after 2011, changes were only slightly higher in drilling counties and similar between non-drilling and counties with limited drilling (Table 19B).

Table 19B. Market Value of Land and Buildings per Acre, by State (2002-2007)

	Number of Wells	*New York (0 wells)*	*Ohio (238 wells)*	*Pennsylvania (6,230 wells)*	*West Virginia (2,270 wells)*	*All States (8,738 wells)*
	Average Percent Change					
All Counties		21.8%	14.3%	27.1%	51.9%	26.9%
Drilling Activity	None (0)	21.8%	13.8%	13.4%	70.5%	20.0%
	Any (1+)	-	16.3%	36.5%	47.8%	37.7%
	Significant (21+)	-	39.2%	37.3%	45.1%	40.9%
Drilling Intensity						
	Limited (1-20)	-	12.0%	35.3%	50.4%	34.8%
	Medium (21-80)	-	42.7%	31.0%	47.5%	39.2%
	Extensive (81+)	-	32.1%	42.7%	43.0%	42.4%
	Average Change					
All Counties		$1,831.5	$351.0	$548.0	$870.4	$816.9

Table 20B. Market Value of Land and Buildings per Acre, by Land Resource Region (2002-2007)							
	Number of Wells	*Central Feed Grains and Livestock Region (2 wells)*	*East and Central Farming and Forest Region (5,157 wells)*	*Lake State Fruit, Truck Crop and Dairy Region (0 wells)*	*Northeastern Forage and Forest Region (3,499 wells)*	*Northern Atlantic Slope Diversified Farming Region (80 wells)*	*All Land Resource Regions (8,738 wells)*
	Average Percentage Change						
All Counties		10.8%	39.7%	15.9%	18.9%	33.2%	26.9%
Drilling Activity	None (0)	10.8%	32.0%	15.9%	17.2%	31.2%	20.0%
	Any (1+)	9.8%	41.6%	-	23.4%	40.2%	37.7%
	Significant (21+)	-	43.7%	-	25.9%	30.0%	40.9%
Drilling Intensity							
	Limited (1-20)	9.8%	39.0%	-	21.8%	41.5%	34.8%
	Medium (21-80)	-	42.1%	-	14.8%	30.0%	39.2%
	Extensive (81+)	-	45.3%	-	30.4%		42.4%
	Average Change						
All Counties		$343.5	$708.5	$355.2	$588.9	$2,201.0	$816.9

I. Market Value of Machinery and Equipment per Farm

As with the market value of land and buildings, increased farm wealth from shale development can lead to farm investments in the form of purchases of machinery and equipment.

The average percentage change in market value of machinery and equipment per farm is positive for the Marcellus region at 14.9 percent, as well as for each State and each LRR (Table 21B, and 22B). The largest average percentage change is in West Virginia, at nearly 25 percent, while the lowest is in New York, at 5.3 percent. The average change is $11,500 across the region, while the largest average change is over $20,000 per farm for Ohio. The average percentage change for West Virginia was double that of Pennsylvania, and the average change is similar for both States, at nearly $7,500/farm. The largest regional increases are in the two regions with little or no drilling activity, the Central and Lake State regions. The average percentage change of the East and Central region, 17.8 percent, is twice as large as that of the Northeastern region's 8.5 percent.

Across the region, counties with drilling have a higher average percentage increase in market value of machinery and equipment than counties without drilling. This pattern holds for both Pennsylvania and West Virginia. In Ohio, where the drilling onset was 2011, counties with drilling have a lower average percentage change than counties without drilling. For Pennsylvania, counties with 81 or more wells have the greatest increase (as is the case for the region overall), while counties with 21-80 wells have the greatest increase in West Virginia. As the level of drilling increases, the average percentage change of market value of machinery and equipment increases in every region with drilling activity (Table 21B). In the East and Central

region, counties without drilling saw a small average percentage change of less than 1 percent, while counties with any level of drilling average an increase of about 20 percent or more. The increase in Northeastern counties with 81 or more wells was almost three times as large as counties without drilling (Table 22B).

Table 21B. Market Value of Machinery and Equipment per Farm, by State (2007-2012)						
	Number of Wells	*New York (0 wells)*	*Ohio (238 wells)*	*Pennsylvania (6,230 wells)*	*West Virginia (2,270 wells)*	*All States (8,738 wells)*
	Average Percent Change					
All Counties		5.3%	17.3%	11.2%	24.8%	14.9%
Drilling Activity	None (0)	5.3%	19.7%	7.1%	6.2%	11.9%
	Any (1+)	-	8.5%	14.1%	28.9%	19.5%
	Significant (21+)	-	10.3%	14.9%	34.9%	23.6%
Drilling Intensity						
	Limited (1-20)	-	8.2%	12.8%	23.2%	15.9%
	Medium (21-80)	-	8.0%	14.0%	42.4%	25.9%
	Extensive (81+)	-	14.8%	15.7%	28.6%	21.6%
	Average Change					
All Counties		$6,562.3	$20,248.5	$7,449.8	$7,391.3	$11,518.9

Table 22B. Market Value of Machinery and Equipment per Farm, by Land Resource Region (2007-2012)							
	Number of Wells	*Central Feed Grains and Livestock Region (2 wells)*	*East and Central Farming and Forest Region (5,157 wells)*	*Lake State Fruit, Truck Crop and Dairy Region (0 wells)*	*Northeastern Forage and Forest Region (3,499 wells)*	*Northern Atlantic Slope Diversified Farming Region (80 wells)*	*All Land Resource Regions (8,738 wells)*
	Average Percentage Change						
All Counties		25.9%	17.8%	19.0%	8.5%	5.2%	14.9%
Drilling Activity	None (0)	26.9%	0.8%	19.0%	6.5%	3.4%	11.9%
	Any (1+)	8.7%	22.1%	-	14.0%	11.7%	19.5%
	Significant (21+)	-	24.0%	-	20.7%	28.6%	23.6%
Drilling Intensity							
	Limited (1-20)	8.7%	19.9%	-	9.8%	9.5%	15.9%
	Medium (21-80)	-	25.6%	-	27.1%	28.6%	25.9%
	Extensive (81+)	-	22.4%	-	18.1%	-	21.6%
	Average Change						
All Counties		$31,464	$6,246	$25,078.5	$7,442	$2,686.3	$11,518.9

There is a slightly different pattern for the overall market value of machinery and equipment. Across the region, the value of machinery and equipment was similar between drilling and non-drilling counties. However, at the Marcellus region level, when we take into account the changes in the number of farms, it does not seem that the shale gas development has increased capital investments in farms relative to non-drilling counties. That is the case for every State excluding Ohio and LRR with drilling.