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NATURAL GAS INVESTMENT IN WEST VIRGINIA, 2010-2016

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Natural Gas Investment in West Virginia: 2010-2016

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Table of Contents

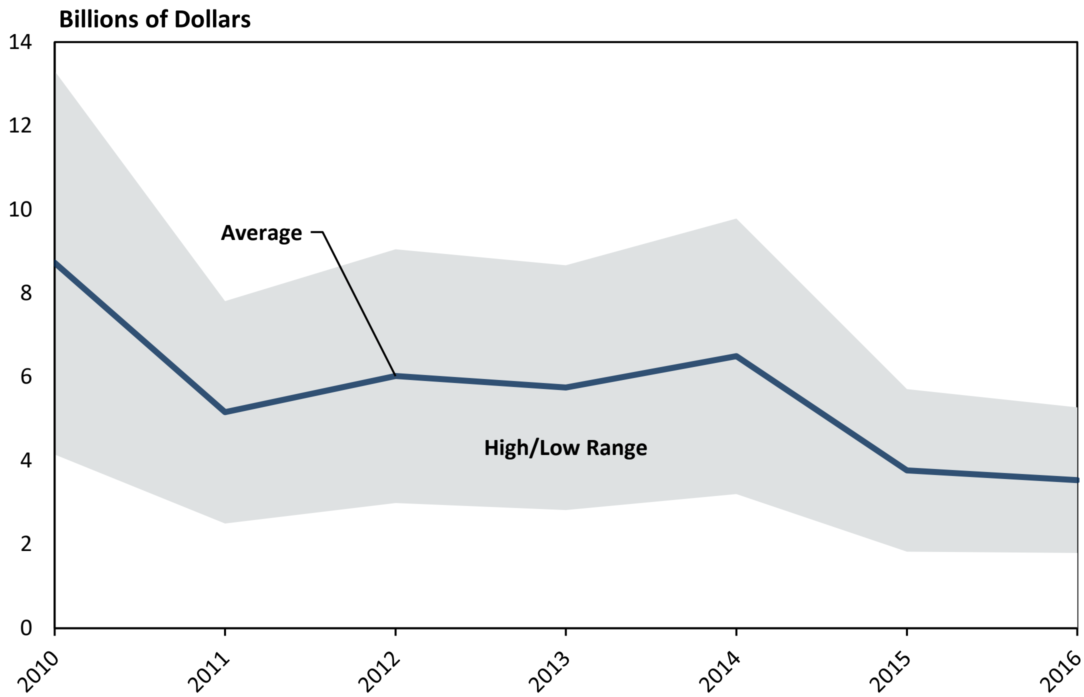
List of Figures and Tables

Executive Summary

West Virginia's natural gas boom began in 2010 as hydraulic fracturing and horizontal drilling techniques began to be applied to the state's shale formations. Since then, West Virginia has become the nation's ninth-largest natural gas producer in 2017, with gross withdrawals of more than 1.6 trillion cubic feet. Since the gas boom started, the natural gas industry has made considerable investments in the state to pay for well drilling, mineral royalties, and pipeline infrastructure, among other investment costs. In this report, we estimate these investments in two key areas: upstream costs and midstream infrastructure.

- Total investment in upstream and midstream activities **is estimated to be nearly $40 billion** between 2010 and 2016.
- Natural gas companies **drilled more than 4,600 wells** in the state between 2010 and 2016.
- Total investment for **direct well drilling costs is be $38 billion**.
- Royalties are estimated to **total approximately $694 million.**
- Total midstream expenditures are **estimated to be about $635 million.**
- As shown in Figure 1, investment is highly uncertain, and **could range from a low of $20 billion to a high of $60 billion**.

Figure 1: Estimated Natural Gas Investment



Source: Author Calculations

1 Introduction

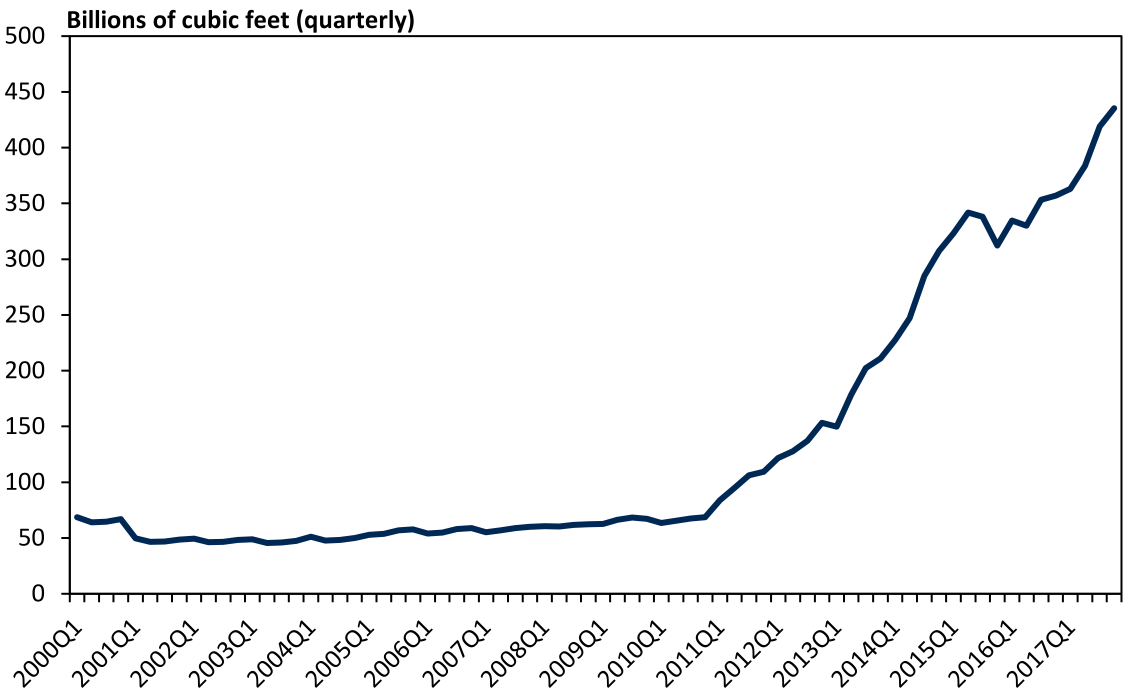
West Virginia's natural gas boom began in 2010 as hydraulic fracturing and horizontal drilling techniques began to be applied to the state's shale formations. Since then, West Virginia has become the nation's ninth-largest natural gas producer in 2017, with gross withdrawals of more than 1.6 trillion cubic feet.

Since the gas boom started, the natural gas industry has made considerable investments in the state to pay for well drilling, mineral royalties, and pipeline infrastructure, among other investment costs. In this report, we estimate these investments in two key areas: upstream costs and midstream infrastructure. We begin in Section 2 with a discussion of the natural gas industry in West Virginia and its rapid rise in the most recent decade. In Section 3, we estimate upstream investments, including well costs and royalty payments to mineral rights holders. Finally, in Section 4 we estimate investments in midstream pipeline infrastructure that have allowed natural gas from West Virginia to enter the national market.

2 Overview of the Natural Gas Industry

Natural gas production in West Virginia was relatively stable in the first decade of the 2000s (see Figure 2). Production in the state's shale region began to rise starting in 2010, and quadrupled over the next five years, with annual production rising from about 265 billion cubic feet (Bcf) in 2010 to more than 1.3 trillion cubic feet (Tcf) in 2015. While production held steady during 2015 and 2016, production began to rise again in 2017, ending the year with 1.6 Tcf of production, a gain of 16 percent over 2016 levels.

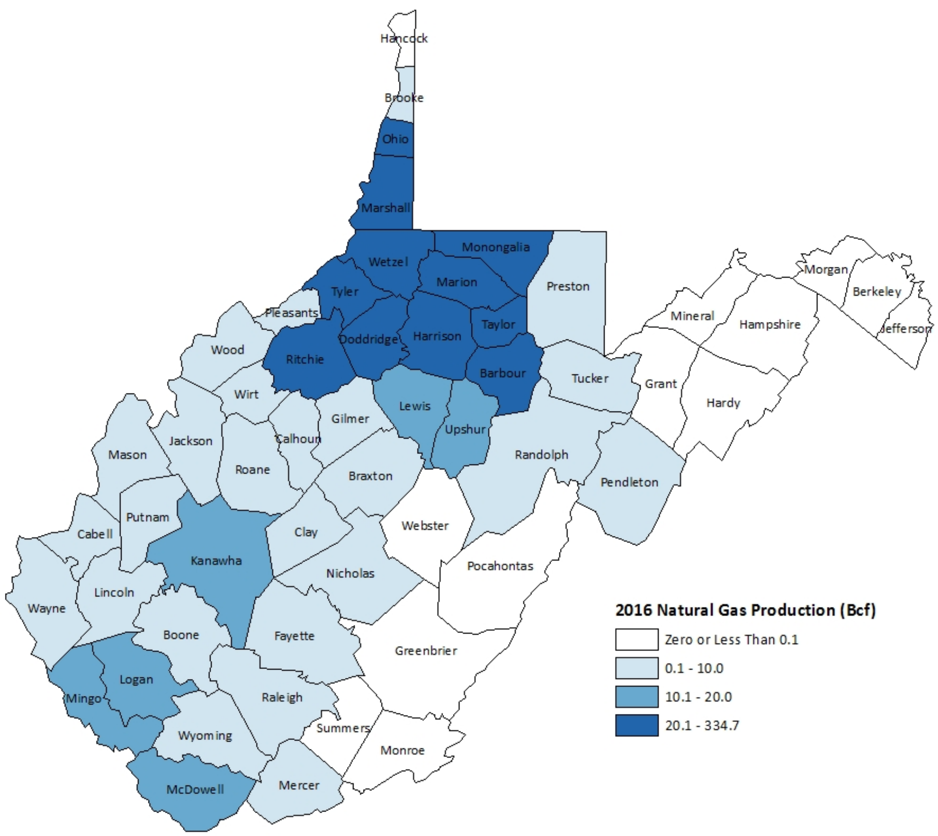
Figure 2: Quarterly Gas Production



Source: US Energy Information Administration

West Virginia's gas boom has been felt primarily in the state's Northern Panhandle and North-Central regions, as shown in Figure 3. In 2016,[1] the state's largest producing counties were Doddridge, Wetzel, Marshall, Ritchie, and Harrison, each of which produced more than 125 billion cubic feet of natural gas in 2016. This is a marked contrast with 10 years ago, when the top four producers—Wyoming, McDowell, Kanawha, and Lewis counties—were primarily in the southern part of the state.

Figure 3: Gas Production by County

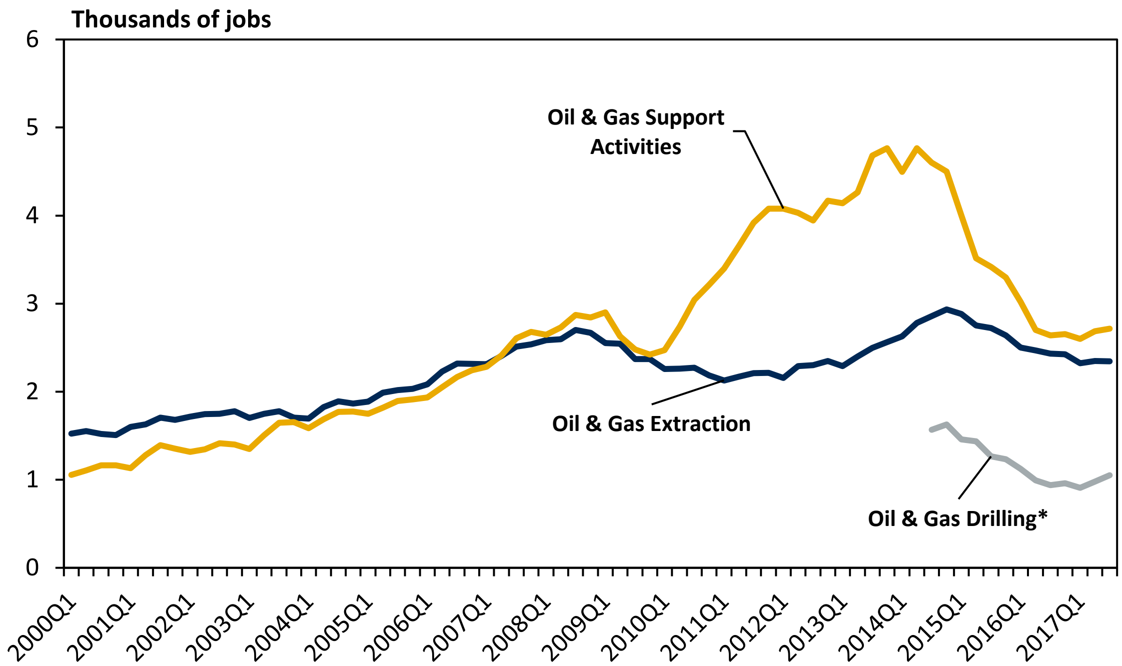


Source: WV Department of Environmental Protection

[1] County and well data is available only through 2016.

Natural gas employment has grown largely in step with increases in production. As shown in Figure 4, employment in the Oil & Gas industry began to rise starting in 2010, when employment in Oil & Gas Extraction and Support Services totaled about 4,700 workers. These two industries together peaked at about 7,500 workers in 2014 mostly due to rapid growth in the Oil & Gas Support Services industry. Employment in the Oil & Gas Drilling industry[2] totaled approximately 1,600 workers in 2014, which fell to about 1,050 workers by the third quarter of 2017.

Figure 4: Oil & Gas Employment

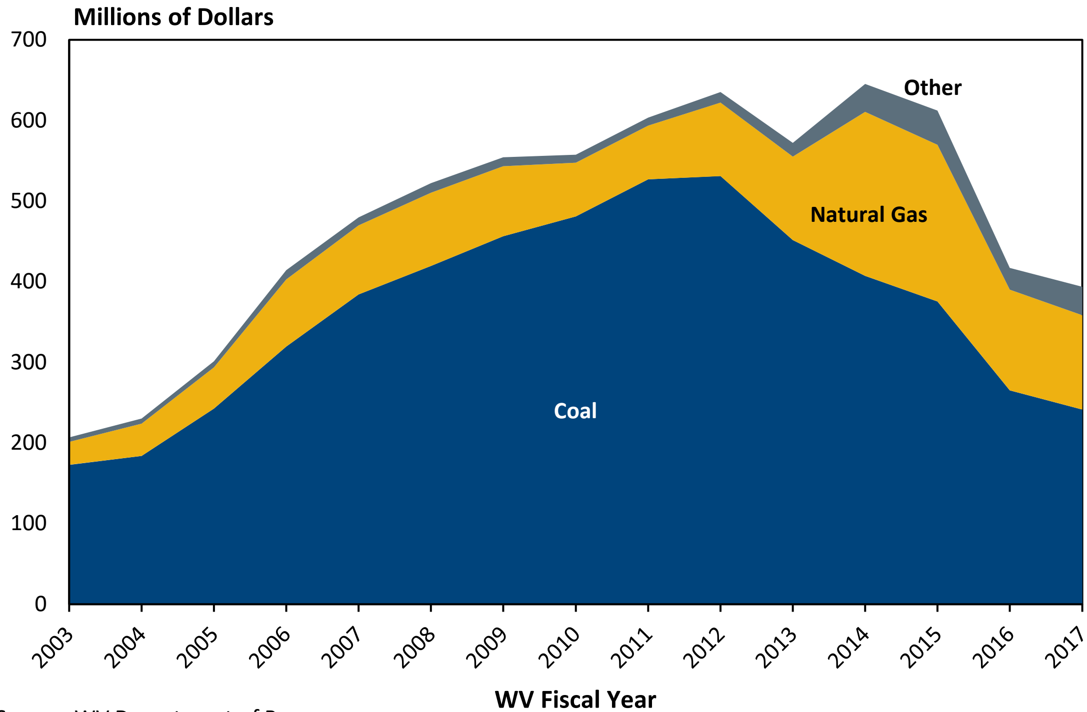


Source: US Bureau of Labor Statistics
*Drilling Jobs unavalable prior to 2014

[2] Employment numbers for Oil & Gas Drilling were unavailable until 2014 due to US Bureau of Labor Statistics non-disclosure requirements.

Natural gas played a relatively minor role in West Virginia's severance tax revenue prior to the start of the gas boom. As shown in Figure 5, severance tax revenue from natural gas was mostly below $90 million until fiscal year 2012, when it started to rise along with gas production. Severance tax revenue from natural gas rose to $204 million in fiscal year 2014, before tapering off over the next three years as a result of lower gas prices diminishing the gross value of the resource.

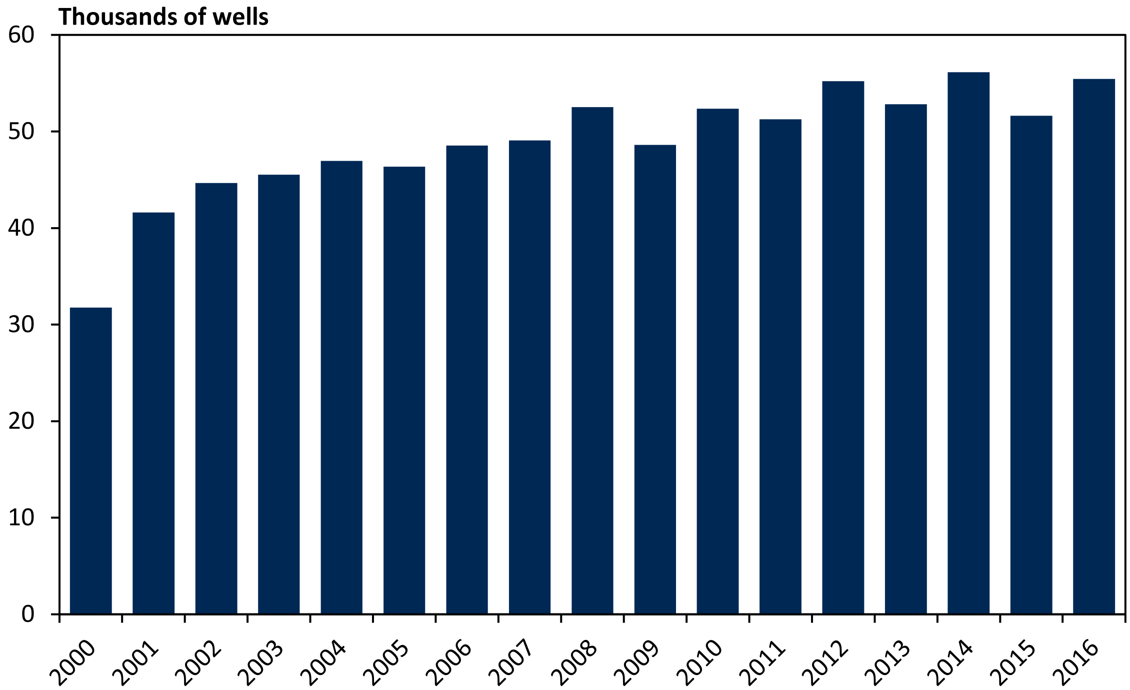
Figure 5: Severance Tax Revenue by Mineral Type



Source: WV Department of Revenue

Despite the rapid growth in natural gas production, the number of active gas wells has not grown considerably since 2010. As shown in Figure 6, the total number of active wells in 2016 was about 55 thousand, an increase of about 3,000 wells since 2010. This level of growth represents a gain of 6 percent in the well count during a period when production rose by more than 400 percent.

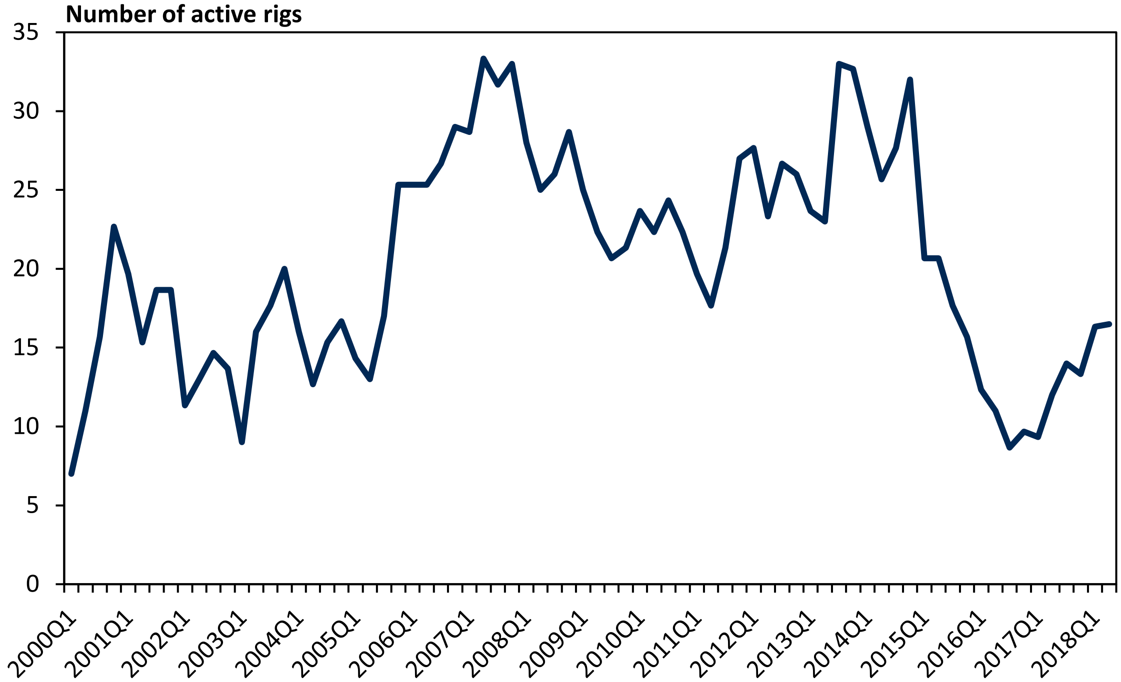
Figure 6: Active Natural Gas Well Count



Source: WV Department of Environmental Protection

While the total number of active wells in West Virginia was fairly stable over time, the state had wide fluctuations in well drilling during the last decade. As shown in Figure 7, the number of drilling rigs in West Virginia was at a high point of 33 in 2007, and then fell by nearly half through the middle of 2011. However as new horizontal wells began to enter the market, the rig count began rising again back and reached its peak in 2013 and stayed fairly stable at that level through 2014. Starting in 2015 the number of drilling rigs fell steeply, falling to less than nine rigs in the middle of 2016 before bouncing back during 2017 and 2018.

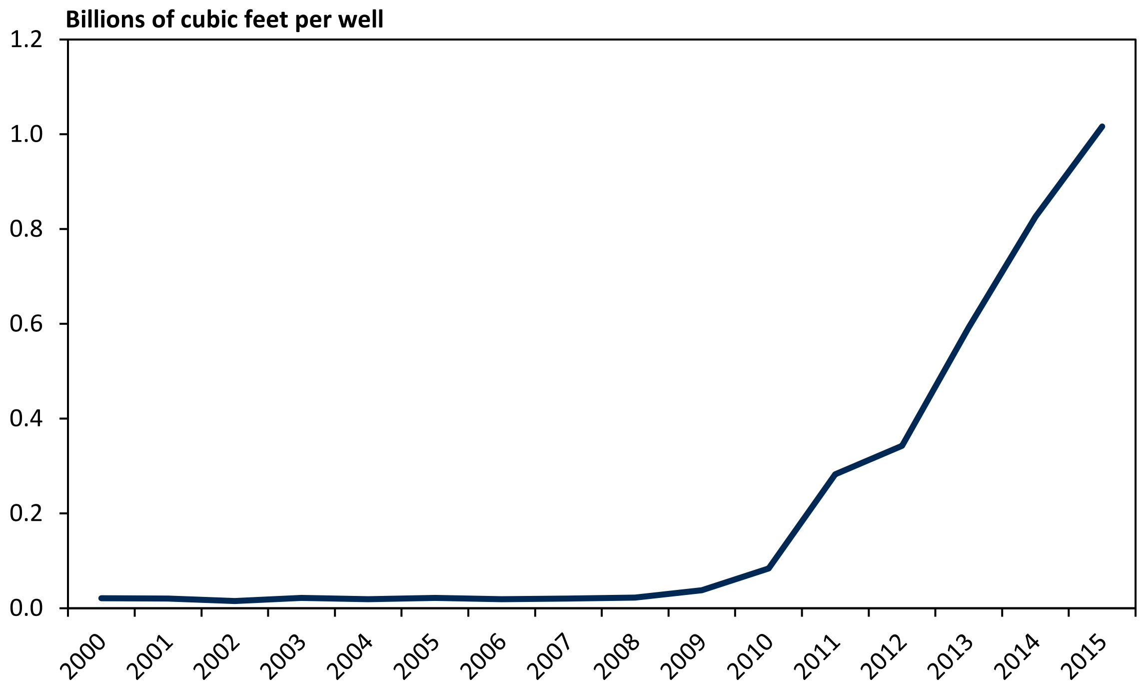
Figure 7: Active Rig Count in West Virginia



Source: Baker Hughes

The difference in well counts vs. production growth can be traced to massive increases in well productivity since 2010. As hydraulic fracturing began to be used in the state, first-year production per well[3] rose from 84 million cubic feet per well in 2010 to more than 1 billion cubic feet per well (see Figure 8). This increase in productivity has allowed a smaller number of wells to produce significantly more gas than in years prior to the shale gas revolution, thus reducing the need for additional drilling in the state.

Figure 8: First-Year Well Productivity

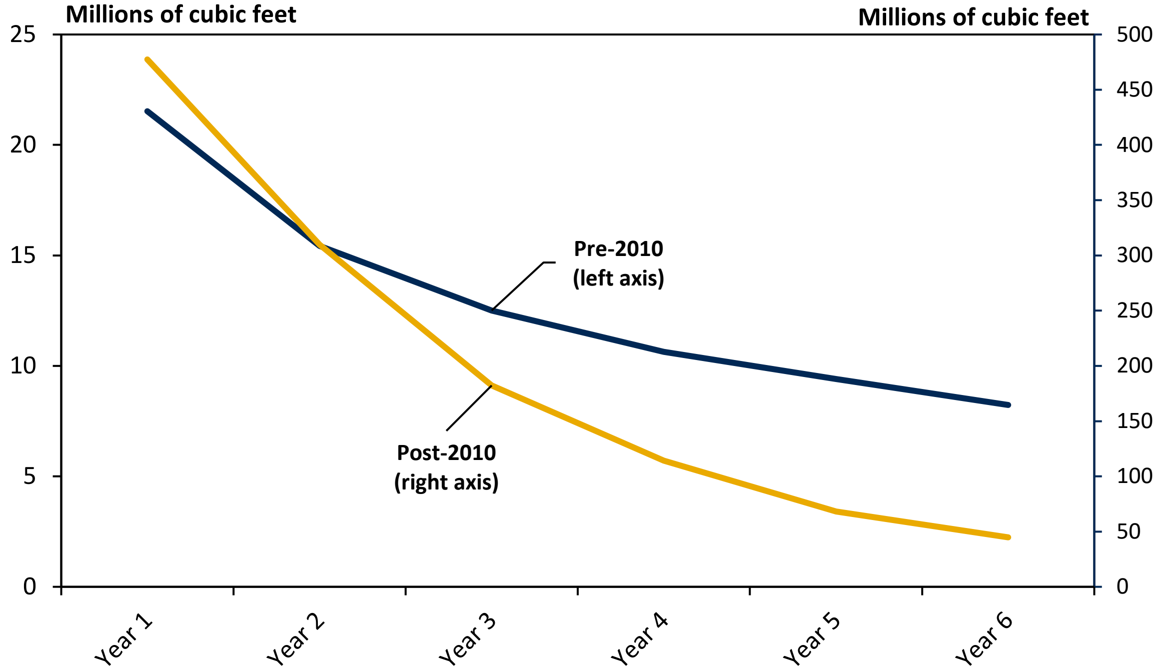


Source: WV Department of Environmental Protection, Author Calculations

[3] A well's first year of production is defined as the total production during the first 12 months of measured gross withdrawals.

Though horizontal wells are substantially more productive than vertical wells in all stages of production, they tend to decline more quickly than older vertical wells. As shown in Figure 9, average productivity for wells drilled since 2010 show a decline rate of approximately 96 percent over the first six years of production. This compares with a decline rate of 65 percent for traditional vertical wells drilled before 2010. The high decline rate for shale gas wells may indicate the need for additional fracking of existing wells or drilling of new wells to maintain current levels of production.

Figure 9: Average Well Production Decline Curves



Source: WV Department of Environmental Protection, Author Calculations

3 Upstream

Upstream investment comprises all activity needed to drill and produce natural gas up to the point of transporting it to market. For the purposes of this analysis, we include the following costs in our upstream estimates:

- Direct Well Costs
    - Land acquisition
    - Well construction and drilling
    - Road construction
    - Near-lease gathering pipeline
- Royalty payments to mineral-rights holders

Estimating the capital investment that natural gas companies have made in the West Virginia economy is a difficult task, as most of the data on production costs in the industry is proprietary and thus not publicly available. In order to make our investment estimate, we pursue two tracks to estimate production costs.

First, we present cost estimates based on the methodology in (Thomas, Dick, & Scully, 2017).[4] In this publication, the authors estimate upstream well costs based on a number of sources, including industry publications, public investment documents, and industry interviews. These costs are determined for Ohio-based producers, but they should be similar to those found in West Virginia, as the two states have similar shale basins.

Secondly, we independently survey a variety of literature to determine costs found in West Virginia. Unfortunately, well-level data is less developed in West Virginia than in neighboring Ohio. Data is available only until 2016, thus our analysis will focus on the period between the start of the boom in 2010 and that year. Secondly, while we were able to determine the number of wells drilled each year, we were unable to determine horizontal lateral lengths, royalty rates, and other important data to determine the costs. In addition, cost estimates varied widely in the available literature, thus we were unable to determine a stable average cost structure for wells in West Virginia. Instead, we provide an average cost found in the available literature and include a range of possible expenditures above and below that number. Lastly, we have chosen to ignore lease operating costs, as we were unable to verify operating expenses for wells in West Virginia.

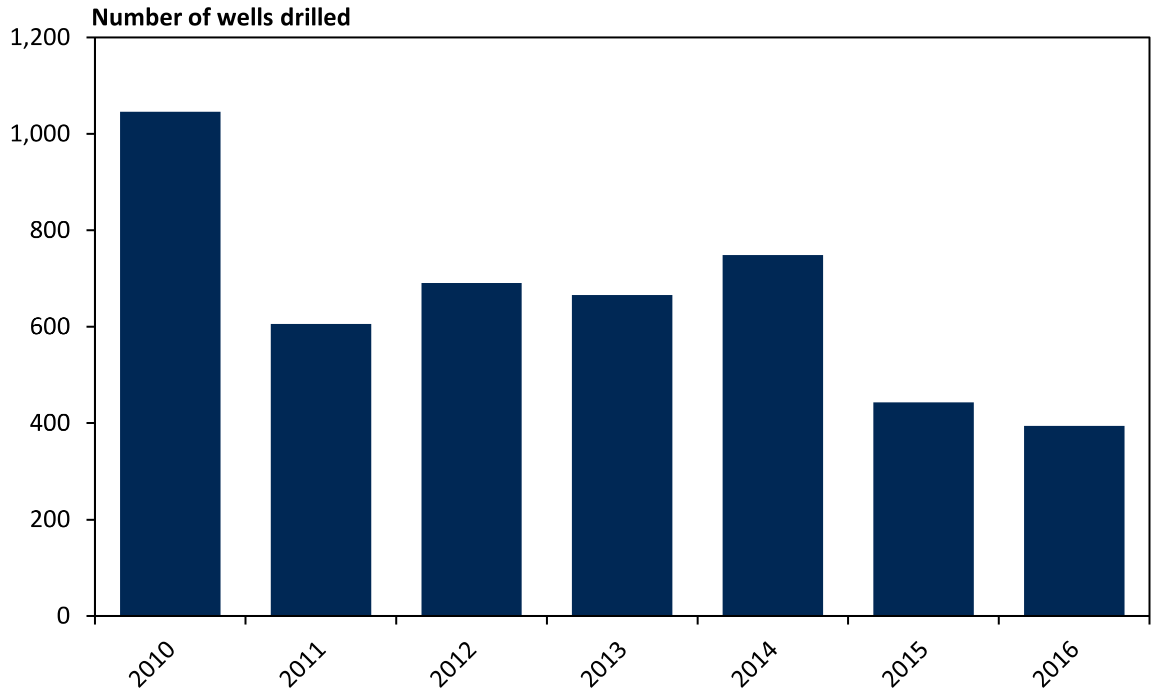
To estimate the investments of natural gas companies in the state, we begin in Section 3.1 with estimates of direct well-drilling costs, followed by estimates of royalties paid to mineral rights holders in Section 3.2.

[4] Thomas et al. analyze a number of other drilling costs associated with new well construction, including lease operating expenses and bonus payments. However, we focus only on direct well costs and royalties, as we were able to procure data on these items.

3.1 Direct Well-Drilling Costs

As mentioned in Section 2, the number of active wells in West Virginia has been fairly consistent over the last decade. However, the state has continued to see an active program of well drilling. As shown in Figure 10, between 2010 and 2016, natural gas companies drilled a total of about 4,600 wells in the state. The highest number of wells was drilled in 2010, when more than 1,000 new wells were added to the state's producing stock.

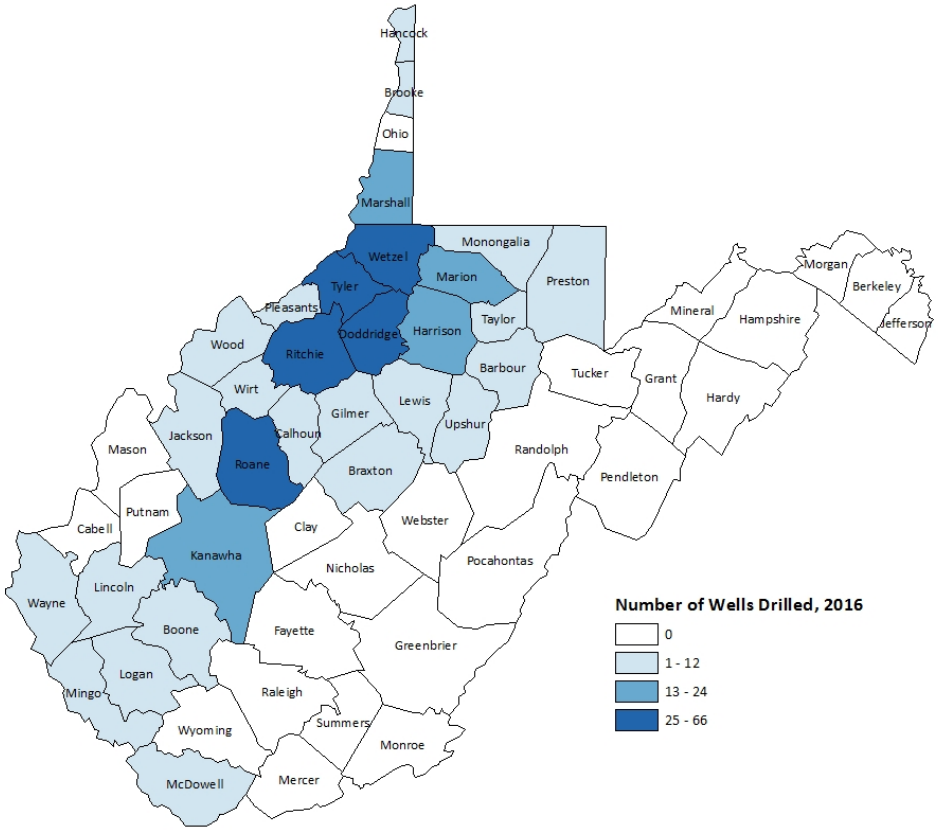
Figure 10: Wells Drilled Since 2010



Source: WV Department of Environmental Protection, Author Calculations

As may be expected, the large majority of these wells were drilled in the areas of the state that have seen increases in gas production. However, during the last two years as natural gas prices fell, drillers have concentrated on the most productive areas of the state. As shown in Figure 11, the bulk of new wells drilled in 2016 were in just four counties: Ritchie, Doddridge, Tyler, and Wetzel.

Figure 11: Wells Drilled by County, 2016



Source: WV Department of Environmental Protection

3.1.1 Well cost estimate

To estimate the investment value of the wells drilled since 2010, we follow the procedure in (Thomas et al., 2017). The authors identified four general types of costs incurred when building a new well pad and then drilling a new well to completion. As detailed cost breakdown is listed in Table 1. Land acquisition payments to surface rights holders are estimated to be about $1.5 million per well and include bonus payments and per-acre costs. Drilling costs of $7 million per well include all aspects of the drilling process: well pad construction, rig and drilling costs, fracking, and flowback water recycling and disposal. Well pad access road construction is assumed to cost about $500 thousand for each well, assuming each three wells per pad. Lastly, gathering pipelines are assumed to cost $1.5 million per well.

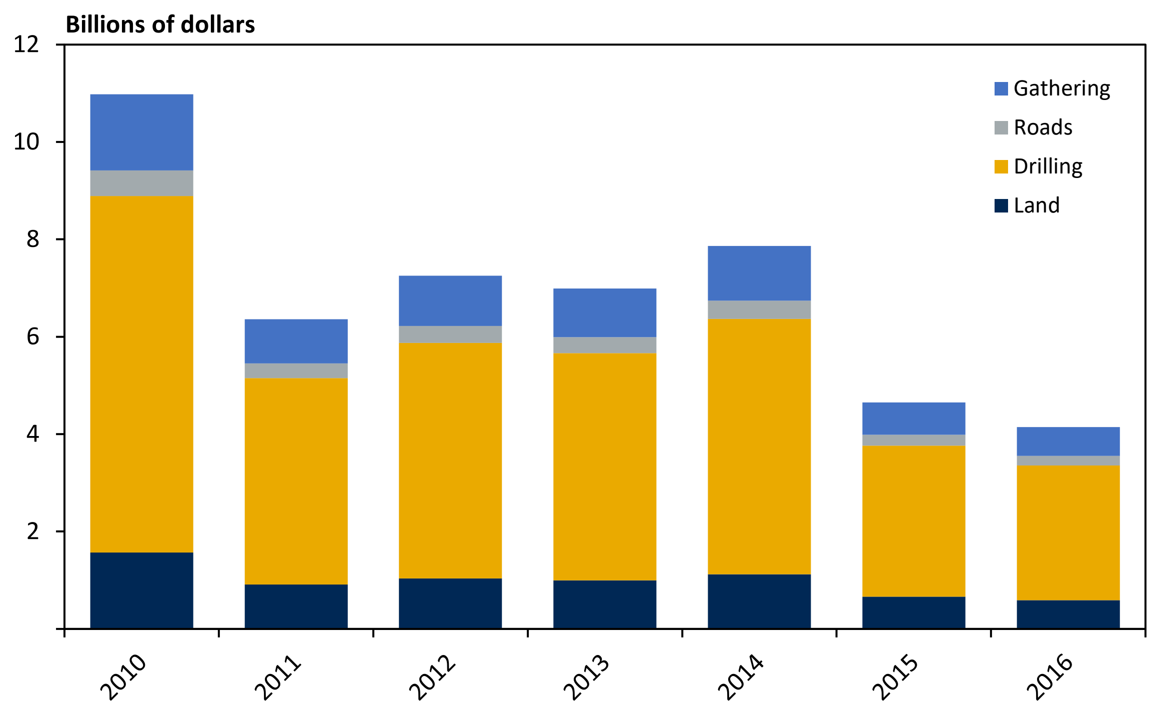
Table 1: Direct Well Drilling Cost Assumptions

Investment Type	Cost per Well (millions of $)	Assumptions
Land	1.5	• $7,500 per acre bonus • 192 acres per well
Drilling	7.0	
Roads	0.5	• $1 million per mile • $450,000 for bridges and culverts • 3 wells per pad
Gathering	1.5	• miles of 8-inch gathering pipe • $140,000 per inch-mile • 3 wells per pad
Total	**$10.5 million**	

Source: (Thomas et al., 2017)

Using these cost assumptions, we estimate that the total investment between 2010 and 2016 made by the natural gas industry for direct well drilling costs was approximately $48.3 billion. As shown in Figure 12, annual cost estimates range from $11 billion in 2010 to just over $4.1 billion in 2016.

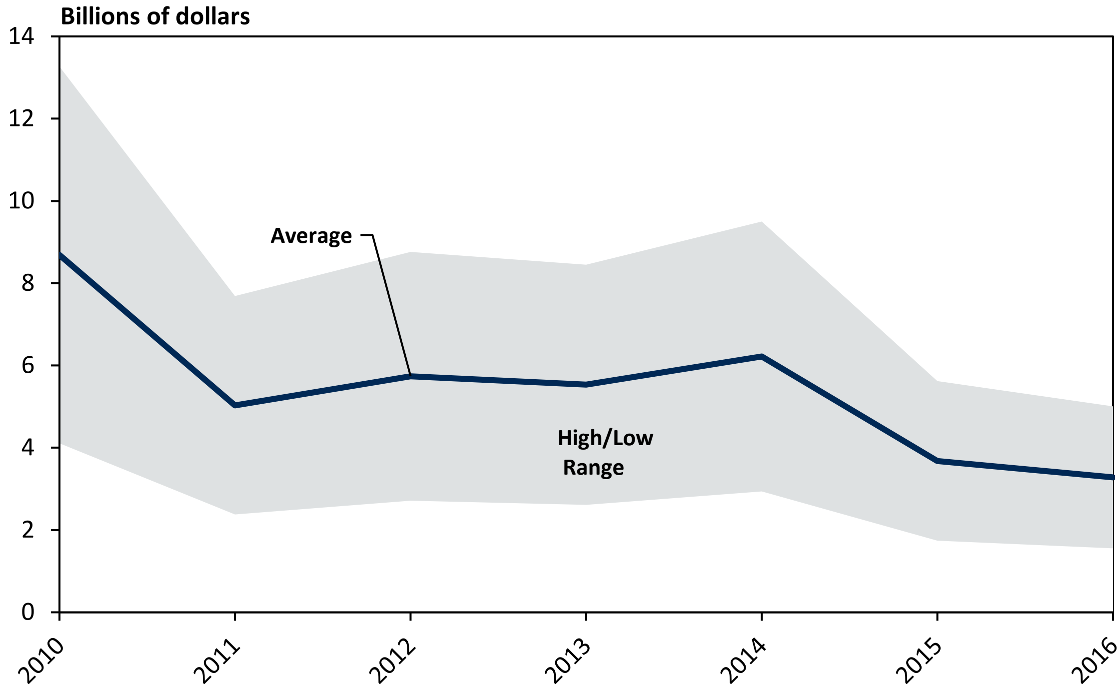
Figure 12: Estimated Well Costs



Source: Author Calculations

In our review of the literature on natural gas investment, we found that well drilling costs ranged widely between sources. In order to reflect this uncertainty, in Figure 13 we present the potential range of well costs invested in the state between 2010 and 2016. In our literature review, the average cost we found was approximately $8.3 million per well drilled. This figure is reflected in the average investment line in the figure. However, costs estimates ranged from nearly $4 million per well on the low end to nearly $12.7 million on the high end. Thus the gray area represents potential investment of one standard deviation above and below our average cost estimate. Using these cost ranges, we estimate that total natural gas investment for direct drilling costs fell between $18 billion and $58 billion dollars with a reasonable degree of confidence.

Figure 13: Well Cost Range



Source: Author Calculations

3.2 Royalties

After drilling costs, royalties—which are payments to mineral rights holders for the production of the resource—constitute the next largest cost for natural gas companies looking to develop the region's shale gas. Royalties are generally paid as a percentage of the value of the gas produced, as thus are dependent both on production and the price paid for the resource.

To estimate royalty payments to mineral rights holders in West Virginia, we again follow the procedure in (Thomas et al., 2017). For this procedure, we make several assumptions:[5]

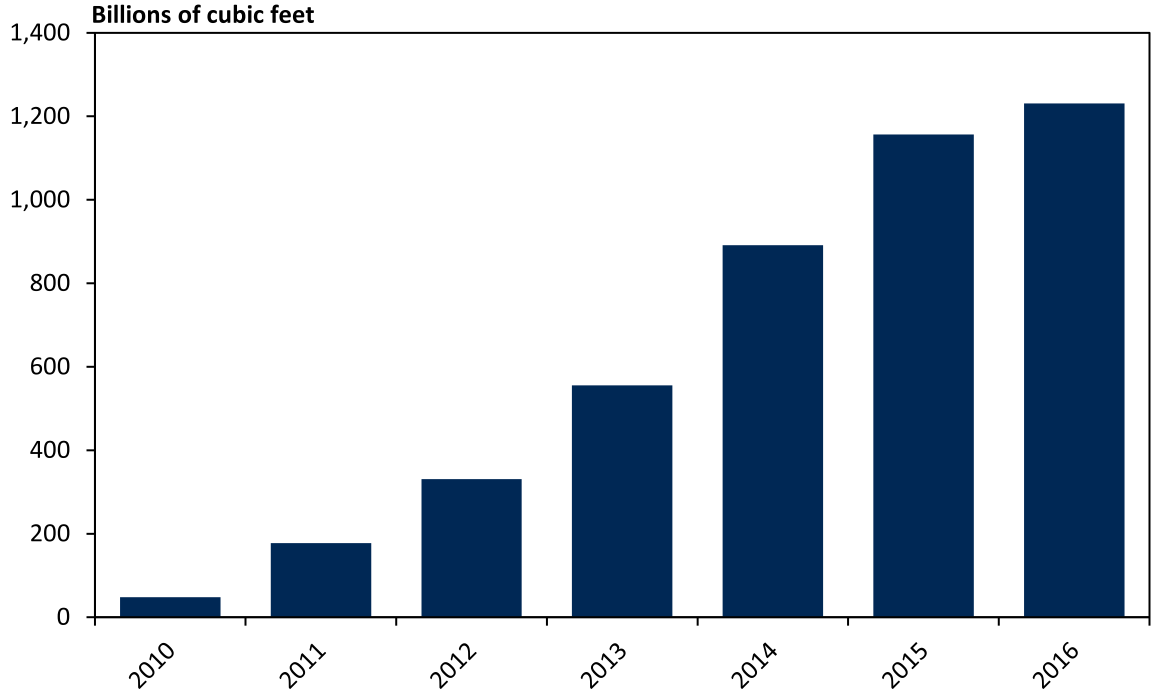
- A shrinkage rate of 12 percent. Natural gas production is subject to shrinkage as the gas is processed and separated for transport in the pipeline network.
- All sales were made at the price reported at the Tennessee Zone 4 (TZ4) hub, which serves the Marcellus region. Where prices were not available for this hub, we assume a local price differential of $1.10 below that of the benchmark Henry Hub price, which was the average differential for the period between 2011 and 2016.
- Prices for the TZ4 hub are quoted in dollars per MMBtu, so we used a conversion rate from the US Energy Information Administration of 1.037 MMBtu per Mcf.[6]
- Transportation costs of 65 cents per Mcf were deducted from royalties.
- Severance tax of 5 percent of gross value was deducted from royalties.
- Royalty rate of 20 percent of total value.

[5] In 2018, the West Virginia Legislature passed a law mandating a minimum 12.5 percent royalty rate regardless of post-production deductions, including severance taxes, and transportation costs (See "WV Gov Justice Signs Bill to Guarantee 12.5% Minimum Royalty," 2018). However, this rate applies only to flat rate royalty leases, which are not commonly used in more recent royalty contracts.

[6] (EIA, 2018a)

In Figure 14, we report total production from wells drilled in West Virginia since 2010. Though the number of wells drilled declined during this period (see Figure 10), these wells continued to produce natural gas. Thus the state saw increasing amounts of production from new wells throughout this period, rising from 48 billion cubic feet in 2010 to 1.2 trillion cubic feet in 2016.

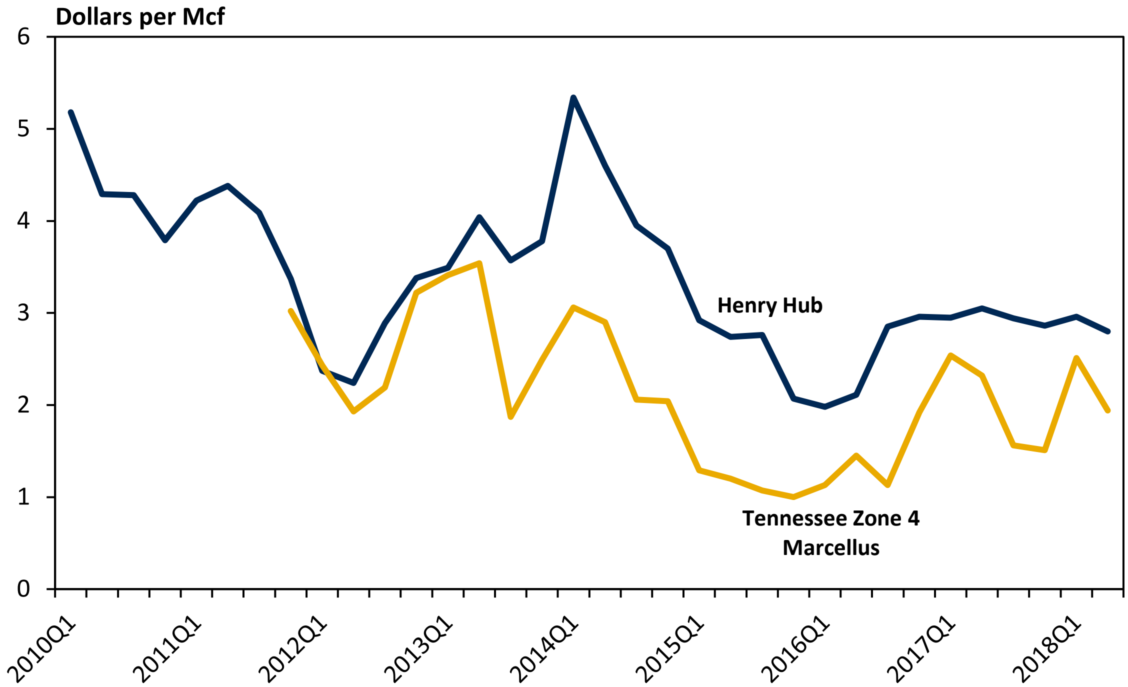
Figure 14: Production from Wells Drilled Since 2010



Source: WV Department of Environmental Protection, Author Calculations

In Figure 15, we report average spot prices at the benchmark Henry Hub, and prices paid at the Tennessee Zone 4 (TZ4) hub that serves most of the Marcellus region. Average natural gas prices were consistently lower at the TZ4 hub than at the Henry Hub throughout most of the period of interest. This is largely due to increased volumes of natural gas produced, coupled with limited outgoing transportation pipeline infrastructure, which led to a glut of gas in the local region. Because of this price differential, we assume mineral rights holders in West Virginia were paid about $1.11 less per MMBtu on average for their gas than the benchmark Henry Hub price.

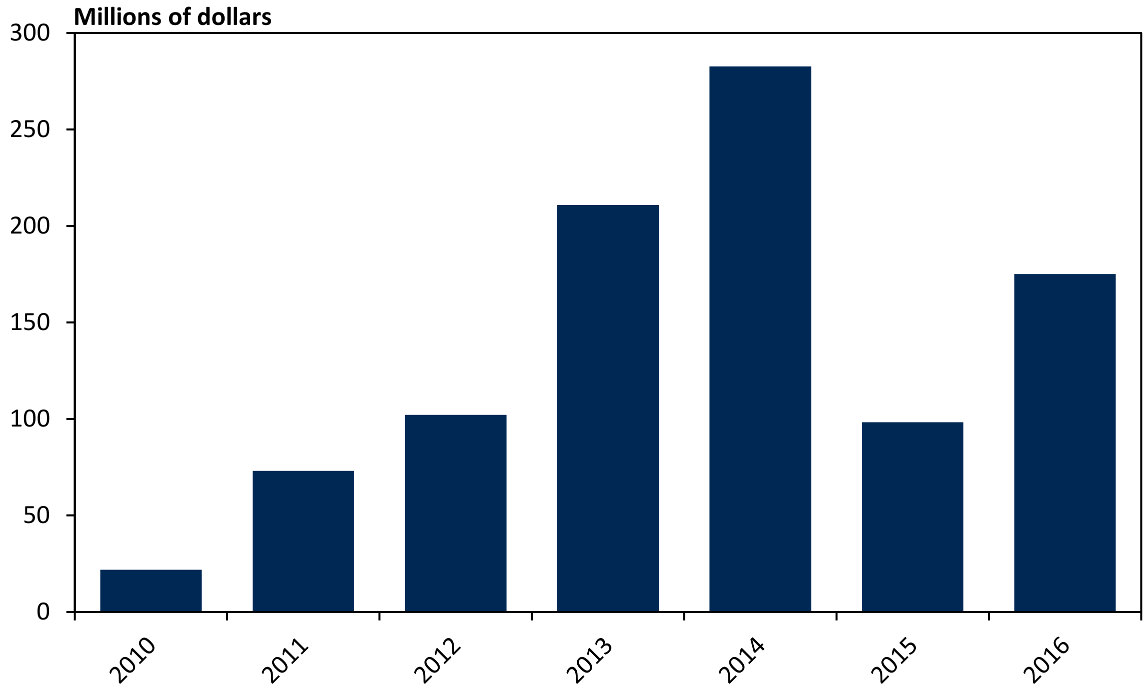
Figure 15: Average Natural Gas Prices



Source: Bloomberg

Using these assumptions, we estimate that mineral rights holders received a total of approximately $963 million in royalty payments throughout the 2010 to 2016 period. As shown in Figure 16, we estimate that royalty payments were about $22 million in 2010, then peaked in 2014 at about $283 million, and fell back to about $175 million in 2016.

Figure 16: Estimated Royalties from Wells Drilled Since 2010

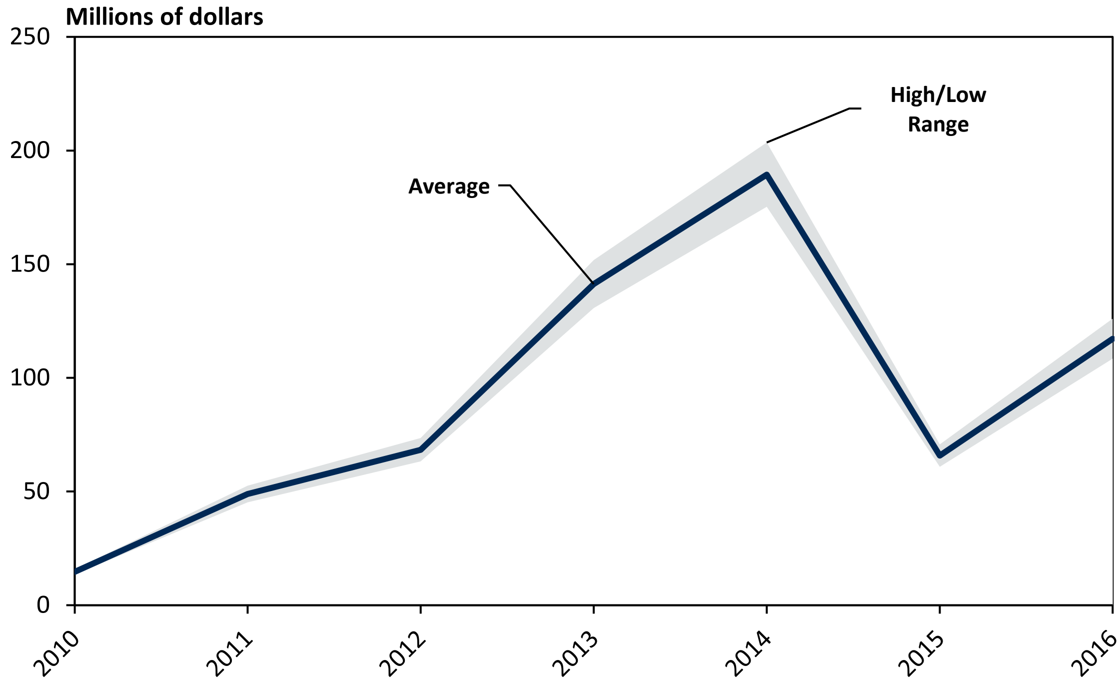


Source: WV Department of Environmental Protection, Bloomberg, Author Calculations

Royalty rates fluctuated considerably in the literature we surveyed for this analysis. Though Thomas et al. (2017) assumed a royalty rate of 20 percent of the total value, we found the average royalty rate cited in literature was significantly lower, at an average of 13.4 percent with a standard deviation of about 1 percentage point on either side. Using this figure, we find that royalties could be considerably smaller than the amounts calculated using the (Thomas et al., 2017) rate.

In Figure 17, we report estimated royalties using this lower royalty rate and provide a range of estimates one standard deviation above and below the average. Using this lower average rate, we estimate royalties to total approximately $694 million, with a range of $598 million on the low end to a high of $694 million.

Figure 17: Estimated Royalties Dollar Range



Source: WV Department of Environmental Protection, Bloomberg, Author Calculations

4 Midstream

Midstream costs comprise all types of expenditures associated with transporting natural gas from the wellhead to market. These expenditures include costs for pipeline construction, compression, processing, and storage. Because of a lack of data, we were unable to make independent estimates of pipeline mileage costs, and thus use estimates from (Thomas et al., 2017) exclusively. As in that publication, we assume the following costs:

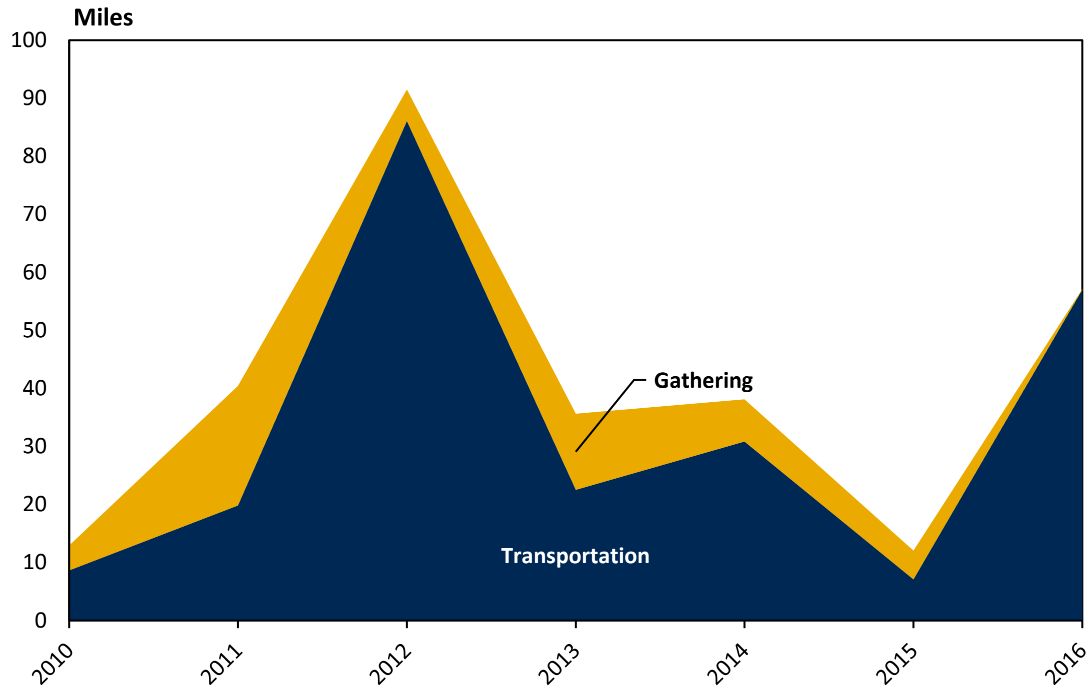
- $2.4 million per mile for 20-inch transportation pipeline
- $1.4 million per mile for gathering pipeline
- $400,000 per million cubic feet per day in processing costs

We also ignore costs associated with distribution pipelines, as these costs are not directly related to growth in natural gas production, but are determined largely by population growth and replacement of aging pipeline infrastructure. Data for this section come from the US Pipeline and Hazardous Materials Safety Administration.[7] As these data include mileage only for federally regulated pipelines, these estimates are most likely smaller than the total pipeline mileage built during this time period. Because of this, these investment estimates can be considered a conservative estimate of total costs.

[7] (PHMSA, 2018)

In Figure 18, we report total pipeline mileage construction for the period between 2010 and 2016. As shown in the Figure, total pipeline mileage added during this period was approximately 288 miles, consisting of 232 miles of transportation pipeline and 56 miles of gathering pipeline.

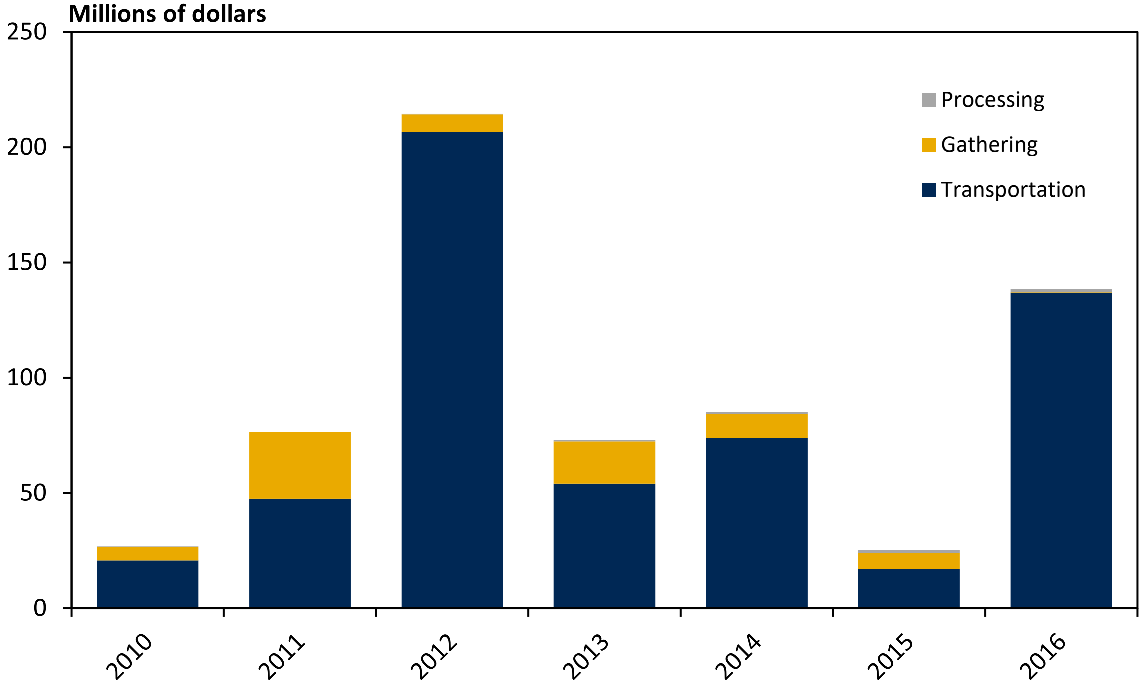
Figure 18: Annual Pipeline Mileage Growth



Source: US Pipeline and Hazardous Materials Safety Administration

Using these pipeline additions, we estimate total pipeline expenditures to be about $635 million between 2010 and 2016 (see Figure 19). The peak of pipeline construction came in 2012, with more than 91 miles of new transportation and gathering pipeline, and the low was reached in 2015 at about 12 miles. Processing costs over this period added another nearly $5 million in expenditures, for a total investment of almost $640 million.

Figure 19: Estimated Midstream Expenditures

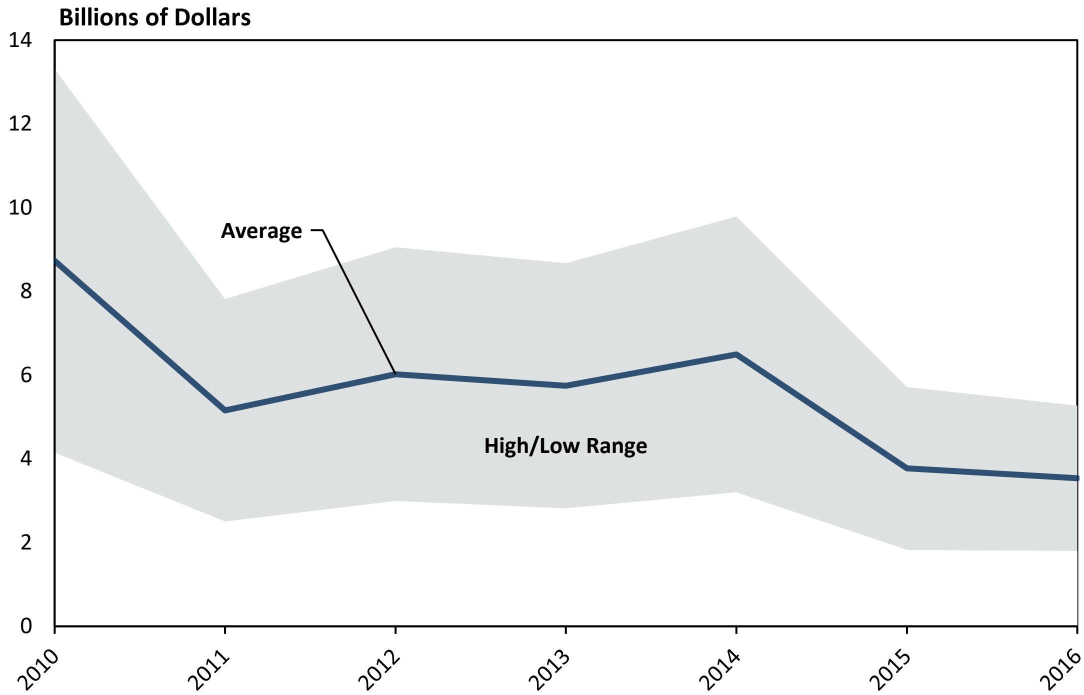


Source: US Pipeline and Hazardous Materials Safety Administration, Author Calculations

5 Conclusion

We estimate that investment in upstream and midstream activities totaled nearly $40 billion over the seven-year period between 2010 and 2016, as shown in Figure 20. However, our investment cost estimates are highly uncertain, as cost data varied widely in the literature we surveyed. Using alternative cost estimates puts the total estimate as much as $20 billion below or above the average number, meaning that we expect the actual investment to be somewhere between $20 billion and $60 billion.

Figure 20: Total Natural Gas Investment



Source: Author Calculations

We caution that it is difficult to know how much of this investment remained in the West Virginia economy after it was spent by the industry. Estimates from input-output accounts[8] indicate that as much as two-thirds of the initial investment expenditures were spent outside the state's economy. Also, we do not have adequate data on the number of workers in the industry who live outside West Virginia, and thus spend their income largely in their home region. Lastly, we have not attempted to examine the degree to which mineral rights holders spend their royalties within the state. These limiting factors suggest that the spillover effects of natural gas investment into the rest of the West Virginia economy is significantly lower than the investment amounts estimated above would indicate.

Despite these limitations, our analysis suggests that natural gas companies have invested tens of billions of dollars in the West Virginia economy since the natural gas boom started in 2010. This investment has provided a significant boost to the state's economy and tax revenue.

[8] Input-output models come from IMPLAN modeling software, an industry-standard model of the economy. More information about IMPLAN can be found at http://www.implan.com.

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