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Ownership of Oil and Gas Rights: Implications for U.S. Farm Income and Wealth

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Abstract

With the shale revolution, annual oil and gas production in the United States grew by 69 percent from 2005 to 2014, and almost 67 percent of the production occurred on farmland in 2014. The effect of oil and gas development on farm sector finances is not well understood. Limited nationwide information exists on issues such as the extent that farm operators and landlords own the rights to the oil and gas beneath their land, the value of the rights, or the timing and prevalence of leasing with energy firms. Subsurface ownership affects the ability of operators and landlords to benefit financially from development and to shape the terms on which it occurs. Using data from USDA's Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey, Drillinginfo, and USDA's 2012 Census of Agriculture, this report quantifies the farm sector's oil and gas wealth and income, and provides a basis for understanding how booms and busts in oil and gas production and prices might affect farm-sector finances.

Keywords: oil and gas, farm income and wealth, split estate

Acknowledgments

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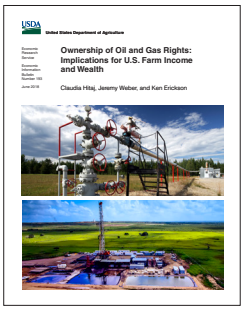


Ownership of Oil and Gas Rights: Implications for U.S. Farm Income and Wealth

Claudia Hitaj, Jeremy Weber, and Ken Erickson

What Is the Issue?

From 2005 to 2014, high energy prices and innovation in extraction methods spurred annual U.S. production of oil and gas to grow by 69 percent, with almost 67 percent of the production occurring on farmland in 2014. The growth generated tens of billions of dollars in additional revenue for owners of oil and gas rights and increased the value of the rights. Ownership of oil and gas rights affects the ability of farm operators and landlords to benefit financially from development and to shape development terms. Yet oil and gas development's effect on farm-sector finances as a whole is poorly understood. In this report, we quantify the farm sector's oil and gas wealth and income, including the extent that farm operators and landlords own the rights to the oil and gas beneath their land, the value of the rights, and the timing and prevalence of leasing with energy firms. Since oil and gas production is expected to grow by 23 percent from 2016 to 2025, the effect of such income could be significant.

What Did the Study Find?

Most farm operators and non-operator landlords do not own the oil and gas rights associated with their land and are thus unable to receive payments. In the 1,080 counties with oil and gas production in 2014, only 13 percent of non-operator landlords and 10 percent of farm operators (including both owner-operators and renters) reported receiving oil or gas payments.

In 2014, farm operators and non-operator landlords owned $32.9 billion in oil and gas rights that generated $7.4 billion in payments through leases with energy firms, which represented almost 17 percent of total net cash farm income for farm operators and non-operator landlords in oil- and gas-producing counties.

Because the benefits and challenges regarding oil and gas production differ substantially for farm operators and non-operator landlords, the findings that follow are grouped by these ownership categories.

Farm Operators:

- Farm operators owned $19.1 billion in oil and gas rights in 2014. In counties with oil and gas production, farm operators' oil and gas rights amounted to 3 percent of the value of land owned, and in the high-production States of Oklahoma and Pennsylvania, those shares were 7 percent and 9 percent of the value of land owned, respectively.
- Nationally, oil and gas rights generated $3.8 billion in payments in 2014, equal to about 4 percent of net cash farm income. In oil and gas counties, payments represented 11 percent of those counties' net cash farm income, and in Oklahoma, Pennsylvania, and Texas, payments represented almost 30 percent of those States' net cash farm income.
- In the oil and gas counties, 11 percent of farm operators reported owning oil and gas rights with positive value, and in Oklahoma and Pennsylvania, the share reached 14 percent.
- Much of the leasing of oil and gas rights to energy firms by farm operators has occurred with the recent growth in drilling in shale formations. Of the operators who leased out their oil and gas rights in 2014, more than 27 percent signed leases after 2011, and 44 percent signed after 2008.
- Consistent with the timing of leasing, drilling, and production, operators who leased their rights between 2006 and 2008 reported the highest mean and median energy payments in 2014, at nearly $90,000 and $30,000 for the year.

Non-Operator Landlords:

- Non-operator landlords reported holding $13.8 billion in oil and gas rights in 2014. Nationally, about 5 percent of non-operator landlords owned these rights, and for those with land in oil and gas counties, that share was 13 percent.
- Oil and gas payments generated $3.6 billion for these landlords in 2014 and represented large shares of net cash farm income: 17 percent nationally, 37 percent in oil and gas counties, and 60/70 percent in Texas and Oklahoma, respectively. For landlords, "net cash farm income" comprises rent and other payments, including (for those who possess oil and gas rights) oil and gas payments.
- Although non-operator landlords owned only 31 percent of total farmland in 2014, they received about 49 percent of total oil and gas payments going to farmland owners. One possible explanation is that non-operator landlords are more likely than farm operators to lease out their oil and gas rights or to negotiate lease terms that provide greater compensation.

How Was the Study Conducted?

Farm and landlord-level information from USDA, Economic Research Service (ERS) and USDA, National Agricultural Statistics Service (NASS), 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey was used to quantify the role of ownership of oil and gas rights in the income and wealth of farm operators and landlords. The 2014 TOTAL survey was the first time that a USDA survey collected information on the ownership and leasing of oil and gas rights. This study also uses information on oil and gas production from an ERS data product on county-level oil and gas production and from Drillinginfo, accessed by author Jeremy Weber, and information on land in farms from the USDA, NASS 2012 Census of Agriculture.

Ownership of Oil and Gas Rights: Implications for U.S. Farm Income and Wealth

Introduction

High energy prices and innovation in extraction methods spurred U.S. production of oil and gas to grow by 69 percent from 2005 to 2014 (EIA, 2017a). Much of the development occurred on private land overlying shale formations across the United States, especially those in North Dakota, Pennsylvania, and Texas. Development potentially affects a large number of farms, with diverse effects on agricultural production and farm household well-being. (See box, "Drilling for Shale Oil and Gas" for a primer on drilling.) Hitaj et al. (2015) provide an overview of various impacts, including increased demand for land, water, labor, and infrastructure; increased air pollution; and an increased risk of soil and water contamination. The effect on farm-sector finances is a key impact that is not well understood. Limited nationwide information exists on these issues, such as the extent that farm operators and landlords own the rights to the oil and gas beneath their land, the value of the rights, and the timing and prevalence of leasing with energy firms.

Energy firms typically access oil and gas through a lease with the owner of the oil and gas rights, who may or may not be the owner of the surface rights (see box "Split Estates," p. 7). Although firms often make a one-time payment to the owner when the lease is signed, most compensation occurs through royalty payments. These are based on a share of the value of production, known as a royalty rate, which is specified in the lease. Rights to oil and gas are valuable because of the potential for royalty payments, and the current value of the rights largely depends on the expected stream of revenue from future production.

Owners of oil and gas rights typically lease out their rights instead of selling them (Fitzgerald, 2014). Leasing potentially provides a revenue stream of royalties over time, whereas selling oil and gas rights yields a one-time payment based on the estimated potential revenue from future oil and gas development. We focus solely on leases in our report because they are more common and because it is often unclear if the current landowner acquired the farm before or after the rights were sold.

In 2014, the six major U.S. shale formations generated an estimated $39 billion in payments (Brown et al., 2016). Looking at farms, Weber et al. (2014) used data from the 2011 Agricultural Resource Management Survey (ARMS) to estimate that farm operators received $2.3 billion in energy payments over the year, the vast majority representing oil and gas royalty payments. By 2014, payments to farm operators (excluding non-operator landlords) had increased to $3.8 billion, of which farm businesses (farms with at least $350,000 in annual gross cash farm income or farms where the primary operator spends the majority of work time on agricultural production) received $2.9 billion (Hitaj and Suttles, 2016).[1]

[1]Farm operators can be divided into three categories in terms of ownership of land and oil/gas rights: (1) some farm operators own both the surface (land) and subsurface (oil and gas) rights; (2) some own only the surface rights; and (3) some own neither and rent the land from a landlord, who may or may not own the subsurface rights, which could be owned by a third party.

A limitation of prior research on energy development and farm-sector finances is that it did not cover payments to people who rent land to farmers but do not operate a farm themselves. This oversight misses an important piece of the picture, as approximately 39 percent of U.S. farmland is rented, including more than half of cropland and just over 25 percent of pastureland (Bigelow et al., 2016; USDA-NASS, 2015). Of the 39 percent of farmland that is rented, 80 percent is rented from someone who is not a farm operator (USDA-NASS, 2015). A more serious omission by the research is the lack of estimates about the extent that farm operators or landlords own the oil and gas beneath their land. Subsurface ownership substantially affects how much operators or landlords can benefit financially from oil and gas development, opt in or out of development, or shape the terms on which it occurs.

Another limitation of prior research is that it lacked data on the value of oil and gas rights owned by farm operators or landlords. Research suggests that these rights might be a considerable component of farm wealth in some regions. When reporting farm real estate values, farm operators who own oil and gas rights may include the value of the rights in the reported values. Weber et al. (2014) estimated that each $1 in lease and royalty payments for oil and gas was associated with $2.50 in higher farm real estate values for farms nationwide. Looking at changes in farm real estate values in areas with and without shale gas development on the Pennsylvania-New York border, Weber and Hitaj (2015) estimated that leasing activity led to a nearly 50-percent appreciation in values. The findings of both studies suggest that oil and gas rights may be a substantial farm asset in some regions.

Our analysis is based on several data sources. The Census of Agriculture, which is conducted every 5 years by USDA's National Agricultural Statistics Service (NASS), gives a detailed picture of U.S. farms and ranches and the people who operate them. We used data on land in farms by county from the 2012 Census of Agriculture. The Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey, which was conducted by NASS and ERS in 2014, is a national survey of farm operators (including owner-operators[2] and renters) and non-operator landlords. The TOTAL survey provides the first nationwide data on ownership of oil and gas rights by U.S. farm operators and non-operator landlords. The survey collected information on farm income, debt, assets, and the timing of leasing and total energy payments received by operators and landlords. (The Appendix covers the most relevant survey questions related to ownership of and income from oil and gas rights.) We obtained county-level data on oil and gas production from Drillinginfo.

In the following sections, we distinguish farm operators (including both owner-operators and operators who rent the land they farm) from non-operator landlords, who do not operate the land they own but rent it out instead. Also, by focusing on family farms—which, in 2014, constituted 98.9 percent of U.S. farms and operated 96.2 percent of farmland—we are able to include information on household income and wealth, which is collected only for family farms.[3]

[2]Owner-operators may also rent out part of their land. These owner-operators are technically also landlords, but they do not fall into the non-operator landlord category, because they operate part of the land they own. In this report, we do not distinguish between owner-operators that operate all of their land and owner-operators that operate part of their land and rent out the remainder.

[3]Family farms are defined as those where the operator and individuals related to the operator own the majority of the business.

Drilling for Shale Oil and Gas

The shale revolution began in the early 2000s when energy firms began widespread use of horizontal drilling and hydraulic fracturing to extract oil and natural gas from shale formations. In many instances, shale formations lie below geological layers that had (or continue to have) conventional oil and gas production. Before the 2000s, however, shale formations themselves had not been a focus of extraction, and production from them was negligible.

Shale formations (or shale "plays") can hold large amounts of oil and gas but are highly nonporous, making extraction by conventional methods ineffective. With hydraulic fracturing, the rock surrounding the well is fractured by a pressurized liquid, usually water, some chemicals, and a proppant (usually sand). The proppant remains in the small fractures, keeping them open to allow gas or oil to flow into the well bore. Horizontal drilling allows the well to extend across long sections of the shale, thereby increasing exposure of the wellbore to the shale formation. A well can be refractured at a later time to increase production.

Extraction can begin once a well operator has leased the necessary oil and gas rights, obtained permits, and prepared the well site. A drilling rig is moved into the area to drill the well, including both the vertical and horizontal portions. The wellbore is then cased with cement, and the fracturing fluid is pumped into the well at high pressure, creating fissures in the rock and allowing the trapped oil or gas to escape. The oil or gas (or both) and water flow to the surface and are then transported from the well site by truck or pipeline.

Extraction requires land for the well pad, access roads, water impoundments, and storage of supplies and equipment. Farming can continue around the well site, though farm operators and livestock may be affected by possible air, water, light, and noise pollution from the drill site. Some of these impacts diminish once a well is drilled and hydraulically fractured, which can take several weeks to months. A producing well is topped with valves and connected to a pipeline.

Oil and Gas Production on Farmland

Oil and gas production disproportionally occurs in areas where large shares of land are operated by farmers and ranchers. Using data on land in farms from the 2012 Census of Agriculture and oil and gas production at the county level from Drillinginfo as detailed in the footnote below, we estimate that, in 2014, the value of oil and gas production on land operated by farms amounted to $226 billion, accounting for 67 percent of the total $338 billion in oil and gas production in the contiguous United States.[4] However, in 2012 farmland[5] accounted for only 48 percent of the land area in the contiguous United States.

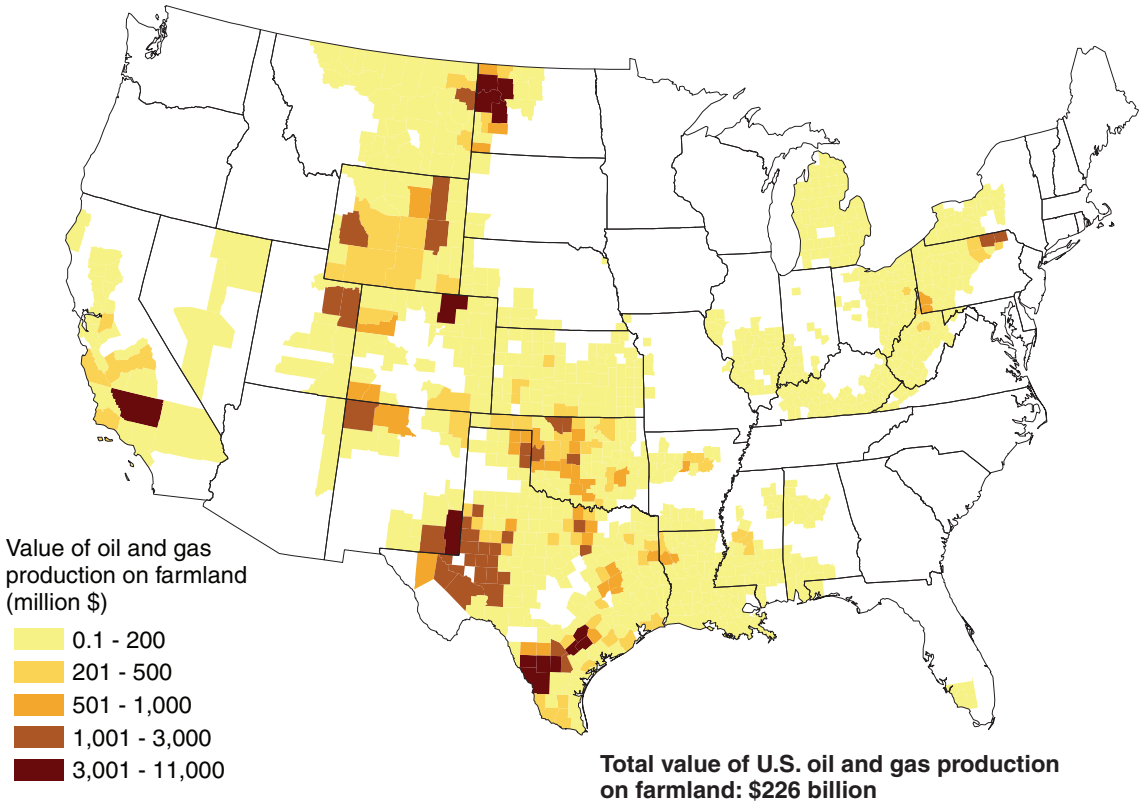
Drillinginfo data show that U.S. oil and gas production on farmland is concentrated (1) in California, (2) in a longitudinal band from North Dakota to Texas, and (3) in the Marcellus Shale region in Pennsylvania, West Virginia, and Ohio (fig. 1).

Drawing from more than 1.7 million lease records across major oil- and gas-producing States, Brown et al. (2016) report an acre-weighted average royalty rate of 17.8 percent. If farmers and landlords had this average rate, the value of production in 2014 from Drillinginfo suggests that farmers and landlords would have received around $40 billion in oil and gas payments if they had owned the oil and gas rights to all of their land and were willing to lease them (table 1), given 2012 Census of Agriculture data on land in farms.

[4]To calculate the percentage, we divide the total oil and gas production on land operated by farms by total production across all land. The value of oil and gas production is based on applying national energy prices from the U.S. Department of Energy's Energy Information Administration to production data from Drillinginfo (accessed by one of the report's authors). To estimate total oil and gas production on land operated by farms, we multiply each county's value of oil and gas production by its share of land that is operated by farms as indicated by the 2012 Census of Agriculture. Summing across counties provides an estimate of total oil and gas production on land operated by farms. The estimation assumes that farmland and nonfarmland are equally likely to lease oil and gas rights to energy companies and receive royalties.

[5]We use "farmland" to mean not only farm-operated land, which includes cropland and pasture, but also any land that the respondent considers a part of the farm, including forests, swamps, or other nontillable land.

Figure 1
Value of oil and gas production on farmland by county, 2014



Source: USDA, Economic Research Service (ERS) analysis using data from Drillinginfo; USDA, National Agricultural Statistics Service (NASS), 2012 Census of Agriculture; and NASS and ERS, 2014 Tenure, Ownership, and Transition of Agricultural Land Survey. The value of oil and gas production in Illinois, Indiana, and Kentucky was estimated using oil and gas production data for 2011 (the most recent year) from ERS (USDA-ERS, 2014), along with oil and gas prices for 2014 from U.S. Department of Energy, Energy Information Administration.

Comparing this $40 billion oil and gas payments estimate to the actual oil and gas payments of $7.4 billion reported in the 2014 TOTAL survey[6] suggests that farmers and non-operator landlords own 19 percent of the rights to oil and gas beneath their farmland (see box "Split Estates"). Our estimated incidence of split estates on farmland is highest in States with a history of oil and gas production, such as North Dakota (91 percent) and Texas (85 percent). Our estimates are lower in States where shale plays extend into new territory (in terms of historical oil and gas production)—such as parts of the Marcellus Shale in Pennsylvania (38 percent split estates) and Ohio (44 percent)—and do not overlie conventional oil and gas fields.

[6]Throughout the report, the statistical reliability of each individual survey estimate presented in charts and figures was measured using the coefficient of variation (CV). For a particular estimate, the CV is measured as the ratio of the standard error to the estimated value. CVs are denoted in each chart and table by placing a caret (^) next to an estimate with a CV between 25 and 50, and a pound sign (#) next to an estimate with a CV greater than 50. Dubman (2000) provides an overview of survey estimators, sample design, disclosure rules, and reliability measures for USDA surveys, as well as a description of how the coefficient of variation (CV) is estimated with the delete-a-group jackknife method (30 replications).

The numbers are rough estimates of the extent of split estates and are similar to a production-weighted average of each acre's status. The estimates are a plausible upper-bound estimate of the extent of split estates because we assumed that all respondents who refused to answer the energy payment question received no payments in the survey year.[7] We also assumed that all farmland owners who owned their oil and gas rights were willing to lease them.

Table 1
Estimated and reported value of oil and gas production on U.S. farmland and for major oil and gas-producing States

	Value of oil and gas production in 2014 (billion $)	Estimated value of oil and gas production in 2014 *on farmland* (billion $)	Estimated oil and gas payments to farmland owners assuming 17.8% royalty rate (billion $)	Oil and gas payments in 2014 from TOTAL survey (billion $)	Estimated incidence of split estates[1] (percent)
U.S.	338.1	225.5	40.1	7.4	81.5
Texas	138.5	115.5	20.6	3.0	85.3
Oklahoma	22.1	20.1	3.6	1.2	65.9
Pennsylvania	19.2	5.6	1.0	0.6^	37.8
North Dakota	36.5	26.6	4.7	0.4^	90.8
Ohio	3.6	1.4	0.2	0.1^	44.2
Arkansas	5.5	2.3	0.4	0.1^	70.8

[1]The estimated incidence of split estates is calculated as 1- (oil and gas payments reported in TOTAL/estimated oil and gas payments to farmland owners). The estimated incidence of split estates describes the share of farmland owners that do not own their mineral rights, given the assumptions described in the main text. In all figures based on the 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey data, a coefficient of variation (CV) between 25 and 50 is denoted with a ^, and a CV greater than 50 is denoted by a #.

Source: USDA, Economic Research Service (ERS) analysis using data from Drillinginfo; USDA, National Agricultural Statistics Service (NASS) 2012 Census of Agriculture; and NASS and ERS, 2014 TOTAL Survey.

[7]The response rates for the energy payment question and the value of mineral rights questions were very high, at 99.94 percent and 99.03 percent, respectively.

Split Estates: Surface and Subsurface Rights Are Owned by Different Entities

The ability of landowners to profit from oil and gas development on their land depends on whether or not they own the oil and gas rights associated with their property.

Split-estate situations occur when the surface (land) rights and subsurface (oil and gas) rights are owned by different entities. Split estates are common (Fitzgerald, 2014), particularly when shale plays that have only recently been developed lie above or below conventional oil and gas fields with a history of drilling, because oil and gas rights may have been sold during a prior development period. Looking at self-reported farm real estate values, Weber and Hitaj (2015) find evidence of broader ownership of oil and gas rights by surface owners in the northeastern part of the Marcellus Shale in Pennsylvania than in the Barnett Shale in Texas, which overlies a conventional gas field.

The Federal Government also owns the oil and gas rights on some privately owned land, since settlers who acquired land through homesteading after the 1916 Stock Raising Homestead Act were granted only the surface rights. The U.S. Department of the Interior, Bureau of Land Management manages 700 million acres of subsurface mineral estates for the Federal Government, including about 58 million acres (8 percent) where the surface is privately owned (BLM, 2007). These split-estate acres are concentrated in Western States, such as Montana, Wyoming, Colorado, New Mexico, and North Dakota, where many land claims were made after the 1916 Homestead Act (Fitzgerald, 2014).

The oil and gas rights to a single piece of land may be owned by multiple entities. Fractionalization of mineral rights is common and often begins when mineral property is conveyed between generations, such as when a mineral owner bequeathes equal shares to multiple children (Fitzgerald, 2014). By default, mineral rights are conveyed as tenants-in-common rather than as owners of separate acreage, such that, for example, each of four legatees owns a quarter of the whole acreage rather than all of one quarter of the acreage (Fitzgerald, 2014).

How oil and gas development affects landowners depends in large part on subsurface ownership (Collins and Nkansah, 2015). When the surface and subsurface rights are owned by different people, oil and gas rights are considered the dominant estate, so they take precedence over other rights associated with the property, including those associated with owning the surface (BLM, 2017). A landowner who does not own the oil and gas rights associated with his/her property has little control over if or how drilling occurs on the property. Moreover, the surface owner receives only payments to compensate for use of (or damages to) the surface, not payments from production.

Oil and Gas Right Ownership and Farm Finances in Aggregate

Based on the 2014 TOTAL survey, farm operators and non-operator landlords owned $32.9 billion in oil and gas rights in 2014 that generated $7.4 billion in payments through leases with energy firms (table 2). The payments and the value of the oil and gas rights that generate them suggest a capitalization rate of 22 percent.[8] The capitalization rate is the ratio of income to the value of the right and it can be interpreted as the rate of return on an investment. Such a high rate is unsurprising given that future energy prices are uncertain and payments from current producing rights will likely decline over time as the most accessible resources are exhausted. Making a finance analogy, there is thus a sizable option value associated with exercising (leasing) oil and gas rights.

Oil and gas payments are economically important, representing 6.3 percent of net cash farm income and 4.7 percent of off-farm household wages and salaries earned by all operators and landlords nationally in 2014.[9] The relative importance of the payments is higher when considering only the 1,080 counties that had oil and gas production in 2014.[10] About 48 percent of all land in U.S. farms was located in these oil and gas counties. For these counties, oil and gas payments represented 17 percent of net cash farm income and 11 percent of off-farm household wages and salaries earned by operators and landlords. Royalty income from oil and gas leases adds substantial revenue to the farm sector in oil and gas counties. This financial boost is particularly noteworthy in Pennsylvania, Oklahoma, and Texas, where oil and gas payments amounted to almost 30 percent of net cash farm income for farm operators.

Non-operator landlords received 49 percent of total oil and gas payments going to farmland owners, but accounted for only 31 percent of the total land operated by farms. This discrepancy may indicate that non-operator landlords are more likely to lease out their oil and gas rights than farm operators or to negotiate better lease terms. A greater propensity to lease land for drilling is plausible because non-operator landlords (typically) do not reside on the property, so they are less likely to experience the dust, noise, or other inconveniences of drilling. Or it may simply be that non-operator ownership of land is more common in areas with the most leasing activity, perhaps even because non-operator landlords sought to buy land in areas rich in oil and gas resources. The share of oil and gas payments going to non-operator landlords varies widely across States (fig. 2).

[8]The capitalization rate of 22 percent that was determined here is simply the discount rate that gives an infinite stream of $7.4 billion and a present value of $32.9 billion. Mathematically, it is the income (oil and gas payments) divided by the value of the rights. High capitalization rates can reflect a number of factors, such as (1) an expectation that payments are in fact finite or (2) uncertainty over actual payments. Both are true of oil and gas royalties.

[9]Oil and gas payments are part of "cash farm-related income" in the ERS data product on "U.S. farm sector financial indicators" available online.

[10]Since our definition of oil and gas counties is very inclusive (any oil or gas production greater than zero), some of our measures of oil and gas payments or leasing activity can be lower for "oil and gas counties" than for individual States, if those States are high-production States.

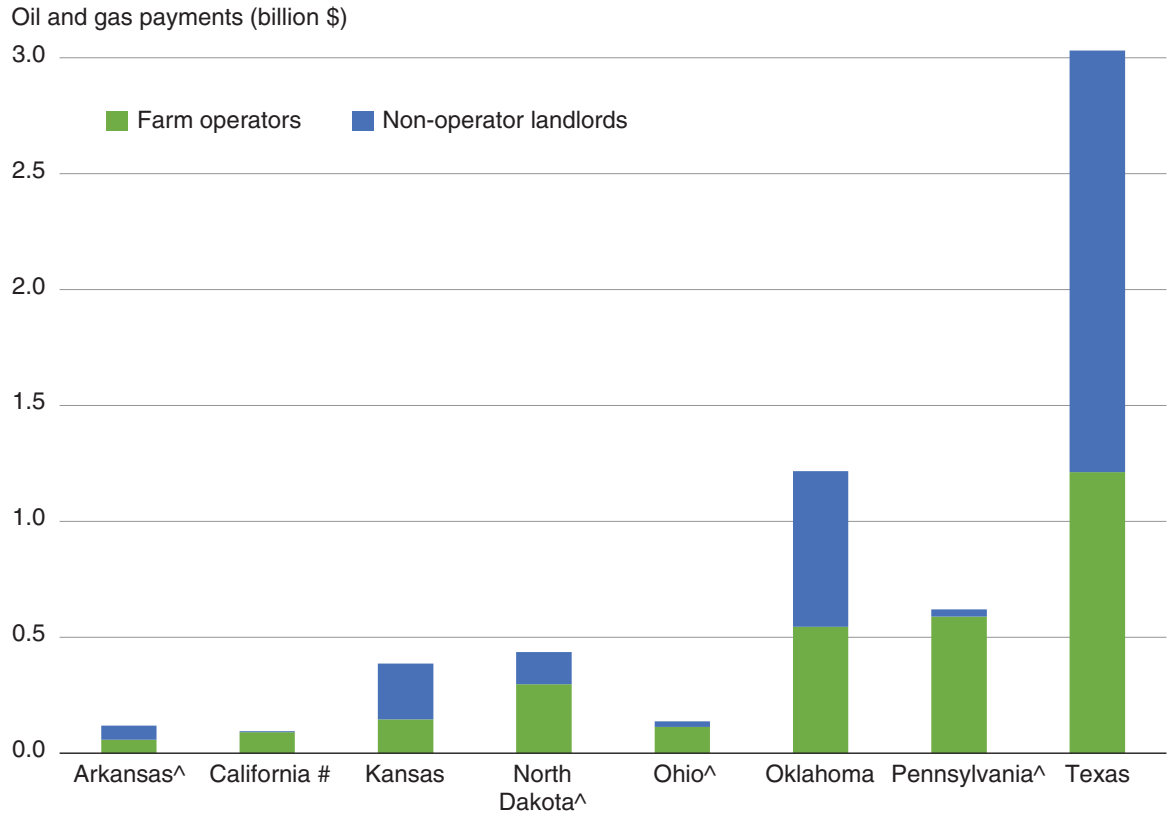
Table 2
Aggregate values of oil and gas payments and rights, 2014

	Total oil & gas payments (million $)	Payments as percent of		Value of oil and gas rights (million $)	Oil & gas rights as a percent of land values (excluding housing structures)
		net cash farm income	off-farm household wages and salaries		
Both farm operators and non-operator landlords					
United States	7,437	6.3	4.7	32,892	1.5
Oil and gas counties	7,152	16.5	10.9	27,562	3.2
Non-operator landlords					
United States	3,612	16.9	5.1	13,753	1.6
Oil and gas counties	3,477	37.1	12.5	12,246	3.6
Farm operators					
United States	3,825	4.0	4.3	19,140	1.4
Oil and gas counties	3,676	10.8	9.7	15,316	3.0
By State (all counties)					
Alabama	2.4#	0.4	0.2	400#	2.4
Arkansas	58.2^	3.6	3.5	216^	1.2
California	90.5#	0.8	2.2	526#	0.7
Kansas	146.4	4.5	6.8	481	0.9
Mississippi	5.9^	0.7	0.5	193^	1.2
North Dakota	296.9^	6.0	30.0	1,041^	2.6
Ohio	113.0^	4.6	3.6	1,882#	4.0
Oklahoma	546.1	29.4	9.5	2,428	6.7
Pennsylvania	589.3^	26.1	28.6	2,594	9.0
Texas	1,213.2	31.4	7.7	3,324	2.5
All other States	763.4^	1.2	1.5	6,054	0.7

Note: Land values exclude the value of housing structures. Only family farms, which account for 98.9 percent of all farms and 96.2 percent of operated land, are included for these estimates. In all figures based on the 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey data, a coefficient of variation (CV) between 25 and 50 is denoted with a ^, and a CV greater than 50 is denoted by a #.

Source: USDA, Economic Research Service (ERS) analysis using USDA, National Agricultural Statistics Service and USDA, ERS, 2014 TOTAL survey.

Figure 2
Total oil and gas payments in 2014, by type of landowner for select States



Note: Only operators of family farms, which account for 98.9 percent of all farms and 96.2 percent of operated land, are included for these estimates. In all figures based on the 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey data, a coefficient of variation (CV) between 25 and 50 is denoted with a ^, and a CV greater than 50 is denoted by a #.
Source: USDA, Economic Research Service (ERS) analysis using USDA, National Agricultural Statistics Service and USDA, ERS, 2014 TOTAL survey.

Oil and Gas Payments in Perspective: Payments From Leasing Wind Rights

Payments from wind power companies are another stream of revenue from the energy sector to the farm sector, as farmland owners can also lease land to wind power developers. Compensation is usually in the form of a fixed annual rate per turbine or on a per-megawatt-hour basis. Farming can still occur around the wind turbine site, though issues can arise. For example, some farmers have encountered challenges with aerial spraying of pesticides when aerial sprayers have refused to fly over fields with wind turbines or requested surcharges or additional insurance (Crane, 2009). Wind power production in the United States is concentrated in the Pacific States, Midwest, and Southern Plains.

For the United States as a whole, leasing wind rights is less common than leasing oil and gas rights. Only 0.4 percent of farmland owners reported receiving payments from leasing wind rights, compared to 4.3 percent receiving payments from oil and gas rights. Average payments to farm operators are also lower, at $8,287[11] for wind compared to $43,736 for oil and gas. In aggregate, farm operators and non-operator landlords received $74.8 million and $68.8 million,[12] respectively, in wind lease payments for a total of $143 million. For comparison, oil and gas payments to the farm sector in 2014 were 50 times larger, totaling $7.4 billion.

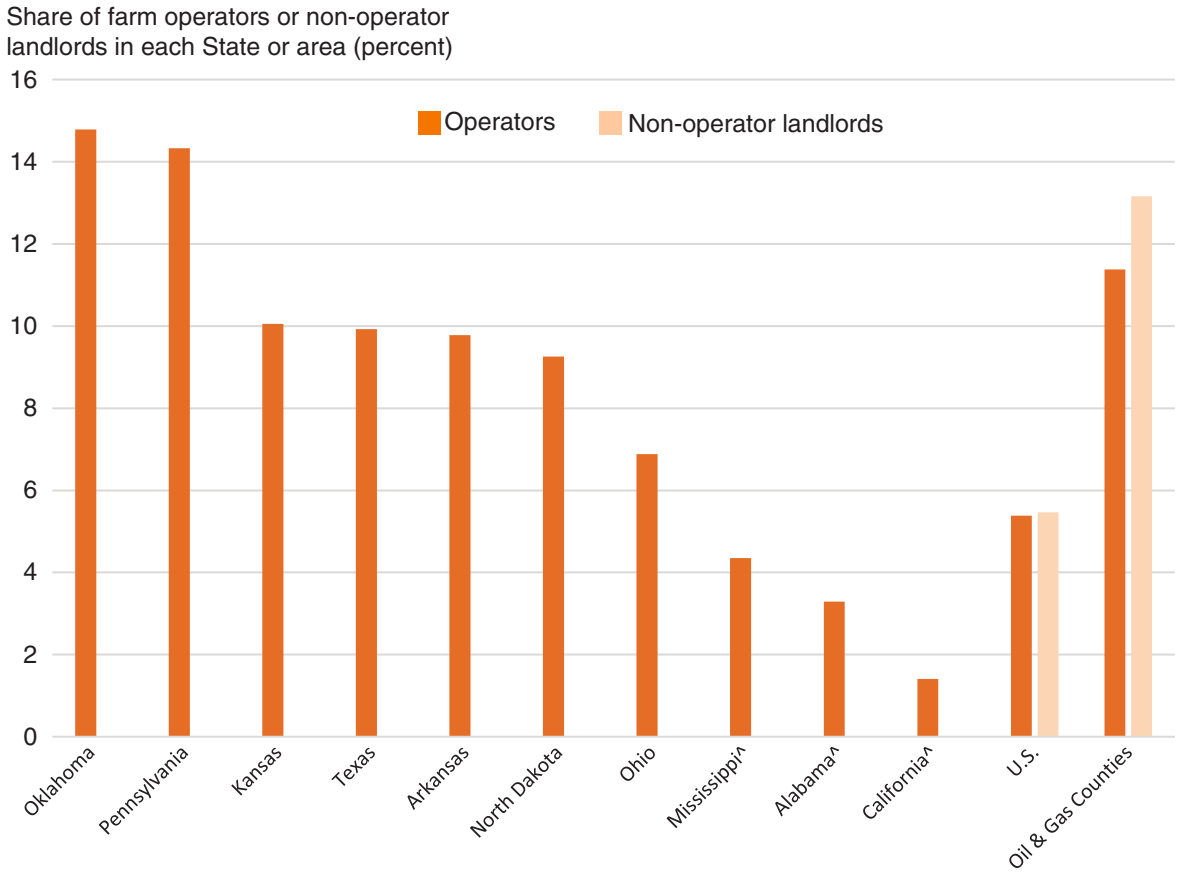
[11]The coefficient of variation for the average wind payment to farm operators is 27.

[12]The coefficients of variation for wind lease payments to farm operators and non-operator landlords are both 25.

Incidence of Ownership and Payments Across Operators and Landlords

Nationally, 5.4 percent of farm operators and a similar share of non-operator landlords reported owning oil and gas rights with positive value (fig. 3). In oil and gas counties, the shares were higher at 11.4 percent of farm operators and 13.2 percent of non-operator landlords. The share of operators who reported owning oil and gas rights with positive value exceeded the national average in States where oil and gas counties were abundant, including Oklahoma and Pennsylvania (each around 14 percent) and Kansas, Texas, Arkansas, and North Dakota (each around 10 percent). As explored above, split estates are more common in the Western United States, so it is not surprising that ownership among farm landowners was highest in Eastern States, such as Pennsylvania. Although Pennsylvania is home to conventional oil and gas fields, a large part of the Marcellus shale play extends into areas with little history of drilling. Unified estates are likely much higher there, increasing the State average.

Figure 3
Ownership of oil and gas rights in 2014



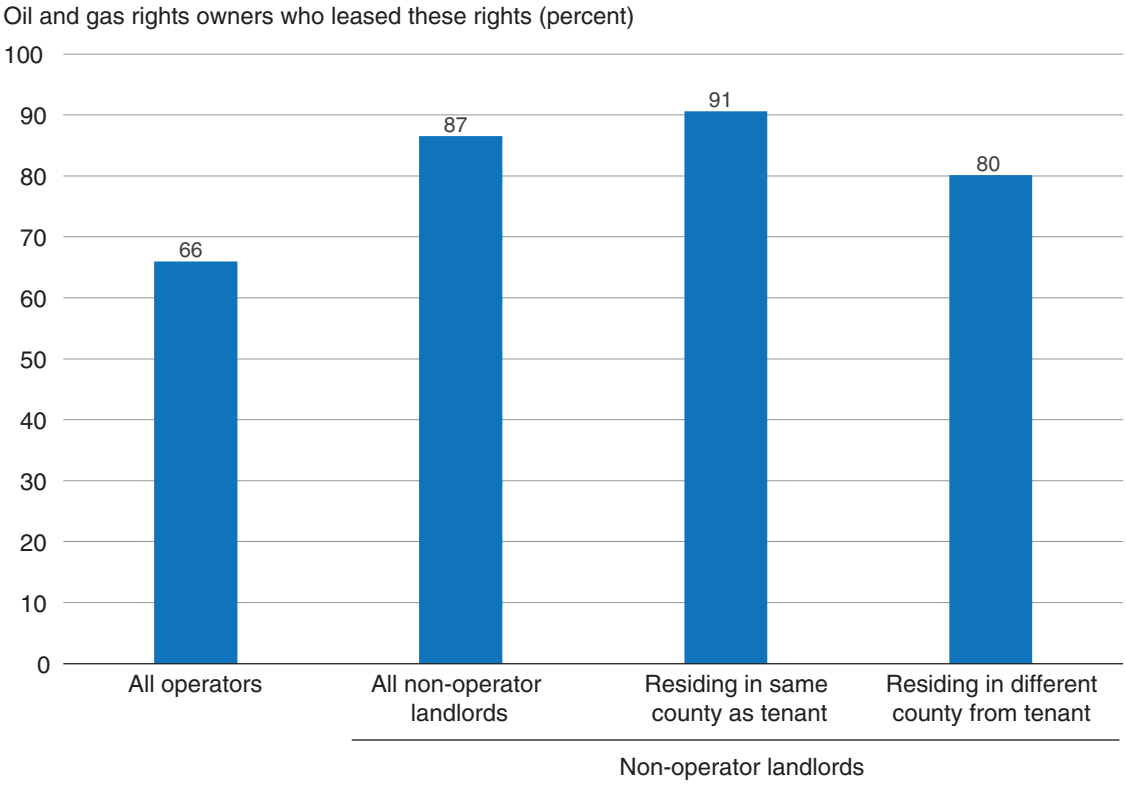
Note: Only family farms, which account for 98.9 percent of all farms and 96.2 percent of operated land, are included for these estimates. In all figures based on the 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey data, a coefficient of variation (CV) between 25 and 50 is denoted with a ^, and a CV greater than 50 is denoted by a #.

Source: USDA, Economic Research Service (ERS) analysis using USDA, National Agricultural Statistics Service and USDA, ERS, 2014 TOTAL survey.

Nationally, in 2014, 4.3 percent of farmland operators and 4.9 percent of non-operator landlords reported receiving oil and gas payments. Even in oil and gas counties, only 10 percent of operators and 13 percent of non-operator landlords reported receiving this income. Hence, in 2014, nearly 90 percent of farm operators and 87 percent of non-operator landlords in oil and gas counties did not benefit financially from oil and gas development in the form of oil and gas payments.

Of the landowners who reported owning oil and gas rights with positive value, non-operator landlords were 21 percentage points more likely than all operators to lease their rights to energy firms (fig. 4). Non-operator landlords who lived in the same county as their tenant were more likely to allow energy development to occur than were landlords who lived in a different county.

Figure 4
Share of oil and gas rights owners who leased these rights, by type in 2014



Note: This figure includes only farm operators of family farms or non-operator landlords who own their oil and gas rights. Family farms account for 98.9 percent of all farms and 96.2 percent of operated land. In all figures based on the 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey data, a coefficient of variation (CV) between 25 and 50 is denoted with a ^, and a CV greater than 50 is denoted by a #.
Source: USDA, Economic Research Service (ERS) analysis using USDA, National Agricultural Statistics Service and USDA, ERS, 2014 TOTAL survey.

Operators who live and work on the property may be less likely than non-operator landlords to lease their oil and gas rights because they would experience the costs or inconveniences associated with drilling and production—including air, noise, and light pollution; increased truck traffic; visual impacts; and risk of water or soil contamination. Because non-operator landlords are less likely than farm operators to reside on the property (40 percent of non-operator landlords live in a different county than their tenant), they are less likely to directly incur these costs and simply receive the benefit of development in the form of oil and gas payments. Owners residing on the farm, in contrast, may demand more lucrative lease terms to compensate for ancillary costs of drilling and production and, as a result, be less likely to sign a lease. Or the difference in participation in leasing may simply indicate that non-operator landlords own more land than farm operators do in areas with high demand for leasing.

Ownership of Oil and Gas Rights Determines Distribution of Benefits and Costs Across Farmers in Shale Areas

Each surface and subsurface ownership arrangement has different implications for the farm operator. The farm operator who owns both the land and associated subsurface rights stands to benefit the most from development. Ownership of the surface and subsurface estate gives the operator the incentive to negotiate lease terms to protect the value of the combined surface and subsurface estate, which would include limiting damages to the surface. One aspect that can be negotiated is the placement of the wellpad. Because horizontal wells can extend 4,000 to 9,000 feet, a single well pad can access oil or gas across large areas. North Dakota, for example, has adopted spacing unit sizes of 320, 640, or 1,280 acres (NDIC, 2015). Depending on his or her bargaining power, the oil and gas right owner could stipulate that no wellpads may be located on the leased property.

However, it is possible that an operator has only partial ownership of oil and gas rights because the rights may be held in common with several other people, such as other legatees of a single estate (e.g., siblings or cousins descended from the same individual). Division of mineral rights upon inheritance may be more common in areas with a history of drilling, where these rights were known to be valuable, than in new shale areas where oil and gas rights were presumed to be worthless before technological advances allowed extraction of oil and gas resources from shale plays.

An owner's ability to refuse to sign a lease may also be limited by State laws on forced pooling, which address the scenario when a single landowner or, more commonly, a group of landowners wish to pool their tracts together for oil or gas development, but one or more nearby landowners (whose land would be necessary to create a spacing unit) hold out against drilling operations (Sylvester and Malmsheimer, 2015). For example, although Pennsylvania and Texas do not allow forced pooling, in other States the majority of acreage (50–80 percent) needs to be voluntarily leased before holdouts can be force-pooled (Sylvester and Malmsheimer, 2015).

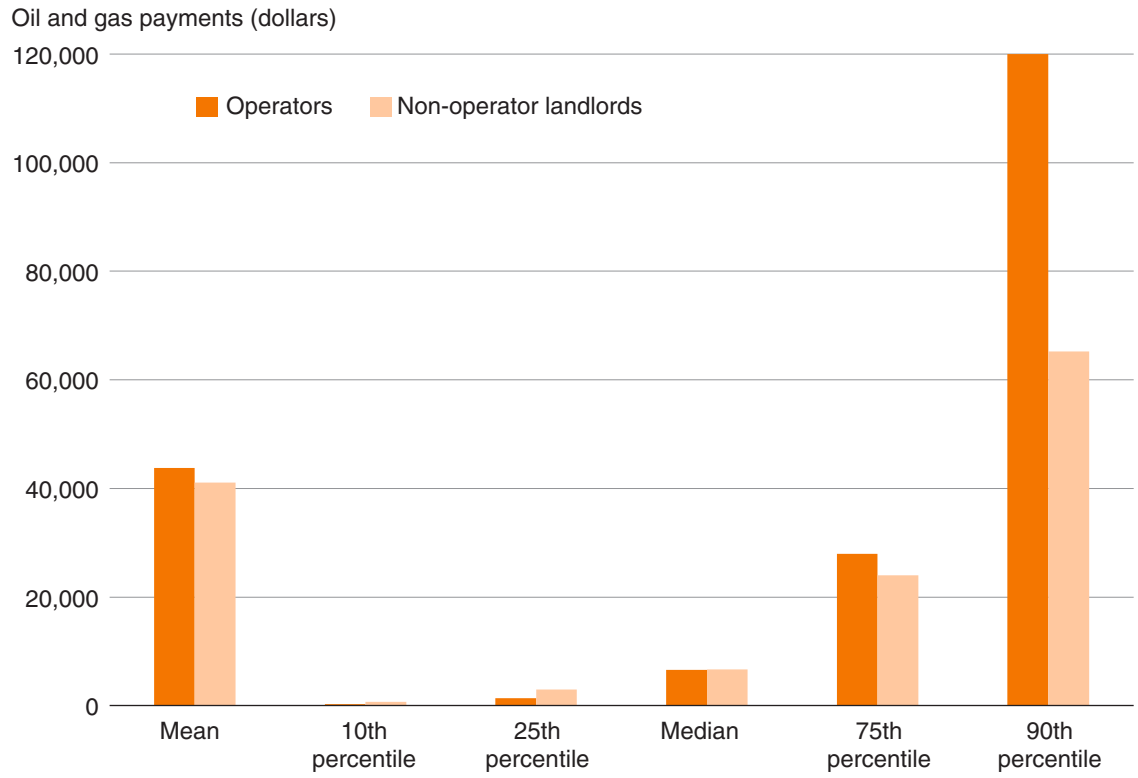
Operators who do not own oil and gas rights have limited opportunity to benefit financially from oil and gas development, aside from potentially selling energy companies materials such as water or straw or receiving surface-use payments for wellpads, access roads, pipelines, or other infrastructure. Compensation for surface use is typically linked to land area and may not reflect the full effect of the activity on the farming operation's profitability.

Operators who only rent land from others—and therefore own neither the surface nor subsurface—may face the same inconvenience of working around drilling infrastructure and activities that owner-operators face. However, rental arrangements are often revisited annually, giving renters an opportunity to negotiate a rental rate that incorporates the cost of working around drilling operations. Thus, operators who rent land are not necessarily worse off than operators who only own the surface. Non-operator landlords who own the oil and gas rights associated with the farmland may choose to negotiate terms that limit drilling activity or infrastructure to protect the value of the surface estate and maintain the farmland rental value.

Distribution of Economic Value of Rights and Payments Across Operators and Landlords

Among operators who received oil and gas payments, the distribution of payments was quite skewed. The top 10 percent of farm operators received oil and gas payments that were more than 18 times larger than those of the bottom 50 percent, and the mean payment ($43,736) was almost seven times larger than the median payment ($6,600) received (fig. 5).[13] The distribution of valuable oil and gas rights is similarly skewed: the median and mean operator owned $25,421 and $173,135 worth of rights, respectively. By comparison, net cash farm income was less skewed, with the mean income ($89,147) about four times larger than the median income ($20,301).

Figure 5
Distribution of oil and gas payments in 2014, by owner type



Note: Only family farms, which account for 98.9 percent of all farms and 96.2 percent of operated land, are included for these estimates. In all figures based on the 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey data, a coefficient of variation (CV) between 25 and 50 is denoted with a ^, and a CV greater than 50 is denoted by a #.

Source: USDA, Economic Research Service (ERS) analysis using USDA, National Agricultural Statistics Service and USDA, ERS, 2014 TOTAL survey.

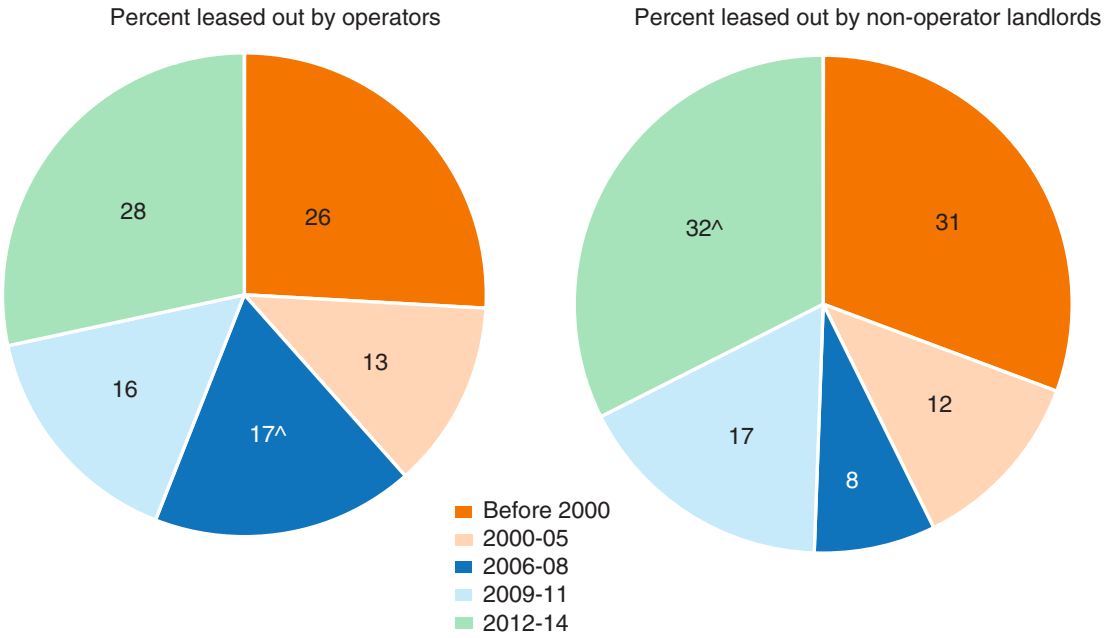
[13]The distribution of payments to non-operator landlords was only slightly less skewed, as the mean payment was six times larger than the median payment.

A skewed distribution of oil and gas payments is expected. Most payments will go to people who have complete ownership of large tracts in geologically rich areas and who will benefit from more acreage and production but also higher royalty rates. In addition, the analysis for figure 5 did not control for the period in which the oil and gas rights were initially leased, which affects the size of payments, because oil and gas payments initially rise after the well is drilled (usually about 4 to 5 years after a lease is signed) and decline rapidly thereafter, unless the well is re-fracked to produce more oil or gas.

Timing of Leasing and Payments

Much of the leasing of oil and gas rights by operators has occurred recently in conjunction with the growth in drilling in shale formations. More than a quarter (27 percent) of operators with leased oil and gas rights in 2014 signed leases after 2011, and 44 percent signed after 2008. In terms of acreage, farm operators and non-operator landlords leasing after 2008 accounted for almost 50 percent of the acreage of all farms with oil and gas leases (fig. 6). Leasing out land to energy firms increased over time, and further growth in leases is plausible, as the EIA forecasts a steady growth in oil and gas production from shale plays to 2040 (EIA, 2017b).

Figure 6
Share (percent) of farm acres with leased oil and gas rights in 2014, by year first leased



Note: Only family farms, which account for 98.9 percent of all farms and 96.2 percent of operated land, are included for these estimates. In all figures based on the 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey data, a coefficient of variation (CV) between 25 and 50 is denoted with a ^, and a CV greater than 50 is denoted by a #.

Source: USDA, Economic Research Service (ERS) analysis using USDA, National Agricultural Statistics Service and USDA, ERS, 2014 TOTAL Survey.

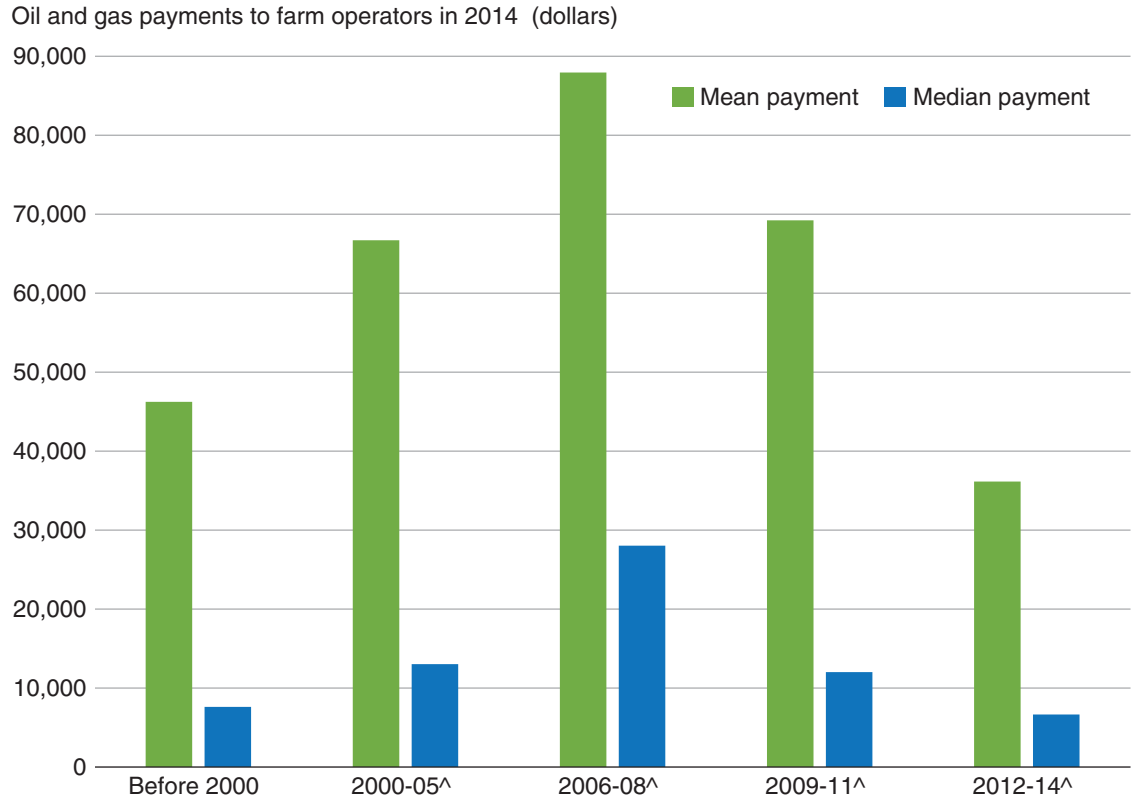
Operators who leased their rights between 2006 and 2008 reported the highest mean and median energy payments in 2014, at nearly $90,000 and $30,000, respectively, for the year (fig. 7). These numbers are consistent with the timing of leasing, drilling, and production. The first well drilled usually occurs near the end of a 3- or 5-year primary lease term, with completion of the well potentially occurring much later. Although production is greatest in the first year of the well, additional wells may be drilled under the same lease.

Farm operators who leased their oil and gas rights before 2000 (before hydraulic fracturing became commercially viable) were still receiving payments in 2014 ($46,000 on average) more than 14 years after the initial lease was signed. This finding suggests some farm operators received royalties associated with conventional oil and gas drilling, perhaps, in addition to those associated with hydraulic

fracturing occurring at a later stage. Similar technological advances may also increase the long-term value of recently signed leases.

Differences in oil and gas payments based on the period first leased may also reflect the productivity of different shale plays and the type of product (oil or gas or both). Hydraulic fracturing began in the early 2000s in the Barnett shale play, spread to the Fayetteville and Haynesville plays in 2006, and extended to the Marcellus, Eagleford, and Bakken plays in 2007–10. From 2010 until 2014 and beyond, all of these major shale plays were producing oil or natural gas on a large scale.

Figure 7
Mean and median oil and gas payments to farm operators in 2014, by year oil and gas rights leased



Note: Only family farms, which account for 98.9 percent of all farms and 96.2 percent of operated land, are included for these estimates. In all figures based on the 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey data, a coefficient of variation (CV) between 25 and 50 is denoted with a ^, and a CV greater than 50 is denoted by a #.

Source: USDA, Economic Research Service (ERS) analysis using USDA, National Agricultural Statistics Service and USDA, ERS, 2014 TOTAL survey.

Leverage and Wealth

Farm operators who had leased oil and gas rights in 2012–14 had farm debt-to-asset ratios (in 2014) roughly twice as high as operators who had leased before 2012 (fig. 8), suggesting that operators use oil and gas payments in part to increase equity in their farm operations. Some use oil and gas income to pay down debt or pay for improvements or assets with cash. Differences in operators' farm debt-to-asset ratios for different lease periods may also reflect productivity variances among shale plays that went into production in different periods. However, by 2010, all major shale plays were producing oil and gas on a large scale, such that pre- and post-2012 comparisons of oil and gas payments and the effect on debt-to-asset ratios represent all of these major shale plays. Farm operators thus appear to use oil and gas payments to improve their farms' financial health over the longer term.

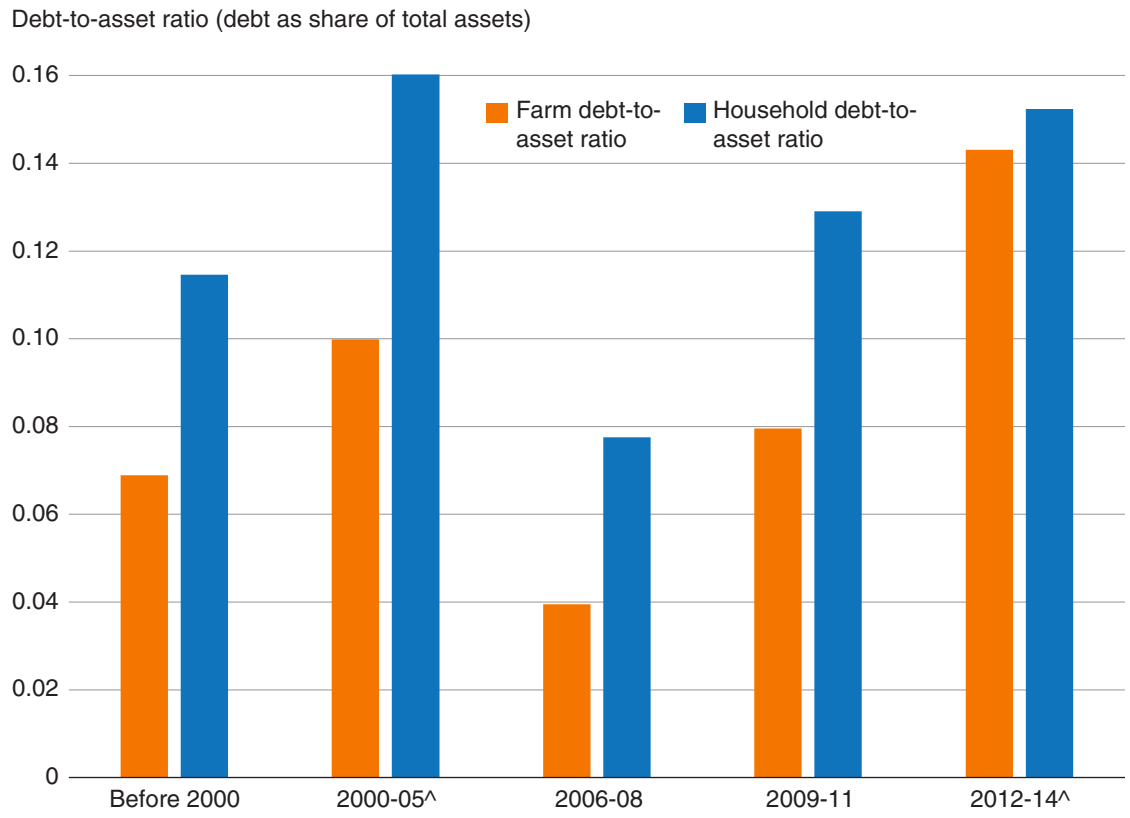
Comparing operators with and without leasing in oil and gas counties, we find that farm operators who did not lease their oil and gas rights (including those who did not own those rights) had a farm debt-to-asset ratio of 8.6 percent on average, compared to 9.0 percent for operators leasing their rights (all periods combined). Operators leasing after 2012 had a ratio of 14.3 percent, much higher than those who never leased. The difference suggests that farm operators who recently leased their rights may be either investing in the farm before the oil and gas income has arrived (i.e., borrowing from their expected oil and gas payments) or are more likely to have financial challenges prior to leasing than farm operators who did not lease their rights. Again, regional differences may play a role if farm debt-to-asset ratios are higher from the outset in regions where oil and gas production took off only in 2012 and later.

Among operators with oil and gas leases, the debt to asset ratio of the households of the farm's principal operator is highest for farms that leased in 2000-05, though the next highest household ratio is for those who leased recently (fig. 8).

If these patterns are not explained entirely by regional differences in farm financial indicators and shale productivity for shale plays that came into production in different periods, then they suggest that operators have had a measured and forward-looking response to their oil and gas wealth despite receiving a quick, unexpected increase in many cases. The mean household net worth of farm operators in oil and gas counties who did not lease or own oil and gas rights was $1.365 million, about 30 percent lower than the $1.940 million for farm operators who did lease.

Figure 8

Operations with leased oil and gas rights in 2014: average household and farm debt-to-asset ratios, by year oil and gas rights leased



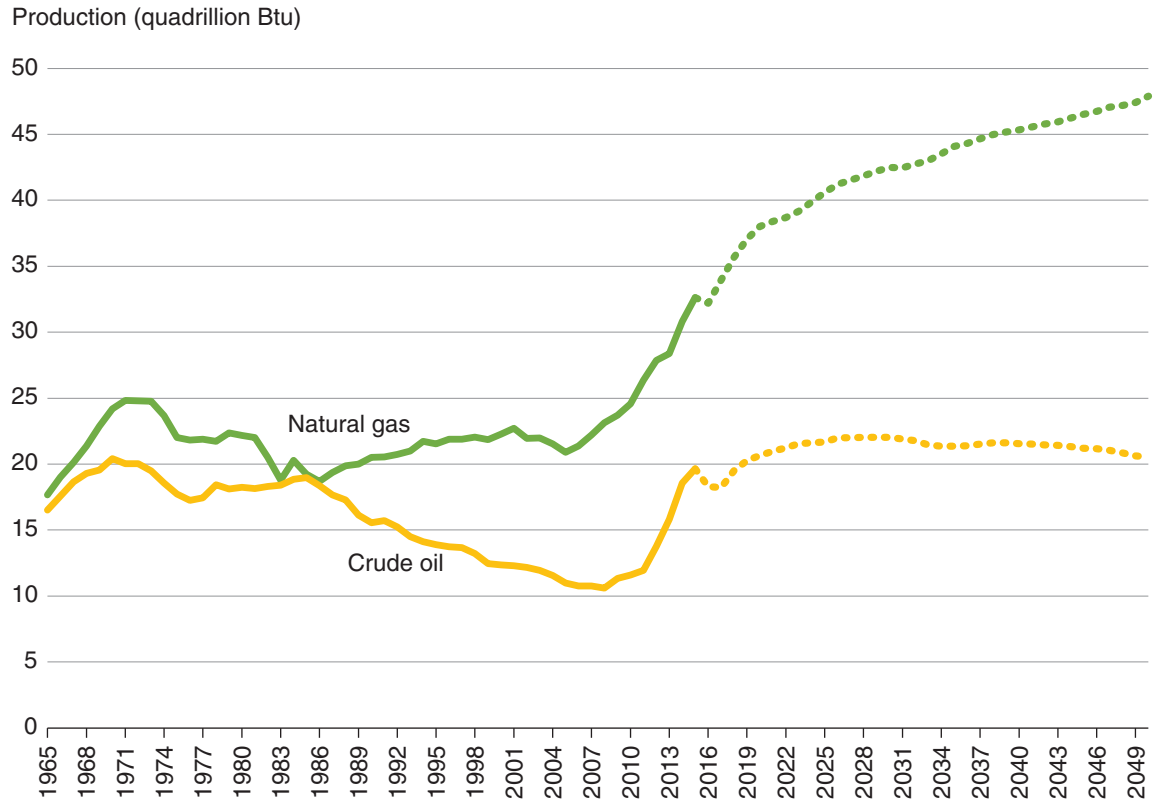
Note: The CV for farm debt-to-asset ratio was between 25 and 50 for 2000-05 only, while the CV for household debt to asset ratio was between 25 and 50 for 2000-05 and 2012-14. In all figures based on the 2014 Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey data, a coefficient of variation (CV) between 25 and 50 is denoted with a ^, and a CV greater than 50 is denoted by a #.

Source: USDA, Economic Research Service (ERS) analysis using USDA, National Agricultural Statistics Service and USDA, ERS, 2014 TOTAL survey.

Looking Forward: Farm Finances and Oil and Gas Production and Prices

Advances in horizontal drilling and hydraulic fracturing brought about the shale revolution: unusually high growth rates in oil and gas production in the last decade (fig. 9) and unusually large revisions to EIA estimates of proven reserves (fig. 10). The charts illustrate the steep, unexpected growth in production and in the value of oil and gas rights.

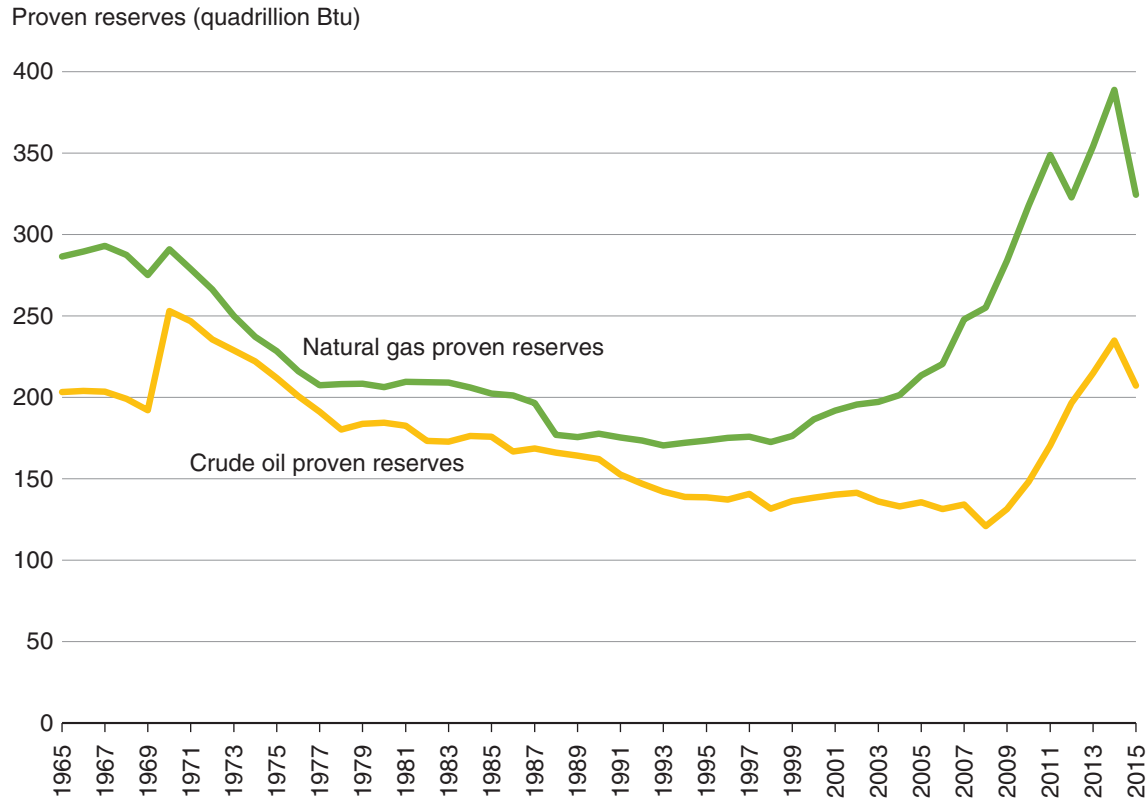
Figure 9
Crude oil and natural gas actual and forecast production, 1965-2049



Note: Btu = British thermal unit.

Source: Crude oil production, natural gas (dry), and natural gas plant liquids production from U.S. Department of Energy, Energy Information Administration's (EIA) *Monthly Energy Review* (April 2017). Forecast production from EIA's *Annual Energy Outlook 2017 with Projections to 2050* (2017).

Figure 10
Crude oil and natural gas proven reserves, 1965-2015



Note: Btu = British thermal unit.

Source: Crude oil and lease condensate and total natural gas proven reserves in U.S. Department of Energy, Energy Information Administration's *Crude Oil and Natural Gas Proved Reserves, Year-End 2016*.

From 2016 to 2025, the U.S. Department of Energy's Energy Information Administration projects domestic production of oil and natural gas to increase by 23 percent (EIA, 2017b). The actual increase—and its associated economic value on which royalty payments are based—will depend on energy prices, which are volatile and difficult to predict. Nonetheless, a plausible scenario illustrates that changes to production and prices can affect farm income, particularly in oil and gas counties. A 25-percent increase to 2014 energy production levels at 2014 prices would add $1.9 billion to net cash farm income through additional energy payments. If agricultural production and prices remained at 2014 levels, the increase would amount to a 1.6-percent increase in net cash farm income to farm operators and non-operator landlords. In oil and gas counties, the increase is the equivalent of a 4.1-percent increase in net cash farm income. A sharp decline in energy prices, such as the nearly 50-percent decrease in the domestic crude oil price from 2014 to 2015, would have the opposite effect. Other effects of increased energy production on agriculture, such as decreased land available for agricultural production, are not taken into account.

Energy price increases are unusually positioned to affect both sides of a farm's ledger: on the credit side, price increases raise royalty payments to farms, which in turn, increase farm profits. On the debit side, higher oil prices mean greater expenses for diesel fuel and gasoline; higher natural gas prices generally mean greater fertilizer and electricity expenses. The negative effect of rising oil and gas prices on farm finances is, therefore, partially offset by greater royalty payments, and expected growth in oil/gas production from private land will strengthen this offsetting effect. At the same time, the offsetting effect occurs only for farms in oil- and gas-producing areas and only for those who own and lease out their subsurface rights. As discussed earlier, only 10 percent of farm operators and 13 percent of non-operator landlords in oil- and gas-producing counties received oil and gas payments in 2014.

Beyond Royalties: Other Issues Facing Farmers

Oil and gas development has widespread local and regional effects on landowners and farm operators, irrespective of whether they own oil and gas rights. Development is associated with more air pollution from diesel and road dust emissions from trucks and from well drilling and hydraulic fracturing—including diesel combustion and combustion emissions from natural-gas-powered compressor stations (Litovitz et al., 2013)—which may play a role in nearby infant health issues (McKenzie et al., 2012). Increased truck traffic is also associated with damaged roads. Abramzon et al. (2014) find that a new well in Pennsylvania required on average about 600 to 1,000 one-way loaded heavy truck trips, which created $13,000 to $23,000 worth of damages to State-maintained roadways per well. On the positive side, Brown et al. (2017) find that each royalty dollar received by county residents created an additional $0.50 in local income, mostly through greater wage income. Development can also generate substantial revenues for local governments, which can be used to address costs created by the industry and fund tax breaks or improved services (Weber et al., 2016; Newell and Raimi, 2018).

Drilling activities can have direct short- and long-term impacts on agricultural production. The most direct route is using agricultural land for a well pad, access road, or pipeline. Some of the land is needed only during the drilling period and can be returned to agricultural use after the well has been drilled. Other land will remain in its industrial use. Allred et al. (2015) conclude that vegetation removal to construct drilling pads and roads during oil and gas development is likely longlasting and potentially permanent. They find that oil and gas development in the United States and Canada between 2002 and 2012 affected about 7.4 million acres of land, of which about 3.5 million acres was rangeland, 2.7 million acres cropland, 1.2 million acres forestland, and 0.2 million acres wetland.

Aside from taking land out of production, temporary and permanent access roads and pipelines can also damage agricultural drainage systems that are installed underground and thereby affect the productivity of agricultural land immediately surrounding the road or pipeline (Zoller, 2016). Another impact on agriculture is increased demand for transportation infrastructure, which can affect the ability of farmers to bring their product to market. The flow of oil shipments by rail from the Bakken Shale and a record crop year in 2014 caused a backlog in grain rail shipments, depressing local crop prices by $0.11 to $0.18 per bushel and reducing cash receipts of grain and oilseed producers by 3 percent (USDA, 2015).

Increased demand for labor affects agricultural operations that may rely on seasonal labor to help with planting or harvest. Hitaj et al. (2014) find that farms in counties overlying shale plays experienced a larger increase than other farms in hired labor costs from 2002 to 2012. Thus, farms depending on hired labor would have had lower net cash farm income, while smaller farms with fewer labor demands may have benefited from more lucrative offseason, off-farm employment opportunities.

Like demand for labor, demand for water for oil and gas development may benefit some farms and harm others. In Western States, farmers who own water rights may choose to lease these to energy companies, insofar as their State allows for a temporary change of use from irrigation to industrial use. This provision would benefit farms with ample water rights and harm those dependent on purchasing water from others.

Finally, agricultural production is vulnerable to accidental soil and water contamination. Contamination of soil can occur through spills of fluids during well drilling and fracturing and during transport by truck or through wastewater pipelines and the failure of well casings and equipment failures or corrosion of pipes and tanks (Pichtel, 2016). The effects of soil contamination can be long term. Lauer et al. (2016) find elevated radium levels in soils at spill sites of oil and gas wastewater in North Dakota. They also observe elevated levels of contaminants in surface water around spill sites up to 4 years following the spill events.

Bamberger and Oswald (2012) document 24 cases in 6 States of how shale gas drilling operations have harmed livestock health, mainly through accidental water contamination. In their case studies, livestock near shale gas drilling sites, particularly those exposed to accidental water contamination, experienced dust pneumonia, sudden death, difficulty breeding, and increased incidence of stillborn offspring and offspring with congenital abnormalities. Human health can also be affected by accidental water contamination of drinking water wells (Jackson et al., 2013; Osborn et al., 2011).

Some of the localized effects of development can be limited through terms of leases or surface use agreements. If an accident occurs during oil or gas production, the farmer (whether with or without subsurface rights) must expend effort and resources to obtain compensation even if the oil and gas company was clearly liable.

Still, much research shows that attitudes toward oil and gas development are related to whether the landowner is receiving lease and royalty income (Jacquet, 2012; Brasier et al., 2011). In an analysis of a survey of West Virginia landowners with completed shale gas wells located on their property, Collins and Nkansah (2015) find that surface owners of split estates had a statistically greater number of reported problems with drilling than did surface owners who also owned their mineral rights and that dissatisfaction was explained by a perception of inadequate compensation. This finding is noteworthy considering that for oil and gas counties, only 10 percent of farm operators and 13 percent of non-operator landlords reported receiving oil and gas payments. Those not receiving payments may not have owned oil and gas rights, may have refused to lease their land, or may have been located in a part of the county without development.

Overall, it appears that oil and gas development in shale areas has had negligible or positive effects on average farm real estate values (Weber et al., 2014; Hitaj et al., 2015). Weber and Hitaj (2015), in particular, find that average farm real estate values increased slightly in the Barnett Shale over time, even though local ownership of oil and gas rights is probably low in that region. The finding holds even for the period after the development slowed. Likewise, development of the northern part of the Marcellus Shale brought large and widely dispersed increases in values among farms (Weber and Hitaj, 2015). This is not to say that development has not harmed the value of particular farms but that these occurrences appear to be too limited to offset financially positive effects on average.

Conclusion

Since the early 2000s, advances in horizontal drilling and hydraulic fracturing have made it possible to exploit oil and gas resources trapped in shale formations, opening up new areas of the country to production and providing new streams of revenue to oil and gas rights holders. The boom in production and associated decline in energy prices create broad benefits for households and firms across the country, but oil and gas production (and the associated localized costs and benefits) occurs disproportionately in farming areas, as farmland accounted for 48 percent of the land area in the contiguous United States but an estimated 67 percent of onshore oil and gas production in 2014.

Only farmland owners who also own the oil and gas rights associated with their land can receive royalties generated by this increase in oil and gas production. Ownership of these rights is less common in areas with a history of energy production, such as in parts of Texas and North Dakota. In 2014, 10 percent of farm operators and 13 percent of non-operator landlords in oil and gas counties reported receiving oil and gas royalty payments from energy companies. Payments to farmland owners (operators and non-operator landlords) amounted to $7.4 billion, but could have been as high as $40 billion, by our estimation, if all farmland owners had also owned the oil and gas rights associated with their farmland.

Owners of farmland who do not also own the oil and gas rights (split estate) may encounter additional problems because (unlike landowners who also own oil and gas rights) they cannot negotiate the terms of oil and gas production on their land and may not be adequately compensated for any harm from drilling. Possible uncompensated or insufficiently compensated damages include lost revenue from removing farmland from agricultural production to serve as well pads or access roads; air, light, and noise pollution from drilling; soil or water contamination from spills; soil erosion; and truck traffic. Adequate compensation, however, is hard to define because many of the goods in question—clean air, good health, a quiet setting—do not have a market price. Of the landowners who reported owning oil and gas rights with positive value, non-operator landlords were 21 percentage points more likely than farm operators to lease their rights to energy firms and allow energy production to occur on their land. This difference may indicate that concerns about the economic, environmental, and health consequences of development are not inconsequential. Alternatively, the difference in participation in leasing may simply indicate that non-operator landlords own more land than farm operators do in areas with high demand for leasing.

Farm operators who owned their oil and gas rights benefited financially from the shale boom. In oil and gas counties, oil and gas payments to farm operators amounted to 11 percent of their net cash farm income, and in Oklahoma, Pennsylvania, and Texas, these payments reached almost 30 percent of net cash farm income. The payments appear to have longlasting effects on the financial health of farms and their households: farm operators who signed leases in the early to mid-2000s have farm debt-to-asset ratios much lower than those who signed later, likely reflecting more years of royalty payments and paying down debts or purchasing assets with cash. Similarly, early lessees have greater household net worth.

Almost 27 percent of operators with leased oil and gas rights in 2014 had signed leases after 2011, and leasing activity has increased steadily over time. It is plausible that leasing, production, and royalty payments will continue to increase in the coming decade. The U.S. Department of Energy's Energy Information Administration projects onshore oil and gas production to increase by 23 percent from 2016 to 2025. As such, oil and gas development on agricultural land will continue and likely grow.

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Appendix: Survey Questions

The relevant survey questions for oil and gas rights, leasing, and royalties on both the operator and non-operator versions of the Tenure, Ownership, and Transition of Agricultural Land (TOTAL) survey are listed in appendix table 1. The royalty income variable does not distinguish between income from oil/gas leases and wind leases. For oil and gas income, we excluded observations with positive royalty income but no leasing or selling of oil and gas rights. For wind income, we included observations with positive royalty or lease income, no leasing or selling of oil and gas rights, and positive leasing of "other rights" (operator version) or "wind rights" (non-operator landlord version).

Appendix table 1
Wording of survey questions on oil and gas rights, leasing, and royalties in TOTAL

	Operator version	Non-operator landlord version
Value of oil and gas rights	What was the MARKET VALUE of the following assets OWNED by this operation on December 31, 2014: Oil, gas and mineral rights [None] or [Dollars]	What was the Market Value of the following on the **total owned acres rented out in [STATE]** on December 31, 2014? Oil, gas, and mineral rights [None] or [Dollars]
Royalty income	In 2014, what was the total income received by you (the operator) and all partners for: income from royalties or leases associated with energy production (e.g. natural gas, oil, and wind turbines)? [None] or [Dollars]	For the **total owned acres rented out in [STATE]** in 2014, how much income was received from the following sources in 2014? Royalty or lease payments associated with energy production (natural gas, oil, wind turbines, etc.) [None] or [Dollars]
Leasing oil and gas rights	For all the acres **OWNED,** including acres rented to others, how many acres have the oil and gas rights been LEASED? [None] or [Acres] and [Year Sold or First Leased (YYYY)]	Of the **total owned acres rented out in [STATE]** in 2014, how many acres had the following rights been **LEASED** and what was the first year of the lease? Oil and gas rights leased [None] or [Acres] and [First Year of Lease (YYYY)]
Leasing other rights / wind rights	For all the acres **OWNED**, including acres rented to others, how many acres have: Other rights been LEASED? (**Include** leases for hunting and wind turbines) [None] or [Acres] and [Year Sold or First Leased (YYYY)]	Of the **total owned acres rented out in [STATE]** in 2014, how many acres had the following rights been **LEASED** and what was the first year of the lease? Wind rights leased [None] or [Acres] and [First Year of Lease (YYYY)]

Source: USDA, National Agricultural Statistics Service and USDA, Economic Research Service, 2014 Tenure, Ownership, and Transition of Agricultural Land survey (TOTAL).