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Impacts of Higher Energy Prices on Agriculture and Rural Economies

Ronald Sands and Paul Westcott (coordinators)

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Impacts of Higher Energy Prices on Agriculture and Rural Economies

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Abstract

Agricultural production is sensitive to changes in energy prices, either through energy consumed directly or through energy-related inputs such as fertilizer. A number of factors can affect energy prices faced by U.S. farmers and ranchers, including developments in the oil and natural gas markets, and energy taxes or subsidies. Climate change policies could also affect energy prices as a result of taxes on emissions, regulated emission limits, or the institution of a market for emission reduction credits. Here we review the importance of energy in the agricultural sector and report the results of a case study on the economic implications for the farm sector of energy price increases that would arise from plausible, constructed greenhouse-gas-emission reduction scenarios.

Higher energy-related production costs would generally lower agricultural output, raise prices of agricultural products, and reduce farm income, regardless of the reason for the energy price increase. Nonetheless, farm sector impacts were modest for the scenarios and time periods examined. We demonstrate the unique distribution of effects resulting from price (or cost) increases for different types of energy due to pricing their carbon content, as well as the relative use of energy in production of different agricultural commodities.

Our analysis focuses on relatively short-term adjustments to higher energy-related costs and does not include potential financial benefits from sequestering carbon or reduced climate change. Finally, we find that agricultural sector impacts on farming-dependent counties would not be substantial but would be potentially largest where education and employment levels are relatively low, while effects on rural communities due strictly to energy production adjustments would be concentrated in the few U.S. counties with significant employment in energy extraction industries.

Keywords: energy prices, costs of production, fuel, fertilizer, farm income, agriculture, greenhouse gas emissions, farming dependent counties, rural economy, Economic Research Service, ERS, U.S. Department of Agriculture, USDA

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Summary

What is the Issue?

Agricultural production consumes large amounts of energy, either directly through combustion of fossil fuels, or indirectly through use of energy-intensive inputs, especially fertilizer. Over 2005-08, expenses from direct energy use averaged about 6.7 percent of total production expenses in the U.S. farm sector, while fertilizer expenses represented another 6.6 percent. However, these sector averages mask much greater energy intensities for major field crops. Agricultural production is therefore sensitive to changes in energy prices, whether the changes are caused by world oil markets, policies to achieve environmental goals, or policies to enhance energy security.

To illustrate the flow of energy prices through the agricultural system from farm to retail, we construct three scenarios: a reference scenario of agricultural production from 2012 through 2018, and two alternative scenarios over the same time period with energy price increases expected to result from pricing greenhouse gas emissions. Price increases for different energy sources in the alternative scenarios are based on their carbon content. Results are compared to the reference scenario to estimate economic implications. Higher energy-related production costs would generally lower agricultural output, raise prices of agricultural products, and reduce farm income in the short run.

What Did the Study Find?

- Energy-related production expenses vary significantly for different crops. On a per-acre basis, corn and rice have the highest energy-related costs of the eight major crops (corn, sorghum, barley, oats, wheat, rice, upland cotton, and soybeans) examined in this report, while soybeans have the lowest. With higher energy-related expenses (fuel up an average of 2.6 to 5.3 percent; fertilizer up 4 to 10 percent), total acreage for these eight crops would decline by an average of 0.2 percent (under the lower price change scenario) to 0.4 percent (higher price change scenario) over 2012-18. Planted area would decline for seven of the eight crops, the exception being soybeans.

- Energy-related expenses also affect livestock producers. Although their direct energy costs are lower than for crop production, livestock producers would face higher feed costs under both the lower (0.2 to 0.6 percent higher annually, 2012-18 average) and higher (0.6-1.3 percent higher) energy price change scenarios. Poultry production would be less affected than beef and pork, since poultry is the most efficient feed-to-meat converter of the animal types.

- The scenarios analyzed did not account for potential changes in technology (beyond those implicit in the reference scenario) in response to sustained increases in energy prices. Additionally, a decades-long declining trend in energy use per unit of output in the agricultural sector is likely to continue, which is only partly represented in the scenarios by increasing yields. For these reasons, reported impacts of higher energy prices on the agricultural sector may be somewhat overestimated.

Additionally, longer run impacts of further energy price increases would not be proportionately as large as the short-term impacts we report here.

- Effects also vary regionally. The Mississippi Portal region is most affected by higher energy costs, due to the predominance of fertilizer-intensive crops like cotton. Farms in that region would see net cash income decline by 8 to 19 percent on average (in 2014) under the lower and higher energy price change scenarios, respectively.

- Although increased agricultural commodity prices affect consumer food prices, retail food prices are more affected by energy costs in food processing, distribution, and marketing than in agricultural commodity production. For the scenarios and time period focused on in this report, the Consumer Price Index (CPI) for food—including food at home and food away from home—would be 0.6 to 0.9 percent higher than without the simulated energy-related cost increases for electricity, diesel fuel, and natural gas.

- It does not appear that impacts through the agricultural sector of the higher energy prices scenarios studied in this report would have a substantial effect on farm county economies and populations. In general, farm counties tend to have relatively few people without high school degrees, very high proportions of adults employed, and low poverty rates compared with other nonmetro counties. Some farm-dependent counties in the Mississippi Portal region may be relatively more affected by energy-related farm income losses.

- A decrease in fossil fuel production under an emissions tax or a cap-and-trade program would reduce overall employment in related energy extraction industries. Counties specializing in energy production are overwhelmingly rural. However, few nonmetro counties derive a substantial share of nonfarm employment from energy production, so overall rural impacts would be small, with the exception of some mining counties, principally located in eastern Kentucky and West Virginia.

How Was the Study Conducted?

Two key economic models at USDA's Economic Research Service (ERS)—the Food and Agricultural Policy Simulator (FAPSIM) and the Farm-Level Partial Budget Model—were used as the foundation of this analysis. We started with a range of prices for carbon dioxide emissions, taken or derived from studies by the U.S. Environmental Protection Agency and the U.S. Energy Information Administration. Both studies are based on the American Clean Energy and Security Act of 2009 (House Resolution 2454), which specified an increasingly stringent cap on U.S. greenhouse gas emissions from 2012 through 2050. Corresponding impacts on prices for electricity, natural gas, and petroleum products were also provided by these studies. We focus on the 2012-2018 timeframe, which corresponds to the timeframe of results provided by the FAPSIM model.

Implications of these energy-related price impacts for changes in agricultural production costs were used as input to FAPSIM to provide national agricultural sector effects. The Farm-Level Partial Budget Model was used to convert national impacts into changes in farm business net cash income for nine resource regions in the United States. Econometric regression analysis provided a link from agricultural producer prices to retail food prices, including energy costs in food processing, distribution, and marketing channels from the farm to retail.

Results focus solely on effects of higher cash expenses associated with emissions pricing, and do not include potential financial benefits from sequestering carbon or reduced climate change.

Chapter 1

Introduction

Agricultural production consumes large amounts of energy, either directly through combustion of fossil fuels, or indirectly through use of energy-intensive inputs, especially fertilizer. Over 2005-08, expenses from direct energy use averaged about 6.7 percent of total production expenses in the U.S. farm sector, while fertilizer expenses represented another 6.6 percent. However, these averages mask much greater energy intensities for major field crops. Several factors can influence energy prices faced by U.S. agriculture: availability of natural gas, world oil prices, energy taxes, or a greenhouse gas policy designed to reduce carbon dioxide emissions.

To illustrate the flow of energy prices through the agricultural system from farm to retail, we construct three scenarios: a reference scenario of agricultural production from 2012 through 2018, and two "what-if" scenarios over the same time period with higher energy prices. For illustrative purposes, energy price increases in the alternative scenarios are driven by prices on greenhouse gas emissions. The analysis uses a suite of models maintained at USDA's Economic Research Service (ERS). This case study is designed to (1) demonstrate the use of ERS models to simulate a change in energy prices through the U.S. agricultural system; (2) provide two scenarios of increased energy prices, with price changes for fossil fuels weighted by carbon content; and (3) provide an expanded discussion on methodology used to produce an earlier, related report (USDA, Office of the Chief Economist, 2009).

Different alternatives to limiting greenhouse gas emissions have been proposed over the past several years, and additional approaches are likely to be developed in the future. The assumptions for greenhouse gas emission prices, and resulting energy price impacts used in the two primary scenarios discussed in this report, are taken or derived from analyses by the U.S. Environmental Protection Agency (U.S. EPA, 2009) and the U.S. Energy Information Administration (U.S. EIA, 2009a). As such, the energy prices analyzed are in a range of recent climate change policy discussions and are meant to be illustrative rather than forecasts. EPA and EIA published separate analyses of the American Clean Energy and Security Act of 2009 (H.R. 2454), which includes a cap-and-trade system. However, results discussed here are not dependent on the emissions limitations resulting from cap-and-trade—alternatively, an emissions tax could have been the underlying mechanism driving higher energy prices.[1] The analysis is differentiated from those estimating effects of general energy price increases because of the relationship of price increases for different energy sources to their greenhouse gas emissions based on carbon content.

[1]Greenhouse gas emissions can be reduced by other, non-price options. These include energy-efficiency standards for buildings and motor vehicles and renewable energy standards for electricity generation.

The focus in this report is on relatively short-term impacts of higher energy-related costs and does not include potential financial benefits from sequestering carbon or of reduced climate change. Recent studies that have examined potential benefits from agricultural practices to control climate change include analyses of methane digesters on livestock operations (Key and Sneeringer, 2011) and no-till farming (Horowitz et al., 2010).

Chapter 2

Energy and Agriculture

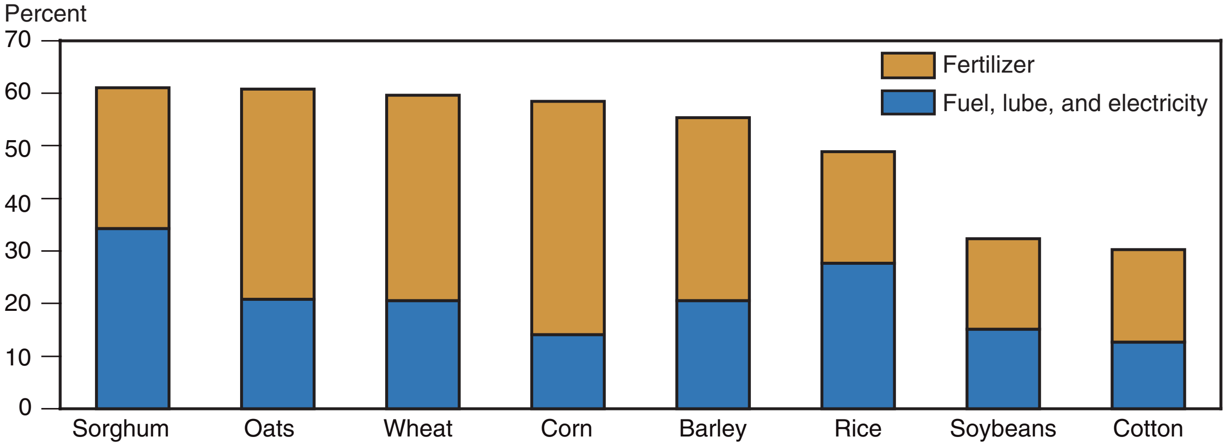
Agricultural production consumes significant amounts of energy, especially in production of field crops. Consequently, energy prices affect costs of production in the agricultural sector. Production costs are important to farmers' net returns (profitability), defined as receipts for selling their output minus costs of its production, and net returns influence farmers' production decisions. Net returns affect what crops are produced by affecting the allocation of acres each season. Net returns affect farmers' livestock production choices as well, subject to biological constraints.

Energy consumption in the sector can be either direct—as with gasoline, diesel, petroleum, natural gas, electricity, and energy use for operating irrigation equipment (see box, "Irrigation and Energy")—or indirect, as with fertilizer (see box, "U.S. Supply of Nitrogen-Based Fertilizer Coming More From Abroad"). Over 2005-08, expenses from direct energy use averaged about 6.7 percent of total production expenses in the sector, while fertilizer expenses represented another 6.6 percent. This time period saw an increase in energy costs, and the combined share of these inputs reached nearly 15 percent in 2008. Additionally, feed costs for livestock production include indirect energy costs due to the influence on crop prices, such as for corn and soybean meal.

The importance of energy and the effects of energy price changes are not uniform across commodities or regions, as energy intensity in production varies considerably. Figure 2.1 shows the share of total operating costs for selected crops represented by the two largest energy-related input categories (fuel, lube, and electricity; and fertilizer) in 2007-08. Operating costs are out-of-pocket cash expenses paid for production inputs for each commodity. Operating expenses reflect the quantities and prices of production inputs and thus depend on production practices used by farmers. Costs cover inputs such as seed, fertilizer, fuel, lube, electricity, feed, chemicals, and repairs.

Figure 2.1

Energy-related inputs relative to total operating expenses, 2007-08 average



Source: USDA, Economic Research Service, Cost of Production Estimates.

Sorghum has the highest share of energy-related inputs while cotton has the lowest. For sorghum, oats, wheat, corn, and barley, energy-input categories are more than 50 percent of operating expenses.[2]

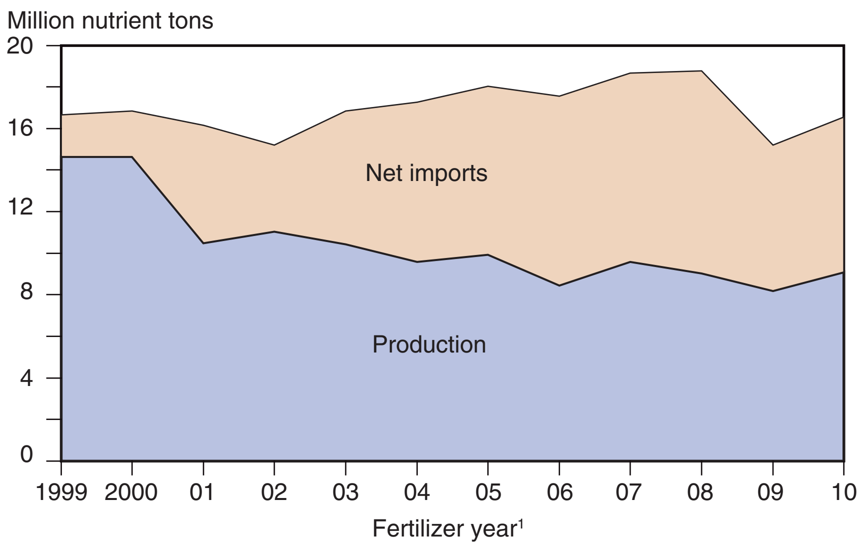
The distribution of energy-related input costs for these crops is different in absolute terms. Per-acre operating costs are important for determining producer net returns, which influence farmers' cropping choices. Rice, corn, and cotton have the highest per-acre expenses for energy-related inputs (fig. 2.2). While rice and cotton have the highest per-acre costs for fuel, lube, and electricity, corn has the highest costs for fertilizer. Again, energy-related costs for soybean production are relatively low.

Direct energy costs account for smaller shares of operating costs for livestock operations, representing about 4 percent of operating costs for hogs, 5 percent for milk production, and about 10 percent for cow-calf operations, on average, in 2007-08 (table 2.1). Livestock operations also see indirect effects of energy costs through higher feed costs. In 2007-08, feed costs accounted for about 11 percent of total operating costs for cow-calf operations, 58 percent for hog production, and 76 percent for milk production.

U.S. Supply of Nitrogen-Based Fertilizer Coming More From Abroad

Fertilizer is an important component of production costs for crops, especially corn. Nitrogen fertilizer production is energy-intensive as natural gas makes up 70 to 80 percent of production costs. U.S. nitrogen fertilizer supplies, while historically domestic, have been increasingly imported over the past decade. Shares of U.S. nitrogen fertilizer are now nearly equal between domestic and foreign suppliers.

U.S. nitrogen supply from domestic production and net imports, 1999-2010

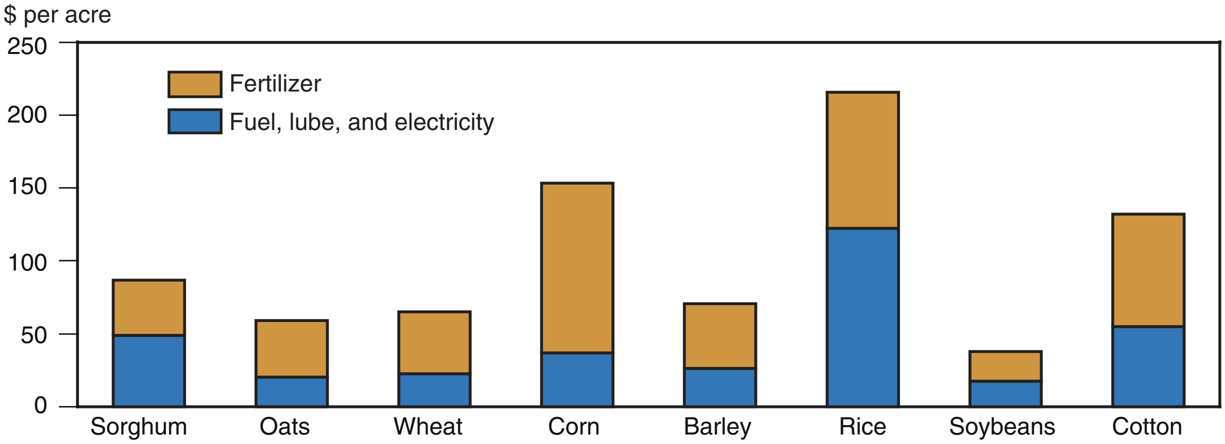


[1]The fertilizer year runs from July of the preceding year to June of the year indicated in the chart.
Source: Huang (2009), USDA, Economic Research Service. Updated using data from the U.S. Department of Commerce for nitrogen production and from ERS for net imports.

[2]Energy shares in figure 2.1 are much greater than the overall sector average of 15 percent reported earlier in this chapter, which is the energy-related share in all production costs, both variable and fixed. Figure 2.1 displays the share relative to operating costs only, and fertilizer is a large share of operating costs for field crops. Also, the agricultural sector average includes other activities such as livestock production, which is less energy intensive.

Figure 2.2

Energy-related expenses, selected crops, 2007-08 average



Source: USDA, Economic Research Service, Cost of Production Estimates.

Table 2.1

Energy-related inputs relative to total operating expenses, livestock, 2007-08 average

	Fuel, lube, and electricity	Feed[1]
	Percent	
Cow-calf, per bred cow	10	11
Hogs, per hundredweight gain	4	58
Milk, per hundredweight sold	5	76

[1]Feed for cow-calf costs includes supplemental feed, concentrates, and other feed; feed for milk costs excludes grazed feed.

Source: USDA, Economic Research Service, Cost of Production Estimates.

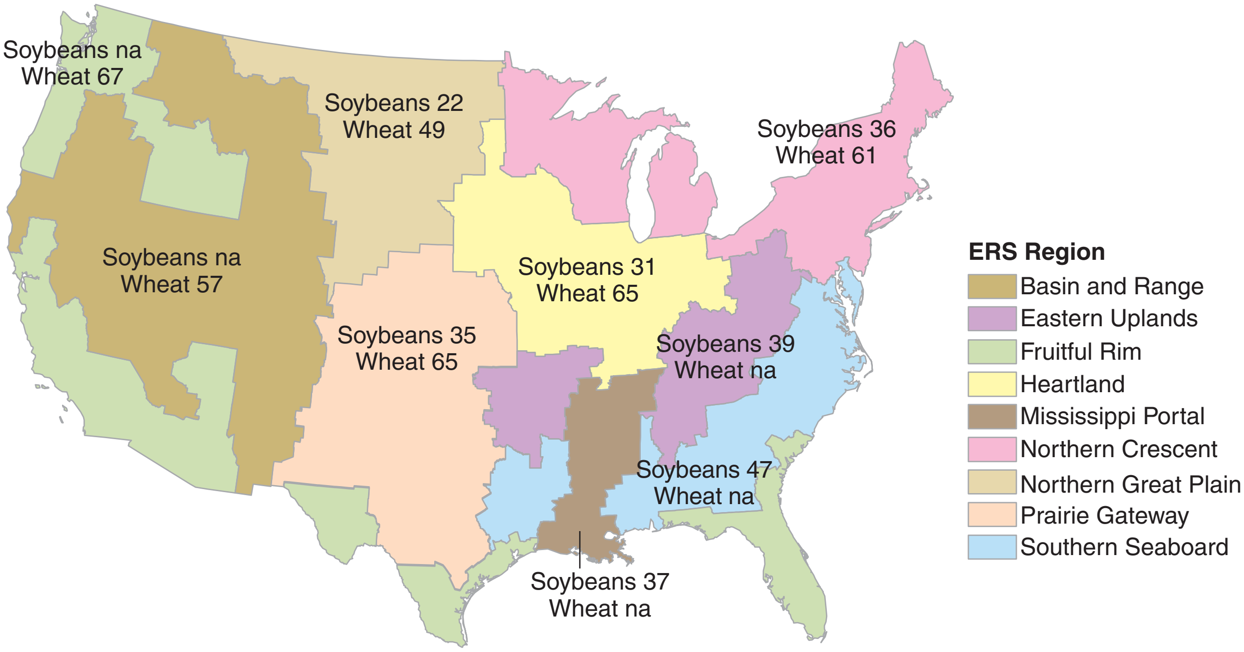
Regional Differences in Costs of Energy Inputs

Energy-related input costs also vary by region, due primarily to crop composition and reliance on irrigation. Figure 2.3 illustrates this variation for wheat and soybeans, two sectors at opposite ends of the energy-input share spectrum. For wheat, the regions with the largest shares of costs from energy-related inputs are the Fruitful Rim, the Heartland, and the Prairie Gateway. For soybeans, the regions with the largest share of costs from energy-related inputs are the Southern Seaboard and the Eastern Uplands. The Northern Great Plains has the lowest share of energy-related inputs for both wheat and soybeans, well below the national averages of 60 percent and 31 percent.

Wheat production costs in the Northern Great Plains and the Prairie Gateway, where the majority of the crop is grown, present an interesting contrast in operating expenses. While the two regions have a similar share of production costs attributable to fertilizer expense (37 percent), the shares of costs accounted for by fuel, lubrication, and electricity are much different (28 percent for the Prairie Gateway, versus 12 percent for the Northern Great Plains). This is largely due to the high level of irrigation used in the Prairie Gateway.

Figure 2.3

Energy input costs as a share of operating costs for soybeans and wheat by ERS Resource Region, 2007-08 average

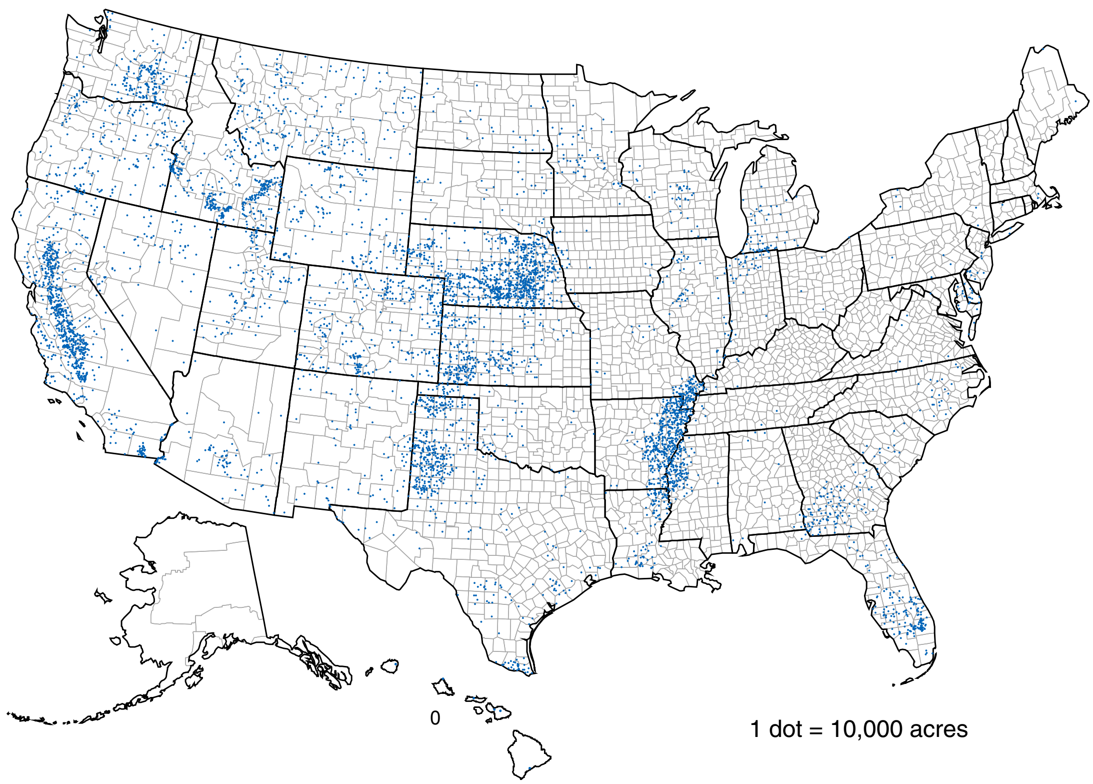


na = Not available.
Source: USDA, Agricultural Reserve Management Survey.

Irrigation and Energy

Irrigation makes a significant contribution to U.S. agricultural production. For 2007, the market value of agricultural products sold for all farms was $297.2 billion, with irrigated farms (a farm irrigating any land) accounting for nearly 40 percent of this total. The average farm value of products sold for an irrigated farm ($393,700) was more than 4 times the average value for a non-irrigated farm ($93,900). Irrigation makes an obvious contribution to the value of crop products sold, but it also contributes to the farm value of livestock and poultry products via the use of irrigated crop production used as feed.

Acres of irrigated land, 2007



Source: USDA/National Agricultural Statistics Service.

In 2007, 56.6 million acres in the United States were irrigated (51.5 million harvested cropland acres and 5.1 million pastureland and other cropland acres), accounting for about 7.5 percent of total cropland and pastureland acres. About 16.6 percent of U.S. harvested cropland acres nationwide were irrigated, while only about 1.2 percent of total U.S. pastureland acres were irrigated. The map shows 2007 irrigated acres by State, with each dot representing 10,000 acres. Most irrigated agriculture occurs in the 17 Western States.

Energy use in irrigated agriculture is determined primarily by the amount of land devoted to irrigation, the quantity of applied irrigation water, and the status of irrigation efficiency—more conserving irrigation systems and water-management practices generally mean lower per-acre energy costs.

In 2008, energy costs for irrigation pumping for U.S. agriculture were over $2.6 billion, again mostly in the 17 Western States (see table). This regional distribution of energy-related irrigation costs influences the regional farm-business impacts derived from the Farm-Level Partial Budget Model, discussed in chapter 5.

Energy expenses for irrigation pumping are the dominant cost for irrigated agriculture. However, for the 17 Western States, total irrigation costs for 2008 also include $671.5 million for purchased water costs, $659.6 million for irrigation maintenance and repair costs, and $870.0 million for hired and contract irrigation labor.

Expenditures for groundwater (well) and surface-water pumps on irrigated farms, 2008

	Expenditure by energy source					
Region	Total expenditure	Electricity	Natural gas	Liquid petroleum gas, propane, butane	Diesel	Gasoline
			$ million			
Western States	2,223.2	1,411.9	412.3	27.1	368.9	3.0
Leading Eastern States[1]	409.6	118.8	3.9	8.7	276.7	1.5

Source: Farm and Ranch Irrigation Survey (2008), National Agricultural Statistics Service, USDA.
[1]The 11 Leading Eastern States are Arkansas, Florida, Georgia, Illinois, Indiana, Louisiana, Michigan, Minnesota, Mississippi, Missouri, and Wisconsin.

Chapter 3

Defining a Case Study—Linking Energy Prices to Greenhouse Gas Emissions

For illustrative purposes, we analyze the potential impacts of higher energy prices resulting from pricing greenhouse gas emissions. The agricultural sector accounts for approximately 8 percent of U.S. greenhouse gas emissions, mostly as carbon dioxide, methane, and nitrous oxide (U.S. EPA, 2010). Carbon dioxide is emitted when fossil fuels are combusted, methane is emitted through enteric fermentation by livestock and manure management, and nitrous oxide is emitted through the use of nitrogen fertilizer.

Various alternatives have been proposed to limit future U.S. greenhouse gas emissions. A common feature is the establishment of a cap-and-trade system for emission allowances, with an emissions cap covering the majority of U.S. greenhouse gas emissions. The resulting price of greenhouse gas emissions is that which clears the market for emission allowances. In the cap-and-trade proposals, agriculture is not a covered sector: agricultural emissions of methane and nitrous oxide are outside the cap. Nonetheless, a cap-and-trade system affects agriculture indirectly through an increase in fossil fuel prices, based on the carbon content of each fuel and the price of greenhouse gas emissions. A similar increase in fossil fuel prices would result from taxing greenhouse gas emissions directly.[3] Appendix A provides a graphical supply-demand framework for analyzing how the pricing of greenhouse gas emissions affects energy markets, and compares a tax on emissions with a cap-and-trade system.

[3]See Climate Change 101: Understanding and Responding to Global Climate Change: Cap and Trade, by the Pew Center on Global Climate Change, for an introduction to cap and trade, along with a glossary of key terms.

Agriculture consumes significant amounts of energy: refined petroleum for farm machinery, electricity for irrigation and other equipment, natural gas indirectly through nitrogen fertilizer, and coal indirectly through electricity. A price on greenhouse gas emissions affects fuels differently, depending on the carbon content per unit of energy. Among the major fossil fuels—coal, refined petroleum, and natural gas—coal has the greatest carbon emissions per unit of energy and natural gas the least. Therefore, a price on carbon dioxide not only increases the price of energy, but also affects relative prices between fossil fuels. Natural gas becomes less expensive relative to coal and refined petroleum when greenhouse gas emissions are priced.

A common unit of measurement is needed to compare the impact of different greenhouse gases on the climate. Emissions of greenhouse gases other than carbon dioxide are first converted to their carbon dioxide equivalent so that total emissions—in metric tons of carbon dioxide equivalent (t CO_2-eq)[4]—can be summed across different greenhouse gases.[5] Working in terms of carbon dioxide equivalent provides a way to price emissions across the various greenhouse gases in common units, dollars per metric ton of carbon dioxide equivalent. Appendix B provides a detailed description of converting carbon dioxide prices to an increment in the price of various fossil fuels.

[4]Until recently, greenhouse gas emissions were frequently reported in units of carbon equivalent instead of carbon dioxide equivalent. The two approaches differ by the molecular weights of carbon (12) and carbon dioxide (44).

[5]The IPCC Working Group I Technical Summary (IPCC, 2007a) provides background on the weighting of greenhouse gases relative to carbon dioxide.

Greenhouse Gas Price Scenarios

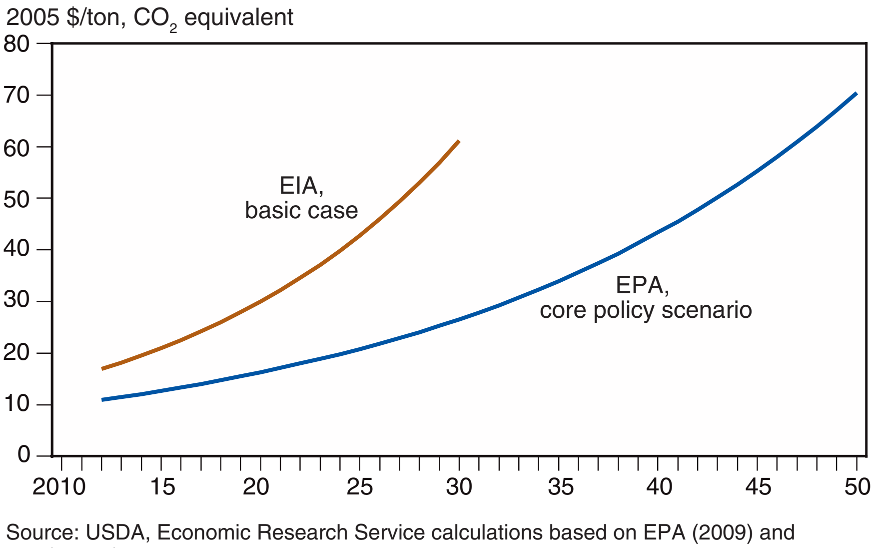
In addition to the direct effects that pricing greenhouse gas emissions has on different energy prices related to the different carbon content of each fuel, further indirect impacts can occur due to adjustments and interactions of the individual fuel markets for coal, natural gas, electricity, and petroleum. To represent these direct and indirect effects, we draw on analyses by EPA and EIA to provide a range of emission prices and energy market impacts to derive price changes for petroleum products, natural gas, and electricity.

Two scenarios of emission prices from these studies are displayed in figure 3.1. The first scenario is based on the "core policy scenario" (U.S. Environmental Protection Agency, 2009) of the American Clean Energy and Security Act of 2009 (H.R. 2454); the second, and higher, price scenario is derived from the "basic case" analysis of the same legislation by the U.S. Energy Information Administration (2009a). Thus, these scenarios provide a range of energy prices consistent with recent climate change discussions.

An important assumption in both the EPA and EIA analyses is that greenhouse gas emission prices increase smoothly over time at a constant annual percentage rate. This follows from provisions in H.R. 2454 for banking emission allowances. EPA's emission prices increase 5 percent per year, while EIA's rise at a 7.4-percent annual rate. Alternatively, these emission prices could result from specifying corresponding emission taxes with fixed annual rates of increase.

The EPA study provided greenhouse gas emission prices at 5-year intervals through 2050; prices for other years in this analysis were calculated by interpolating between the 5-year results and extrapolating back from 2015 to 2012. The EIA study reported emission prices for each year through 2030. Although this report primarily focuses on effects of the pricing of emissions on agriculture over the next decade, figure 3.1 shows the full availability of emission prices from those studies to provide a longer term perspective on

Figure 3.1
Greenhouse gas emission prices under two scenarios, 2012-2050



Source: USDA, Economic Research Service calculations based on EPA (2009) and EIA (2009a).

potential energy cost impacts. (See related box, "Longer Term Adjustments to Higher Energy Prices," p. 19.)

Implications of greenhouse gas emission prices for different fuels (petroleum, natural gas, and electricity) reflect two factors. First is the direct increase in the price for each fuel that reflects the emissions price applied to the carbon content of the fuel. Second is the economic effect that relates to adjustments and interactions of the markets for different fuels and the potential for substitution among alternative fuels in response to changes in relative prices. For example, the composition of fuels to generate electricity shifts away from greenhouse-gas-intensive fuels as the emission price increases. Since coal results in more greenhouse gas emissions per unit of energy than natural gas, coal prices would be more affected by an emissions price than would natural gas prices. Over time, some substitution between these fuels in

Benefits of a Greenhouse Gas Mitigation Policy for Agriculture

In this study, we focus on costs to U.S. agriculture of increases in energy prices associated with two greenhouse gas price scenarios. We do not analyze potential financial benefits from such a policy. However, two types of benefits could be important to agriculture: payments to agricultural and forest land managers for sequestering carbon, and reduced climate change.

Agriculture may benefit by generating and selling emission offsets. The term offset describes a reduction in emissions or increase in sequestration of greenhouse gases produced by one entity that can be used by another entity to offset its own emissions. Agricultural land can sequester carbon through changes in tillage practices, forest management (such as a longer rotation age), and converting land to forests (afforestation). However, developing a market to pay for emissions reductions or enhanced carbon sequestration is challenging.

The amount of carbon stored in soils or trees varies across location, and measurement of the total stock of carbon can be expensive and uncertain, especially for carbon in soils. Nonetheless, one analysis of such a program estimated annual gross revenues to agriculture from offsets could exceed $2 billion (in real 2005 dollars) by 2020 and could reach almost $30 billion by 2050 (USDA, Office of the Chief Economist, 2009). These calculations were based on an analysis underlying the EPA 2009 study.

The state of the science on anticipated climate impacts is summarized by activity and by world region in a 2007 assessment by the Intergovernmental Panel on Climate Change (IPCC, 2007b). For increases in global average temperature up to 2 degrees Celsius, the general trend is for increased yields in colder environments and decreased yields in warmer environments. This may be accompanied by increased insect outbreaks and heavy precipitation events. Plant health declines for larger increases in temperature.

Deriving monetary estimates of climate damages or benefits to U.S. agriculture involves at least three major areas of uncertainty: variation across climate models, effect of carbon dioxide fertilization, and climate impacts outside the United States. Economic adaptation can reduce the consequences of climate change, especially through international trade in agricultural products.

Table 3.1
Change in fuel prices relative to the reference scenario, 2012-18

	Average, 2012-2018		
	Petroleum price	Natural gas price	Electricity price
	Percent increase		
Lower price change scenario	3.2	5.4	10.7
Higher price change scenario:		13.4	14.0
Industrial distillate fuel oil	7.8		
Transportation diesel fuel	6.6		

Source: EPA (2009) and USDA-ERS calculations based on EIA (2009a)
Note: For the higher price change scenario, industrial distillate fuel oil was used to derive impacts on prices for fertilizer and transportation diesel fuel (distillate fuel oil) was used to derive impacts on prices for direct fuel use.

electricity production and other uses would occur in response to the changes in relative prices, shifting more toward natural gas. The net result would be for the price of natural gas, due to heightened demand, to rise more than its technical emissions factor would suggest, while coal's price would increase less. Overall, this suggests an additional impact on the price of fertilizer, the production and price of which are dependent on natural gas.

Table 3.1 displays the percent increase in energy prices relative to those in the reference scenario for three fuels under the two scenarios of greenhouse gas emission prices. These energy price impacts are taken or derived from results in EPA (2009) and EIA (2009a) and reflect both the direct effects of emission prices and the indirect effects of fuel market interactions, as represented in the models underlying those studies.[6] The focus in this study is on short-term impacts, corresponding to the 2012-18 period shown in table 3.1.

[6]Electricity prices reported by EIA include rebates to consumers through 2025 (as provided for in H.R. 2454) and therefore do not reflect the incremental impact of emission prices. Thus, for consistency between the two price scenarios used here, electricity prices in our higher price impact scenario were constructed from the EIA results by adding emissions price increments to the prices from the reference scenario. See page 58 of EIA (2009a) for EIA treatment of electricity rebates.

Chapter 4

National Farm-Level Impacts of Higher Energy Prices

To assess effects on agriculture, assumptions for energy price changes summarized in table 3.1 were used to derive changes in prices paid by farmers for the two largest energy-related agricultural production inputs: fuel and fertilizer. Fuel price impacts in each scenario are based on 80 percent of the percentage change in petroleum prices from the reference scenario. Fertilizer price impacts are based on the percentage changes in natural gas prices (times 0.65) to reflect nitrogen-based fertilizer production costs and the percentage changes in petroleum prices (times 0.15) to reflect phosphate and potash production costs.

Table 4.1 shows the average percentage increase in prices paid by farmers for fuel and fertilizer for the two scenarios. The effect on producer input prices is about twice as large for the higher price impact scenario as for the lower price impact scenario. These price impacts are moderate in comparison to historical variability in these input prices, particularly over the past decade. Prices paid by farmers for fuel and for fertilizer each changed (some increases and some decreases) at double-digit rates in 9 of the 10 years from 2001 to 2010, including an 81-percent price spike for fertilizer in 2008. Nonetheless, despite the price volatility, the 2010 index for fuel had risen 110 percent from 2000 and the fertilizer index was up 123 percent, representing average compound annual rates of 7.7 and 8.3 percent, respectively.

Table 4.1

Prices paid by farmers for energy-related agricultural inputs, 2012-18 average

	Lower price change scenario	Higher price change scenario
	Percent increase	
Fuel	2.6	5.3
Fertilizer	4.1	10.0

To assess the impacts on major field crops and livestock, changes in agricultural production costs arising from higher energy prices are used as inputs to FAPSIM (see box, “The Food and Agricultural Policy Simulator”). This model calculates the impacts of changes in production costs on supply, demand, and prices in major agricultural commodity markets. At the aggregate level, FAPSIM also computes associated changes in sectorwide production expenses and net farm income. Model simulations for the different scenarios and time periods assume no changes in technology beyond those implicit in the reference scenario’s trends. However, some endogenous adjustments in input use are represented in the model through yield responses to fertilizer prices for some crops.

Higher prices for energy-related agricultural inputs (fertilizer and fuel) raise the cost of production for all crops (table 4.2). For the lower price impact

The Food and Agricultural Policy Simulator (FAPSIM)

FAPSIM is an annual, dynamic econometric model of the U.S. agricultural sector. The model was originally developed at the U.S. Department of Agriculture during the early 1980s (Salathe et al., 1982). Since that time, FAPSIM has been continually re-specified and re-estimated to reflect changes in the structure of the U.S. food and agricultural sector. The model includes over 800 equations.

FAPSIM contains four broad types of relationships: definitional, institutional, behavioral, and temporal. Definitional equations include identities that reflect mathematical relationships that must hold among the data in the model. For example, total demand must equal total supply for a commodity at any point in time. The model constrains solutions to satisfy all identities of this type.

Institutional equations involve relationships between variables that reflect certain institutional arrangements in the sector. Countercyclical payment rate calculations are an example of this type of relationship.

Definitional and institutional equations reflect known relationships that necessarily hold among the variables in the model. Behavioral equations are quite different because the exact relationship is not known and must be estimated. Economic theory is used to determine the types of variables to include in behavioral equations, but theory does not indicate precisely how the variables should be related to each other. Examples of behavioral relationships in FAPSIM are the acreage equations for different field crops. Economic theory indicates that production should be positively related to the price received for the commodity and negatively related to prices of inputs required in the production process. Producer net returns are used in the FAPSIM acreage equations to capture these economic effects. Additionally, net returns for other crops that compete with each other for land use are included in the acreage equations. While the model covers the U.S. agricultural sector, trade for each commodity is included through econometrically based export equations.

For the most part, FAPSIM uses a linear relationship to approximate the general functional form for each behavioral relationship. Generally, the parameters in the linear behavioral relationships were estimated by single-equation regression methods. The large size of the model precludes the use of econometric methods designed for systems of equations. Ordinary least squares was used to estimate the majority of the equations. If statistical tests indicated the presence of either autocorrelation or heteroscedasticity in the error structure of an equation, maximum-likelihood methods or weighted least squares were used.

Temporal relationships are empirical equations that describe the inter-relationships between variables measured using different units of time. For example, not all of the variables in FAPSIM are measured using the same concept of a year. Commodity data are reported on a marketing-year basis, budgetary data are reported on a fiscal-year basis, and farm income data are reported on a calendar-year basis. As a result, empirical equations are sometimes needed to establish relationships among variables in these different temporal categories. For example, cash receipts for crops are reported on a calendar-year basis, but production and price information for crops are on a marketing-year basis. Equations are used in FAPSIM to estimate cash receipts using information from both marketing years that overlap the calendar year.

Commodities included in FAPSIM are corn, sorghum, barley, oats, wheat, rice, soybeans (including soybean meal and soybean oil), upland cotton, cattle, hogs, broilers, turkeys, eggs, and dairy. The dairy model contains submodels for fluid milk, evaporated and condensed milk, frozen dairy products, cheese, butter, and nonfat dry milk. Each commodity submodel contains equations to estimate production, prices, and different demand components. FAPSIM also includes submodels to estimate the value of exports, net farm income, government outlays on farm programs, retail food prices, and consumer expenditures on food. All of the submodels are linked together through the variables they share in common.

FAPSIM is primarily designed to evaluate short-term impacts. Therefore, the model does not endogenously account for changes in technology that would likely result from sustained higher energy costs. In the scenarios examined in this analysis, we did not introduce any exogenous changes to technology beyond those implicit in the reference scenario's assumptions. Additionally, a decades-long declining trend in energy use per unit of output in the agricultural sector is likely to continue, only partly captured in the scenarios by increases in yields. For these reasons, the model likely overestimates the impact of higher energy prices on the sector.

However, the model does allow for changes in input use within the context of the reference scenario's technologies. Changes in the mix of crops planted reflect acreage shifting to less energy-intensive crops. Yields decline due to the lower fertilizer use caused by higher energy prices.

Although energy prices explicitly affect crop production, the only linkage to energy prices in the livestock sector in the model is through its effects on feed costs. Thus, the model understates the effects of higher energy prices on the livestock sector.

Table 4.2
Change in variable cost of production, 2012-18 average

	Average annual impact			
	Lower price change scenario		Higher price change scenario	
	$/acre	*Percent*	*$/acre*	*Percent*
Corn	7.37	2.3	17.59	5.4
Sorghum	3.44	2.0	7.87	4.5
Barley	3.09	2.0	7.27	4.8
Oats	2.55	2.2	6.02	5.2
Wheat	3.05	2.3	7.19	5.3
Rice	8.57	1.6	19.63	3.7
Upland cotton	4.93	0.9	11.45	2.1
Soybeans	1.57	1.1	3.65	2.6

case, the largest absolute changes in variable production costs are for crops that use more energy-related inputs, most notably rice, corn, and cotton. However, compared with total crop-specific variable production costs, high-cost rice and cotton are relatively less affected by the energy input changes (up 1.6 and 0.9 percent, respectively) than corn (up 2.3 percent). This is due to the lower energy-input share relative to production costs for rice and cotton producers (fig. 2.1). Soybean production costs—both absolute and relative—are less affected than those of most other crops.

For the higher price impact scenario, production cost impacts for all crops are generally 2-2.5 times as large as those under the lower price impact scenario, largely reflecting the different magnitudes in the underlying assumptions for greenhouse gas emission prices. The relative impacts among the crops are similar across the scenarios.

Higher Production Costs Lower Producer Net Returns and Reduce Overall Plantings

Changes in production costs affect producer net returns, which can cause farmers to adjust planted acreage.[7] With higher production costs for crops, net returns fall and farmers respond by reducing plantings. The resulting decline in overall production raises crop prices, which (with inelastic demand) provides some partially offsetting gains in revenues from crop sales. Nonetheless, overall producer returns are still reduced. Thus, total acreage planted to major field crops decreases by more than 450,000 acres per year (average over 2012-18) in the lower price change scenario, and over 1 million acres (0.4 percent) in the higher price change scenario (table 4.3).[8]

Individual crop results are mixed, however. Relative changes in net returns among cropping alternatives, along with differences in producer responses to changes in economic incentives, result in varying impacts for each crop.

For the lower price change scenario, wheat acreage is down the most at 265,000 acres (0.4 percent) and corn acreage drops about 200,000 acres (0.2 percent). However, cross-commodity relationships among net returns for alternative cropping choices result in soybean acreage increasing by about 93,000 acres—producer returns for soybeans decline less than for corn, providing economic incentives to shift some acreage from corn to soybeans.

[7]Net returns equal the production value of a crop minus its cost of production.

[8]See USDA (2009) for a discussion of the reference scenario.

Table 4.3
Change in planted acres, 2012-18 average

	Average annual impact			
	Lower price change scenario		Higher price change scenario	
	1,000 acres	*Percent*	*1,000 acres*	*Percent*
Corn	-201	-0.2	-467	-0.5
Sorghum	-17	-0.2	-31	-0.4
Barley	-8	-0.2	-19	-0.5
Oats	-34	-1.0	-79	-2.3
Wheat	-265	-0.4	-614	-1.0
Rice	-8	-0.3	-17	-0.6
Upland cotton	-23	-0.2	-55	-0.5
Soybeans	93	0.1	208	0.3
Total	-464	-0.2	-1,073	-0.4

For the higher price change scenario, larger acreage adjustments occur although relative changes among crops are similar. Wheat and corn still experience the largest acreage reductions (making up more than 84 percent of the total acreage decline). Again, there is a net switch in acreage to soybeans (up more than 200,000 acres) as their net returns are affected least among crops.

Lower Crop Production Raises Prices for Most Crops

With the exception of soybeans, crop production is down, leading to higher prices under each scenario (table 4.4). Price increases for the lower price change scenario are moderate, averaging 0.6 percent or less for each crop. The prices for soybeans and soybean products drop slightly as acres shift to soybeans from other crops. Price increases under the higher price change scenario range from 0.5 to 1.4 percent for most crops, while prices for soybeans and soybean products again fall.

Table 4.4
Change in price, 2012-18 average

	Average annual impact on price			
	Lower price change scenario		Higher price change scenario	
	$/bushel	*Percent*	*$/bushel*	*Percent*
Corn	0.02	0.6	0.05	1.4
Sorghum	0.02	0.6	0.05	1.4
Barley	0.02	0.5	0.04	1.1
Oats	0.01	0.6	0.03	1.3
Wheat	0.02	0.4	0.05	0.9
Rice	0.03	0.3	0.07	0.6
Upland cotton ($/cwt)	0.14	0.2	0.34	0.5
Soybeans	-0.01	-0.1	-0.02	-0.2
Soybean meal ($/ton)	-0.17	-0.1	-0.37	-0.1
Soybean oil (cents/lb)	-0.02	-0.1	-0.05	-0.1

Implications for Fruits and Vegetables

A separate model was used for the fruit and vegetable sector since horticultural products are not included in FAPSIM. Data from USDA's Agricultural Resources Management Survey (ARMS) were used to estimate the effects of energy price changes on costs of production in the fruit and vegetable sector. Average per farm effects on variable costs of production were estimated based on the increased input prices for fuels, electricity, and fertilizer described earlier. Implications for market adjustments for fruits and vegetables are discussed in the accompanying box on page 17 by comparing changes to those that occurred in 2008.

Higher Energy Prices and Higher Feed Costs Lead to Lower Livestock Production and Higher Livestock Product Prices

Under both scenarios, higher corn prices and only moderately lower soybean meal prices lead to an increase in feed costs for the livestock sector (table 4.5). In addition, higher energy prices raise other production costs for livestock.[9] As a result, livestock production declines slightly. Although the impacts are not large, they vary across livestock species, mostly reflecting the relative shares of corn and soybean meal in typical feed rations. Consequently, pork and beef are affected more than poultry. Relative results are similar across the two scenarios, with impacts roughly proportional across the different livestock categories.

Table 4.5
Change in feed prices and livestock production, 2012-18 average

	Lower price change scenario		Higher price change scenario	
	Feed cost	Livestock production	Feed cost	Livestock production
	Average annual percent impact			
Beef	0.6	-0.1	1.3	-0.2
Pork	0.4	-0.1	0.9	-0.2
Young chickens	0.2	0.0	0.6	0.0
Milk	0.4	0.0	1.0	-0.1

Aggregate Production Expenses for the Agricultural Sector Rise

Total production expenses in the agricultural sector rise by an average of $1.73 billion per year over 2012-18 (table 4.6) under the lower price impact scenario. The largest changes in production expenses are for fertilizer and lime and for fuel, oil, and electricity due to the changes in the energy-related input prices. Most other categories of expenses decline slightly due to lower production. For the higher price change scenario, increases in production expenses for energy-related and total inputs are 2-3 times larger, in line with the relative magnitudes of underlying energy prices.

[9]Energy-related production costs for livestock are not explicitly included in FAPSIM. To include the effects of higher energy-related costs, FAPSIM results for cattle, hogs, and chickens were augmented by results from a separate meat-sector model that includes detailed production costs (Weimar and Stillman, 1990). Dairy sector FAPSIM results were similarly augmented by estimates of the effects of higher energy-related production costs expressed in corn-equivalent costs in dairy producer net returns using FAPSIM structure. In each case, overall adjustments are dominated by the feed cost effects, reflecting their relative importance in the cost structure of livestock production (table 2.1).

Energy Price Changes and the Fruit and Vegetable Sector

Labor is the single largest variable cost for vegetable, melon, fruit, and tree nut farms. However, the second largest expense component is fertilizer and agricultural chemicals. During 2004-06, fertilizer and agrichemicals accounted for about 18 percent of variable cash expenses for the production of vegetables and melons, and 13 percent for specialized fruit and tree nut operations.[1] Motor fuels and oil used to run tractors, generators, and irrigation pumps accounted for 5 percent of vegetable cash costs and 4 percent of cash costs for fruits and tree nuts. For this analysis, fertilizer application rates per acre were assumed to remain constant. Over the longer run, however, growers would likely adjust application methods, amounts, timing, or the mix of crops produced in response to fertilizer price increases.

In addition, electricity is required by these farms to operate irrigation pumps, ice makers, lights, and sorting and packing equipment. Electricity is the largest component of the public utility expense (which also includes telephone, water, and Internet access). According to Agricultural Resources Management Survey data, electricity accounts for 2-3 percent of cash costs on fruit and vegetable farms.

Impacts of higher fertilizer, fuel, and electricity prices on variable costs within the fruit and vegetable sector are generally small (2 percent or less) across the two price scenarios (see table).

Impact of greenhouse gas emission pricing on variable cash production expenses of fruits and vegetables, 2012-18

Commodity	Lower price change scenario	Higher price change scenario
	Average annual percent impact	
Vegetables and melons	1.1	2.2
Fruits and tree nuts	0.9	1.6
Total fruits, tree nuts, and vegetables	1.1	2.0

By contrast, overall input prices for vegetables and melons jumped an estimated 19 percent in a single year (2008) due largely to rapidly rising fuel and fertilizer prices. Input prices were up 13 percent that year for specialized fruit and tree nut farms. Fruit and vegetable production in 2008 showed little effect from the sharply higher fuel and fertilizer prices. Fruit and tree nuts are largely produced from fixed acreages; as long as adequate labor is available and a viable market exists, fruit will be harvested. Processing vegetables (and an increasing share of fresh vegetables, particularly fresh-cut and packaged products) are almost entirely produced under contract, and growers negotiated higher contract prices for 2008 to offset some of the increased production costs. Because consumer demand for fruits and vegetables is relatively price inelastic (K. Huang, 1993; You et al., 1998) and does not change too much with price changes, much of the 2008 price increases were passed up the marketing chain. The result was the largest increase (6.2 percent) in overall consumer prices for fruits and vegetables in over 10 years.

A similar response with limited production impact is likely under the energy price change scenarios addressed here, particularly since the magnitudes of the cost impacts are much smaller than seen in 2008. Further, to the extent that consumer demand for fruits and vegetables may be more responsive to sustained price changes in the longer term, overall retail price impacts for fruits and vegetables would be smaller than in 2008.

[1]Specialized farms are those that derive at least 50 percent of their revenue from a given commodity or commodity group, such as vegetables and melons.

Table 4.6
Change in farm sector production expenses, selected categories, 2012-18 average

	Average annual impact			
	Lower price change scenario		Higher price change scenario	
	$ billion	Percent	$ billion	Percent
Fertilizer and lime	1.21	4.6	2.95	11.2
Fuel, oil, and electricity	0.88	6.2	1.79	12.8
Total production expenses	1.73	0.6	3.91	1.3

Net Farm Income Reduced

Net farm income declines an average of $1.5-3.4 billion (1.8-4.1 percent) per year over the 2012-18 period (table 4.7) across the two price impact scenarios. This change is due primarily to higher production expenses, which are partly offset by higher cash receipts due to reduced production and higher prices.

Table 4.7
Change in farm income, selected categories, 2012-18 average

	Average annual impact			
	Lower price change scenario		Higher price change scenario	
	$ billion	*Percent*	*$ billion*	*Percent*
Cash receipts				
Crops	0.13	0.1	0.30	0.2
Livestock and products	0.15	0.1	0.39	0.3
Total cash receipts	0.28	0.1	0.69	0.2
Total production expenses	1.73	0.6	3.91	1.3
Net farm income	-1.52	-1.8	-3.35	-4.0

Impact on Retail Food Prices

Changes in consumer food prices come from two major sources: (1) energy-related impacts on commodity prices and (2) higher energy costs in the food marketing system. FAPSIM accounts for the former effects but not the latter. Thus, a separate analysis was conducted to derive impacts in the food marketing system based on historical energy pass-through rates between food processing stages.[10] These results were combined with the FAPSIM results to give the overall retail food price impacts.

Overall, the average 2012-18 effects are annual increases of 0.98 and 1.33 percent in the Consumer Price Index (CPI) for food at home and 0.16 and 0.23 percent for the food-away-from-home CPI (table 4.8). These changes combine for average annual increases of 0.63 and 0.85 percent in the total food CPI over 2012-18 for the lower price and higher price change scenarios, respectively. For each scenario, most of the retail food price impact is from

[10]See Appendix C for the methodology of estimating historical pass-through rates of energy prices in the food marketing system and a description of the analytical process underlying the results.

the effect of higher energy prices in the food marketing system rather than from agricultural commodity price impacts. This partly reflects the low farm-value share (20 percent) of retail prices for domestically produced farm foods.

Table 4.8
Change in retail food prices, 2012-18 average

	Average annual impact	
CPI category	Lower price change scenario	Higher price change scenario
	Percent	
Food at home	0.98	1.33
Food away from home	0.16	0.23
Total food	0.63	0.85

Longer Term Adjustments to Higher Energy Prices

If energy prices were to continue to rise in years beyond the short-term focus in this report reflecting, for example, further increases in prices for greenhouse gas emissions such as depicted in figure 3.1, additional long-term adjustments would occur in the agricultural sector.

Continued shifts in the mix of crop produced would reflect the shift away from energy-intensive crops to those whose production costs are less reliant on energy inputs. As illustrated in the short-term impacts, this would include, for example, shifts in planted acreage away from corn to soybeans. In addition, other structural adjustments in agricultural production practices would take place as farmers seek to improve energy-use efficiency, such as modifying their use of energy-related inputs in the production of specific crops. This could include using less fertilizer, perhaps by targeting its use more effectively, or using production practices that do not require as many trips across fields with tractors and other farm equipment (USDA-ERS). Further, energy use per unit of output in the agricultural sector would be likely to continue its decades-long decline (USDA-OCE and ERS, 2009; Ball, 2010). Some of these effects may be facilitated by the development of new technologies and may be accelerated if higher energy prices spur technological investment and development.

Nonetheless, longer run adjustments to higher energy prices within the agricultural sector would follow the same dynamics as seen in the short-term results. In response to higher production costs, total plantings would be reduced and acreage would shift among crops, leading to changes in commodity prices. Higher overall feed costs would lead to adjustments in the livestock sector. In the farm income accounts, total cash receipts would be higher due to higher crop and livestock prices. But production expenses would rise more, resulting in lower net farm income from the continued rise in energy prices. Retail food prices would rise further, with increases reflecting energy cost-related increases in the food marketing chain more than higher farm-level commodity prices.

The Role of Industry Rebates

One source of energy price changes is the introduction of costs for greenhouse gas emissions, through either a tax on emissions or through a cap-and-trade system. For example, in many cap-and-trade proposals, sectors of the economy are classified as either covered or uncovered. Covered sectors are required to hold allowances equal to the quantity of their greenhouse gas emissions. Typically, agriculture has not been a covered sector with respect to methane and nitrous oxide emissions. Nonetheless, agriculture faces increased prices for fertilizer, natural gas, electricity, and diesel fuel.

However, such proposals also typically provide transition-period rebates to designated industries, which can lessen the effects on agriculture. An example is the treatment of energy-intensive trade-exposed (EITE) industries, such as the nitrogen fertilizer production industry (see box, p. 3). For such industries, foreign competitors would not see the increases in energy prices that occur in the United States, so rebates of emissions allowances to those domestic industries could offset any competitive advantage foreign producers would otherwise gain.

Two additional scenarios were analyzed to assess the effects of such rebates on reducing the impacts of energy price changes on agriculture. Implications of energy price changes for production costs were derived for 2012-2018, years that would be covered in the transition period for the rebates, based on previous legislative proposals. Here, however, impacts for nitrogen-based fertilizer prices were reduced to reflect the rebates that offset higher natural gas prices, resulting in smaller increases in costs of production in the agricultural sector (see table).

With overall production cost impacts reduced, effects throughout the sector are lower as well. For example, aggregate reductions in planting are 133,000 and 354,000 acres in these two scenarios, compared with 464,000 and 1.073 million acres without rebates. Impacts on farm income are about half those that result without rebates (see table 4.7).

Agricultural changes with higher energy prices, but with natural gas-related rebates to nitrogen-based fertilizer industry, 2012-18 average

	Lower price change scenario		Higher price change scenario	
Cost-of-production changes:	*$/acre*	*Percent*	*$/acre*	*Percent*
Corn	1.44	0.4	4.72	1.5
Sorghum	1.52	0.9	3.71	2.2
Barley	0.85	0.6	2.41	1.6
Oats	0.69	0.6	1.97	1.7
Wheat	0.80	0.6	2.31	1.7
Rice	3.74	0.7	9.14	1.7
Upland cotton	1.76	0.3	4.56	0.8
Soybeans	0.55	0.4	1.43	1.0
Farm income changes:	*$ billion*	*Percent*	*$ billion*	*Percent*
Cash receipts				
Crops	0.02	0.0	0.08	0.0
Livestock and products	0.03	0.0	0.12	0.1
Total cash receipts	0.05	0.0	0.20	0.1
Total production expenses	0.80	0.3	1.91	0.6
Net farm income	-0.76	-0.9	-1.72	-2.1

Chapter 5

Impacts by Farm Production Specialty and Region

Impacts for farm businesses by farm production specialty and by region are based on results from the Farm-Level Partial Budget Model (see box). The model uses scenario results from the FAPSIM simulations as inputs to derive the impacts presented in this chapter. Results from the model can be summarized across various groupings of farms such as by resource region, commodity specialization, or farm size. However, since farm business performance varies within any of these groupings, results indicate average impacts within a group rather than impacts on individual farms.

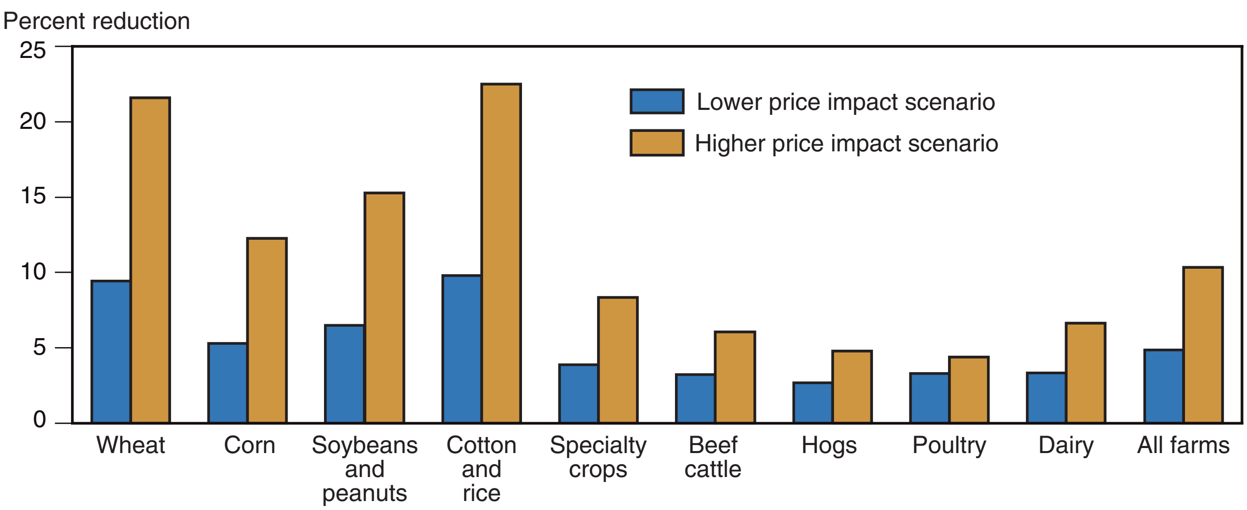
Impacts by Farm Production Specialty

A simulation of how higher energy prices will affect farms with different farm production specialties reveals that some segments of agriculture would be more affected than others. The analysis here focuses on results for 2014.

Net cash income for all farm businesses is estimated to average 5 percent and 10 percent lower in the two price impact scenarios (fig. 5.1), relative to the 2014 reference case, primarily because of higher input expenses. Of the major commodity types, wheat, cotton, and rice farm businesses are estimated to have the most significant bottom-line impacts, with incomes 9-10 percent below the reference scenario in the lower energy price impact scenario and 22 percent lower in the higher impact scenario. Other crop businesses show smaller decreases in net income. Meanwhile, livestock producers (beef cattle, dairy, poultry, and hogs) are less affected (net cash income down about 3 percent in the lower price impact scenario and down 4-7 percent in the higher scenario) as most of their energy-related cost increases are smaller and indirect, coming through higher feed expenses.

Figure 5.1

Reduction in farm business net cash income, by farm production specialty, 2014



Note: Reductions reflect the difference in farm business net cash income in 2014 (with greenhouse gas emission prices) relative to a reference case (without greenhouse gas emission prices).

Regional Impacts

Variation in impacts across farm production specialty explains how higher energy prices affect some regions more than others. The region most affected by higher energy costs in these scenarios is the lower Mississippi Delta (Mississippi Portal) region (figs. 5.2 and 5.3). Fertilizer-intensive crops like cotton dominate in this region, with net cash income for the region estimated to decline by 8 and 19 percent in the two price scenarios. The Basin and Range, Southern Seaboard, Northern Crescent, and Northern Great Plains regions are also estimated to see declines in net cash income, from 6 to 7 percent in the lower price impact scenario and from 12 to 14 percent in the higher price scenario. The balance of the country is estimated to experience a drop in net cash income of 4 percent in the lower price scenario and 9 percent in the higher price scenario.

Farm-Level Partial Budget Model

The Farm-Level Partial Budget Model provides disaggregated regional and farm production specialty information for farm businesses based on the national impacts reported earlier. U.S. farm businesses include more than 800,000 commercial and intermediate family and nonfamily farms where farming is the primary activity of the operator. The model operates on individual farm data from USDA's Agricultural Resource Management Survey to provide estimated impacts on per-farm averages of components of the income statement and balance sheet.

Traditional whole-farm budgeting is done on the basis of fixed-point estimates of production, prices, and financial variables to predict point estimates of financial results. Ideally, a whole-farm budget includes fixed and variable production costs and other non-cash components necessary to measure accrual income. However, the majority of applications are targeted to specific changes in costs or returns, without allowances for changes in depreciation, other noncash charges, inventory changes, and other accrual adjustments. Therefore, it is more appropriate to characterize the modeling approach as partial budgeting analysis.

The model incorporates elements of income and expenses to project cashflow. Totals for assets and debt are used to forecast major elements of the balance sheet and debt repayment ability. The forecast changes are applied to each farm in the survey and then summarized to evaluate changes from the base year. Results reported here focus on per-farm averages of net cash income.

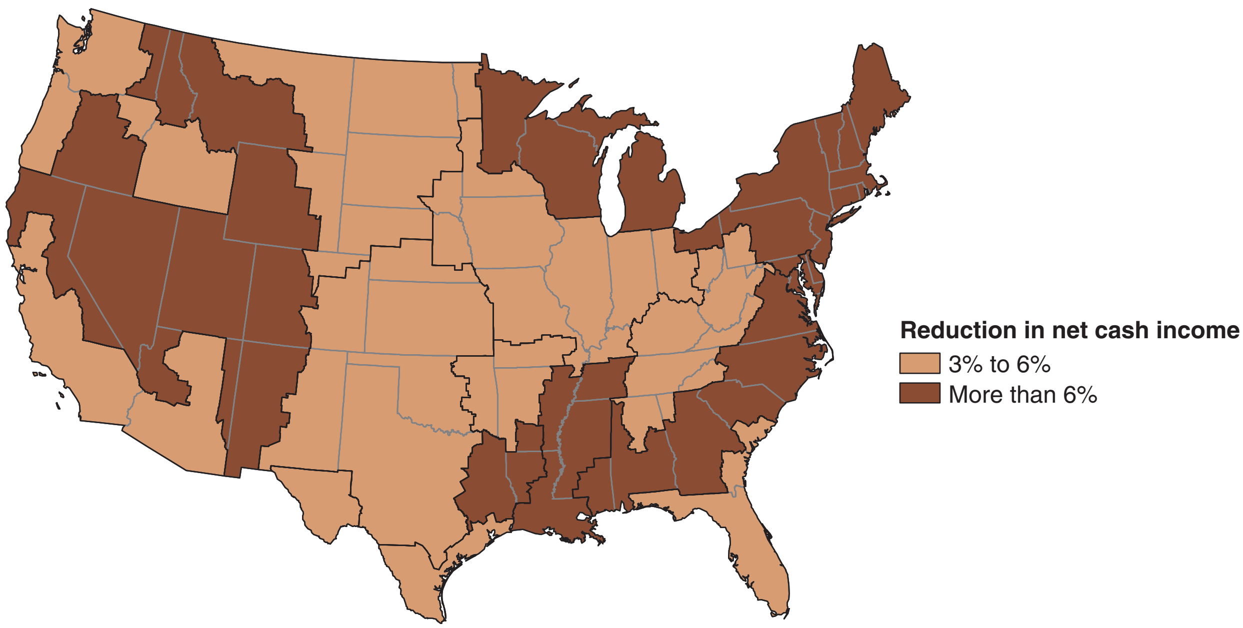
Model Limitations

The model reflects historical production patterns and farm structure. Potential behavioral or production responses by farms are not included in the model. The effects of weather, structural changes, and behavioral response are reflected in the forecast error along with any error associated with the input parameters.

Overall impacts here can be greater than those in the national farm income accounts due to a number of factors. This reflects, in part, the model's focus on "farm businesses" whose concentration of expenses is higher than for all farms. Further, part of the difference relates to the treatment of rent in production expenses. Rental expenses for farm businesses at the individual farm level in the Farm-Level Partial Budget Model are assumed to come directly out of net cash income, regardless of whether the rental payments go to another farmer or go outside the agricultural sector. In contrast, the national farm income accounts use net rental costs to the sector (net rent to non-operator landlords), counting only rental costs that go outside the agricultural sector.

Figure 5.2

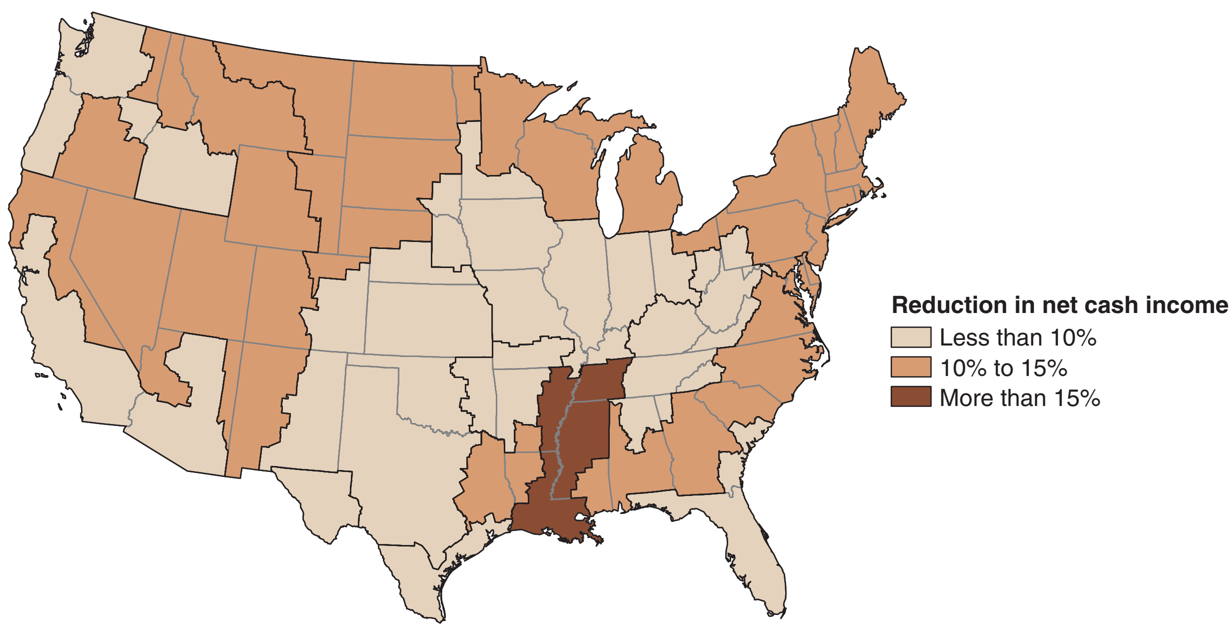
Reduction in farm business net cash income by resource region, lower price impact scenario, 2014



Source: USDA, Economic Research Service.

Figure 5.3

Reduction in farm business net cash income by resource region, higher price impact scenario, 2014



Source: USDA, Economic Research Service.

Chapter 6

Rural Impacts

Earlier chapters of this report focused on how agricultural production, farm income, and food prices would adjust in response to energy price changes resulting from the pricing of greenhouse gas emissions. This chapter considers how those changes in energy prices and related changes in energy production are likely to affect rural communities. We consider three types of industries: farming, energy extraction (coal, petroleum and natural gas), and energy-intensive mining and manufacturing, and identify counties relatively specialized in these industries as likely to be the most affected.

The focus in this chapter is on how resilient affected communities and their populations are likely to be. We consider several county attributes. First, local adjustments are likely more difficult where affected counties are bunched together. Residents have much less chance of commuting to a neighboring county with a healthier economy. Second, low education levels impede adjustment by making it less likely for residents to find jobs elsewhere or for local economies to attract or generate new businesses. Low employment rates and high poverty suggest that the local economy is weak even without any loss of energy-related jobs.

In general, we find that impacts will be small and focused on a small number of nonmetro counties. Few rural counties remain specialized in farming or energy extraction. In some of these counties, those with populations having low educational attainment and high poverty and unemployment rates, energy sector adjustments seem likely to compound existing socioeconomic problems. Other farming or energy counties, largely outside the South, have relatively prosperous populations, but high out-migration.

Farming dependent counties

While land in the United States remains extensively farmed, the rural economy has become diversified and relatively few counties are still highly dependent on agriculture. These counties tend to be thinly settled, remotely located, and lacking in natural amenities. ERS defined 403 nonmetropolitan counties as "farming dependent" in 2004, based on their having at least 15 percent of income from farming or 15 percent of employment in farming. Most are in the Great Plains, although they are also found scattered across the West and South (Fig. 6.1). These are generally the counties likely to be most affected by changes in farm income. About two-thirds of nonmetro farm income is generated outside of these farming counties, where effects are likely to be small due to the small role of agriculture in the local economy. We turn later to the farm county distinction between counties with under 40 percent of their land in crops and counties with higher proportions of cropland.

In the regional results for the higher price impact scenario from chapter 5, over half of the farming dependent counties are in resource regions where anticipated effects of pricing emissions are expected to be minimal (Table 6.1). Most of the rest of the counties are in regions with anticipated modest effects of 10-15 percent. Twelve farming dependent counties are in the

Mississippi Portal resource region, where farm business net cash incomes are estimated to be reduced by over 15 percent.

Although there has been considerable variation over time and from one agricultural area to another, farm incomes overall have risen considerably over the past decade, explaining in part why farming counties have been largely immune from the recent recession. County average total nonfarm earnings rose in farming dependent counties as well in 2001-2008, more than in other nonmetro counties. Some of this rise may reflect the relatively high educa-

Table 6.1

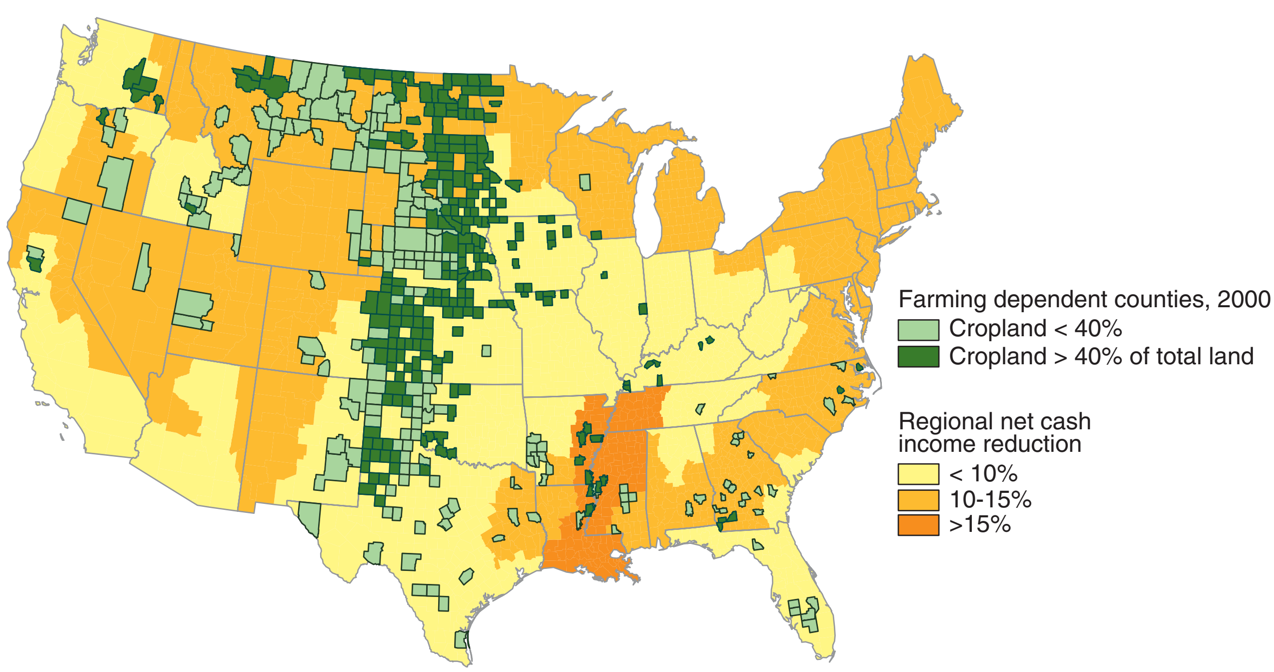
Change in farm and nonfarm income and population for farming dependent counties

County and region type	Number of counties	Change 2001-2008: Aggregate realized net farm income[1]	Change 2001-2008: Average nonfarm earnings	Population change 2001-2010
		Percent		
Farming dependent counties[2]	403	43.9	15.4	-2.8
Resource region loss in farm business net cash income[3]				
Less than 10%	216	35.8	15.5	-2.4
10% to 15%	175	64.2	16.1	-2.7
Greater than 15%	12	31.0	5.2	-12.9
Other nonmetropolitan counties	1,620	70.8	12.5	3.0

[1]Expressed as aggregate as some counties had negative income in base year. Source: BEA REIS data files, adjusted for inflation using the Index of Consumption Expenditures.
[2]See text.
[3]See Figure 6.1.

Figure 6.1

Farming counties and regional reduction in net cash income, higher price impact scenario, 2014



Source: USDA, Economic Research Service.

tion levels in most farming counties (see below), as more highly educated members of the labor force have had an increasing advantage in the labor market. Despite the rise in farm and nonfarm earnings, however, farming dependent counties continued to lose population.

The 12 farming dependent counties with estimated farm business net cash income losses more than15 percent, all in the Mississippi Portal resource region, stand out from most of the remaining farming counties. While these 12 counties had substantial gains in net farm income, their average gain in nonfarm earnings was only 5 percent, only a third as large as the other farming counties, and their average rate of population loss was 13 percent over 2000-2010, much higher than in other farming counties.

These differences reflect socioeconomic characteristics. While farming counties in general tend to have relatively few people without high school degrees, very high proportions of adults employed, and low poverty rates compared with other nonmetro counties, the Mississippi Portal region counties have markedly lower education levels than other counties, only 60 percent of their working age adults employed (12 percentage points less than the average among other nonmetro counties), and nearly twice the poverty rates of other farming counties (table 6.2). Even with substantial growth in farm net cash income in 2001-2008, these counties showed little sign of growth and development.

Changes in farm income over the past decade have depended sharply on whether the farm specializes in crops or in livestock. While the prices of many crops have risen, livestock producers have been hampered, in part, by the rise in feed grain prices, most notably corn. Consequently, we also looked at farming dependent counties separated by crop and livestock specialization.

As an approximation of local specialization, we divided farming counties into those with less than 40 percent of their land in crops, to reflect livestock specialization, and those with 40 percent or more of their land in crops, to reflect field crop specialization and examined past trends and current socio-economic situations.

Table 6.2

County average statistics reflecting vulnerability for farming dependent and other nonmetro counties, by resource region impact on farm income

County type and resource region expected loss in net farm income	No HS diploma, ages 25-64[1]	Employed, ages 22-59[1]	Poverty rate[1]	No. of counties
	Percent			
Farming dependent counties[3]	13.8	77.4	15.7	403
Resource region loss in farm business net cash income				
Less than 10%	15.5	77.7	14.9	216
10% to 15%	10.8	78.2	15.6	175
Greater than 15%	26.5	60.4	30.7	12
Other nonmetropolitan counties	15.1	72.5	17.0	1,620

[1]Source: American Community Survey data files, 2005-2009 averages.
[2]See: *Nonmetropolitan Outmigration Counties: Some Are Poor, Many Are Prosperous*, Economic Research Report No. 107.
[3]Farming dependent counties had either 15 percent of income (1998-2000) or employment (2000) from farming. See Measuring Rurality Briefing Room: http://www.ers.usda.gov/Briefing/Rurality/Typology/

Table 6.3

Comparison of farming dependent counties based on extent of cropland

County characteristics[1]	Cropland as a percent of county land, 1997[2]	
	Under 40%	40% or more
	Percent	
Change in previous decade		
Aggregate change in realized farm net income, 2001-2008	-13.5	85.8
Average gain in nonfarm earnings	18.9	12.5
Population change, 2000-2010	0.3	-5.5
Socioeconomic characteristics, 2005-09 average		
Lacking HS diploma, ages 25-64	15.9	12.1
Employment rate, ages 22-59	73.8	80.4
Poverty rate	17.9	13.8
Number of counties	184	219

[1]For sources, see Tables 6.1 and 6.2.
[2]Source: ERS, based on 1997 Census of Agriculture data files.

The distinction according to extent of county cropland yields two remarkably different pictures. "Livestock counties," farming counties with under 40 percent cropland, saw a loss in net farm income of 14 percent between 2001 and 2008, whereas "crop counties," with at least 40 percent of their land in crops, had an overall gain in net farm income of 86 percent.

Differences are less pronounced in other measures, however. The average gain in nonfarm earnings was 19 percent in the livestock counties, which tended to maintain their population sizes over the decade. Nonfarm earnings in crop counties rose by about 13 percent, comparable to the rise in the nonmetro counties not dependent on farming, but lower than might be expected given their rise in farm income. Moreover, these counties lost an average of more than 5 percent of their population over 2000-2010, a greater rate of loss than in 1990-2000. A major part of the gains in net farm incomes in crop counties might be lost to higher land prices, regional market centers, and the broader world, rather than staying in the community. At the same time, it cannot be said that population loss in these counties reflects economic hardship. The crop counties have highly schooled populations, with an average of 88 percent of the population ages 25-64 having a high school diploma, over 80 percent of the population ages 22-59 actively employed, and an average poverty rate of only 14 percent (for a discussion of prosperous outmigration counties, see McGranahan, Cromartie and Wojan, 2010).

All told, it does not appear that higher energy prices in the scenarios studied in this report would have a substantial effect on farming county economies and populations. Farm dependent counties with relatively high farm income losses that also have lower education levels, higher unemployment, and high poverty would likely be most affected. Livestock counties showed some resilience in 2000-2010, with substantial gains in nonfarm earnings, despite the decline in farm earnings. Some of these gains may reflect growth in value-added activities such as meat packing. Some may reflect the relative attractiveness of these counties to tourists, retirees, and others seeking attractive rural settings.

Energy production counties

Energy production activities in the United States are concentrated in a limited number of nonmetropolitan counties. While effects of changes in energy production related to the pricing of emissions would be small for rural America overall, impacts in energy-producing counties would be more pronounced. Nonetheless, the impact on nonmetro areas would be larger than in metro areas, mainly because local economies specialized in energy production are overwhelmingly rural. Differential regional effects would come from the geographic distribution of energy sectors.

Geographic Concentration of Coal, Crude Oil, and Natural Gas Extraction

The number of places in the United States where coal, crude oil, and natural gas can be economically extracted is limited, explaining why these industries are among the most spatially concentrated in the economy. For this analysis, we identify those counties deriving 5 percent or more of their nonfarm employment from coal, crude oil, or natural gas. At this threshold, employment losses from coal, crude oil, and natural gas extraction of 20 percent imply county-level job losses of 1 percent.

More than 61 percent of coal industry employment is located in counties meeting this 5-percent threshold. The oil and gas industry is less spatially concentrated, with counties meeting the 5-percent employment threshold comprising 38 percent of industry employment. By comparison, textiles is the most spatially concentrated manufacturing industry, with about 60 percent of industry employment located in counties meeting the 5-percent threshold.

The coal industry is most concentrated in eastern Kentucky and West Virginia, where several counties deriving more than 15 percent of nonfarm employment from the industry are adjacent to each other (fig. 6.2). However, counties highly dependent on coal are also found in Pennsylvania, Indiana, Illinois, North Dakota, Utah, and Wyoming. States with counties deriving 5 to 15 percent of nonfarm employment from coal include Montana, Colorado, Texas, Louisiana, Mississippi, and Alabama.

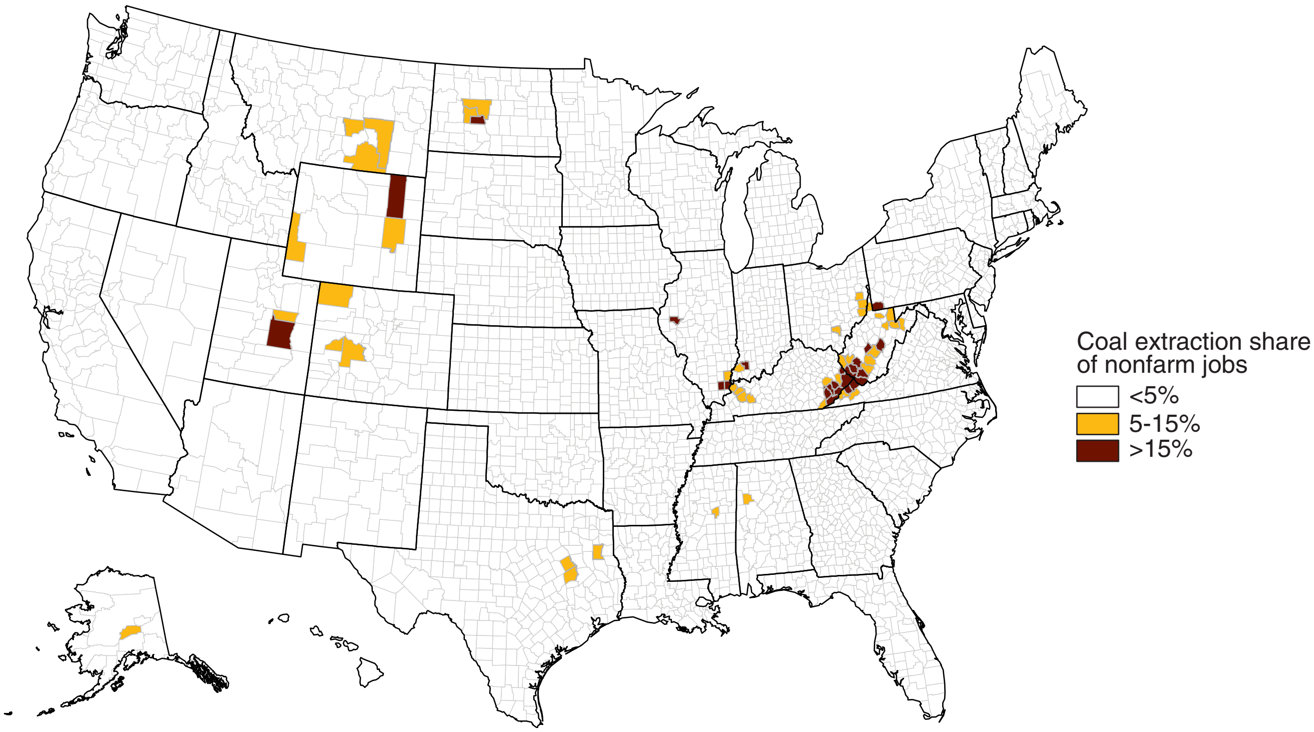
Counties highly dependent on crude oil and natural gas production (over 15 percent of nonfarm employment) are more numerous, and most prevalent in Texas and Oklahoma (fig. 6.3). Contiguous collections of highly dependent counties are found in Texas and Oklahoma as well as on the borders of Colorado and Utah, and North Dakota and Montana.[11] Alaska and West Virginia are two other States with counties highly dependent on crude oil or natural gas extraction, joined by counties in Kansas, Louisiana, Mississippi, and Illinois deriving 5 to 15 percent of nonfarm employment from the industry.

[11]Wyoming is also likely to have a number of counties that are highly dependent on crude oil production, but detailed industry-level employment data from this State have not been made available to ERS.

Figure 6.4 demonstrates the spatial concentration of energy sector jobs in total, including the extraction of coal and crude oil/natural gas, oil refining,

Figure 6.2

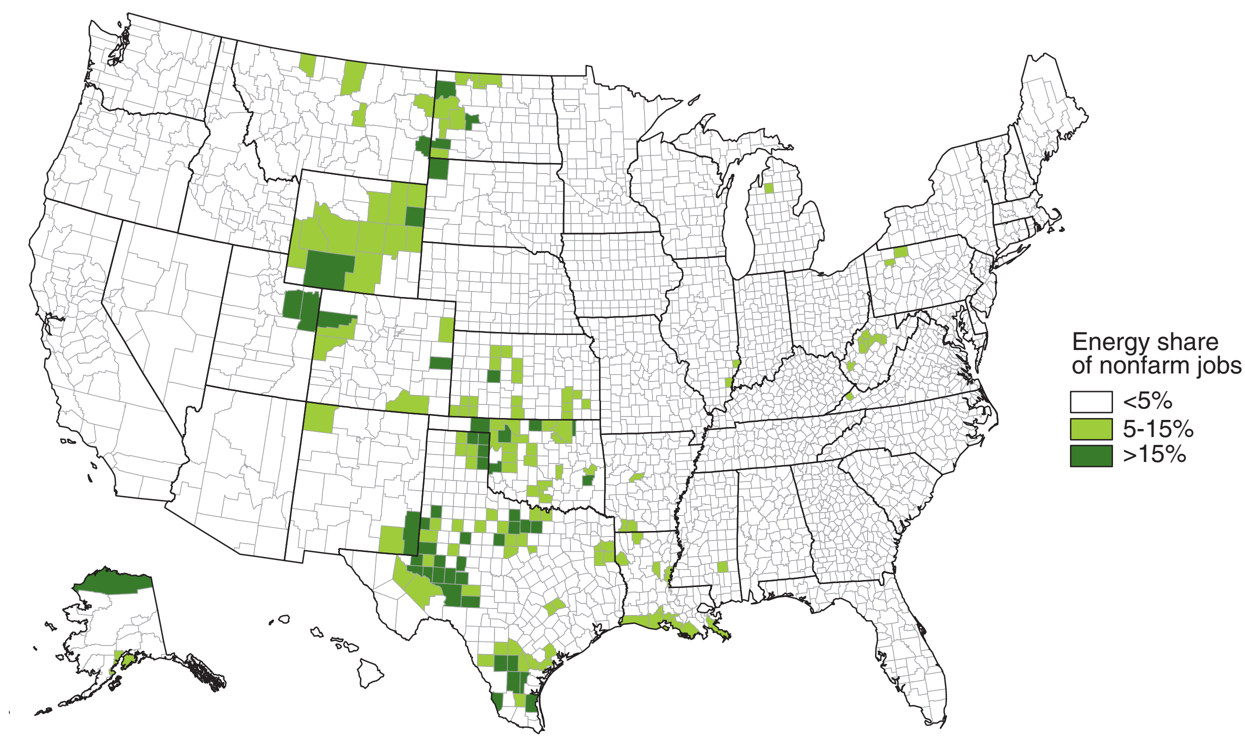
Counties with significant employment in coal mining, 2008



Source: ERS, based on Bureau of Labor Statistics QCEW (Quarterly Census of Employment and Wages) data files and Bureau of the Census County Business Patterns data files. Statistics for some counties are estimates as exact employment numbers are suppressed to maintain confidentiality.

Figure 6.3

Counties with significant employment in oil and gas extraction, 2008



Source: ERS, based on Bureau of Labor Statistics QCEW (Quarterly Census of Employment and Wages) data files and Bureau of the Census County Business Patterns data files. Statistics for some counties are estimates as exact employment numbers are suppressed to maintain confidentiality.

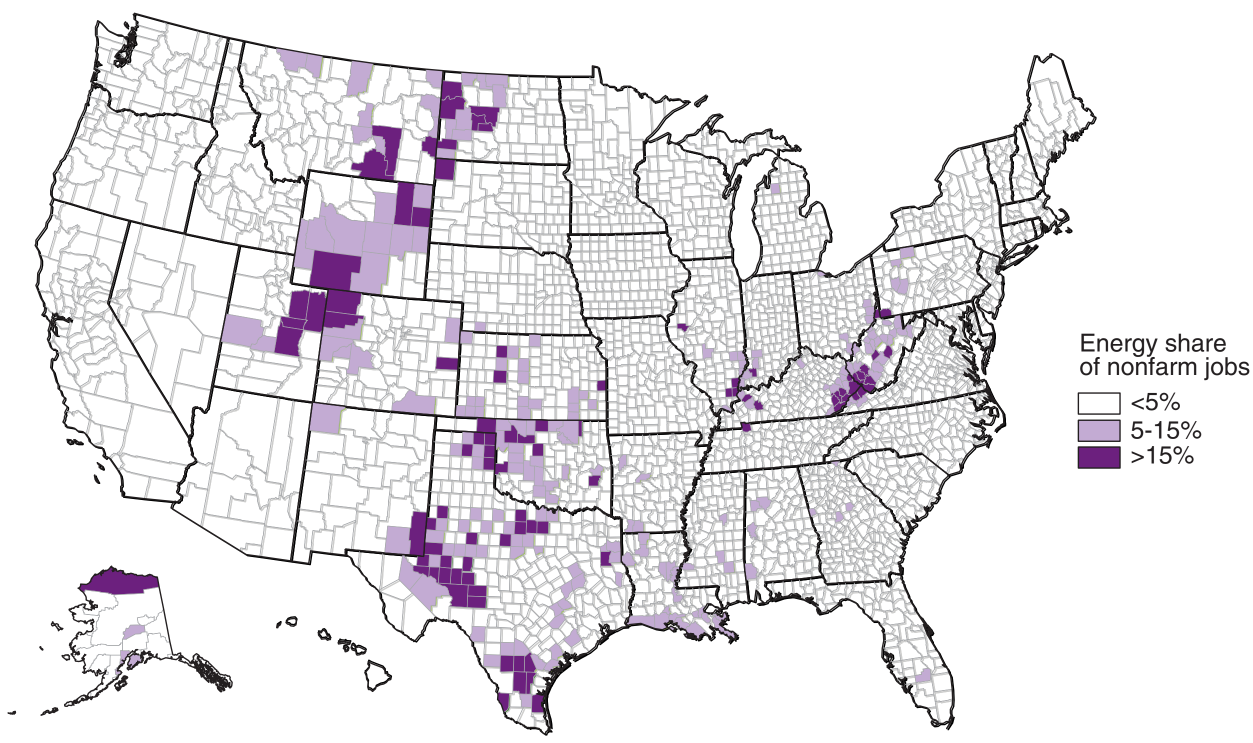
and electricity and natural gas utilities. The number of States containing nonmetro counties deriving 5 percent or more of nonfarm employment from the energy sector overall increases somewhat, but the real jump is in the number of counties identified as highly dependent counties (over 15 percent of nonfarm employment from energy sector jobs). This is mainly because large electricity generation plants often locate in coal counties (much less often in oil and natural gas counties).

Characteristics of Counties Specialized in Coal and Crude Oil/Natural Gas Extraction

Having identified those counties likely to be most affected by reductions in conventional energy production, the follow-on issue is the ability of these counties to adjust to job loss. Coal-mining counties in Appalachia characterized by high volatility in the local economy along with a strong attachment to place by lifelong residents are of special concern, because the implied low-elasticity of migration with respect to unemployment suggests that the response to permanent job loss may be slow, particularly if the job losses are perceived as cyclical.

Only 57.6 percent of residents age 22 to 59 in Southern coal counties were employed in 2005-09 (table 6.4), an employment rate 15 percentage points lower than the national nonmetro average. These same counties also have very low high school completion rates, with over 22 percent of those age 25 to 64 lacking a high school diploma. The low employment rate and educa-

Figure 6.4
Counties with significant employment in energy sectors, 2006



Source: ERS, based on Bureau of Labor Statistics QCEW (Quarterly Census of Employment and Wages) data files and Bureau of the Census County Business Patterns data files. Statistics for some counties are estimates as exact employment numbers are suppressed to maintain confidentiality.

Table 6.4.

Nonmetropolitan county average 2005-09 statistics reflecting economic vulnerability: energy extraction counties

States with energy extraction counties	No High School diploma, ages 25-64	Employed, ages 22-59	Poverty rate	Number of counties
	-------------------Percent-------------------			
South				
Oil extraction counties*	21.9	69.4	18.7	75
Coal extraction counties*	22.6	57.6	23.3	30
Other counties	19.2	68.4	19.6	527
Non-South				
Oil extraction counties*	10.1	79.1	12.1	43
Coal extraction counties*	9.1	76.7	14.3	15
Other counties	10.6	77.3	14.3	436
Other States	13.7	73.1	16.0	922
Total	14.8	72.6	16.7	2,048

*Extraction jobs at least 5 percent of nonfarm jobs, 2006.
Sources: American Community Survey data files, 2005-2009 averages

tional achievement of the population helps explain chronically high poverty rates. Adjustment to permanent job loss in the coal industry in these counties is likely to be protracted.

Counties dependent on crude oil and natural gas extraction in the South, mainly in Texas and Oklahoma, do not appear to be as hindered as the coal counties by structural impediments. Higher high school completion rates and much higher employment rates than in Southern coal counties suggest these local economies may be more resilient to permanent job loss in the energy sector. Non-South counties dependent on coal or crude oil/natural gas extraction should be even more resilient based on very high employment rates, very high rates of high school completion, and poverty rates substantially lower than the national nonmetro average.

Geographic Concentration of Energy-Intensive Industries

Industries in the economy with production particularly dependent on energy are also vulnerable to an increase in energy prices. We consider an industry to be energy intensive if expenditures on energy are greater than 5 percent of total sales.[12] The energy-intensive manufacturing industries are found predominantly in Chemicals (325), Nonmetallic Mineral Product Manufacturing (327), Primary Metal Manufacturing (331), Metal Ore Mining (2122), and Nonmetallic Mineral Mining (2123).[13]

Nonmetro areas contain a higher share (8.19 percent) of counties with 5 percent or more of their employment in energy-intensive industries (table 6.5), but this is not substantially higher than the metro share (6.97 percent). Moreover, the highest share of counties meeting this threshold is found in nonmetro areas adjacent to a metro county (10.7 percent), suggesting that these energy-intensive industries overall do not tend to concentrate in remote locations.

[12]The U.S. Environmental Protection Agency has a list of industries and measures of energy intensity and trade intensity on its website. This list was used to identify industries with an energy intensity greater than 5 percent. This energy-intensive definition is similar to, but less restrictive than, the definition of an energy-intensive, trade-exposed industry in H.R. 2454.

[13] The NAICS (North American Industry Classification System) code for each industry is shown in parentheses.

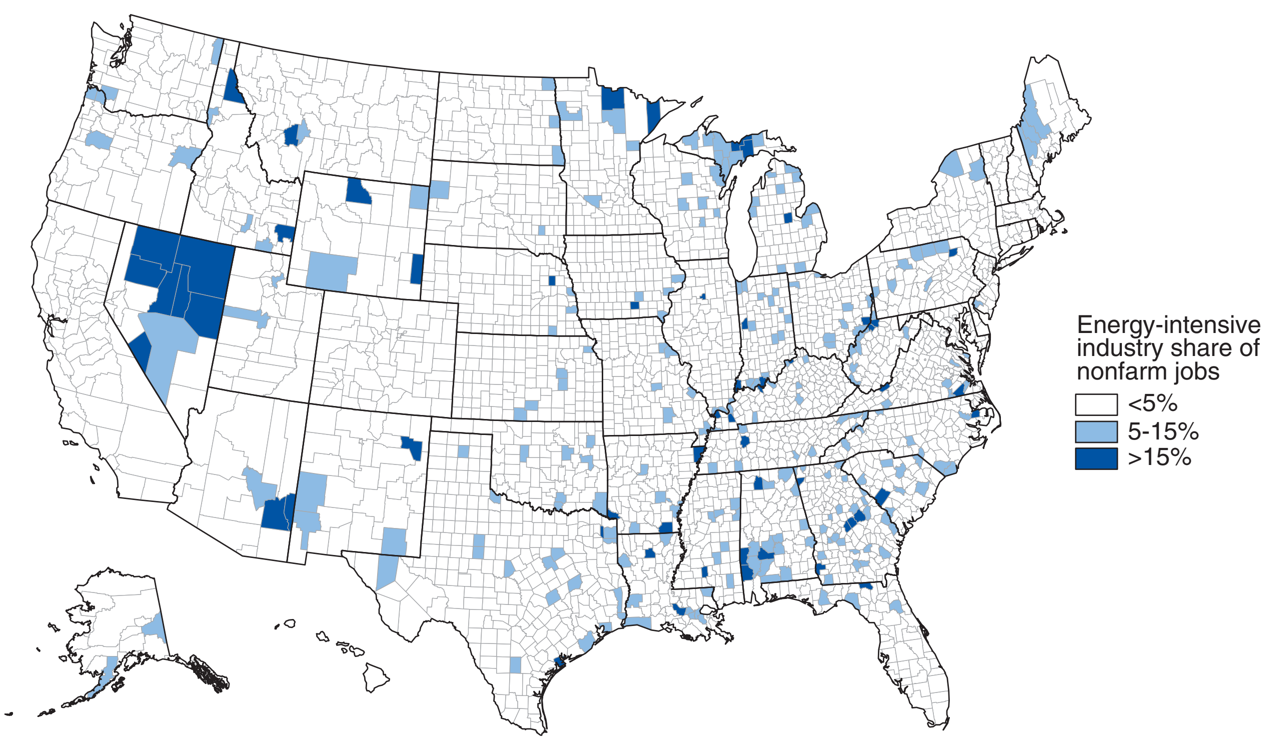
Mining operations in Mountain West States such as Nevada, Wyoming, Montana, and Arizona (fig. 6.5) tend to locate in more remote areas and, in the case of Nevada, are highly clustered. Other notable clusters that are manufacturing based include the groups of counties in southwestern Alabama, western Maine, and the northern tier of Pennsylvania. Overall, energy-intensive industries are distributed much more evenly than either coal or oil/gas extraction.

Table 6.5
Distribution of counties by employment in energy-intensive industries, by county type, 2006

County type	No energy-intensive employment	Energy-intensive employment		
		< 5%	5 to 15%	> 15%
Metropolitan counties (number)	131	883	65	11
Share of metro counties (percent)	(12.02)	(81.01)	(5.96)	(1.01)
Nonmetro counties (number)	619	1,263	137	31
Share of nonmetro counties (percent)	(30.20)	(61.61)	(6.68)	(1.51)
Counties adjacent to metro (number)	228	719	97	17
Share of subcategory (percent)	(21.49)	(67.77)	(9.14)	(1.60)
Counties nonadjacent to metro (number)	391	544	40	14
Share of subcategory (percent)	(39.53)	(55.01)	(4.04)	(1.42)

Source: ERS, based on Bureau of Labor Statistics QCEW (Quarterly Census of Employment and Wages) data files and Census Bureau County Business Patterns.

Figure 6.5
Counties with significant employment in energy intensive industries, 2008



Source: ERS, based on Bureau of Labor Statistics QCEW (Quarterly Census of Employment and Wages) data files and Bureau of the Census County Business Patterns data files. Statistics for some counties are estimates as exact employment numbers are suppressed to maintain confidentiality.

Chapter 7

Conclusions

Energy inputs are important to agriculture, with direct and indirect energy-related expenses representing an average of more than 13 percent of total farm production expenses in 2005-08. To illustrate the role of energy in the agricultural sector, we analyze impacts and adjustments of higher energy prices that other studies suggest would result from the pricing of greenhouse gas emissions, a potential result of climate change policy.

Such a policy could be implemented through a tax on emissions or through a regulatory cap on emissions as part of a nationwide cap-and-trade system. The pricing of emissions would lead to higher energy prices economywide and would result in adjustments throughout the agricultural sector to direct and indirect energy-related increases in costs of production.

In the crops sector, overall planted acreage would decline as higher energy costs lower producer net returns. Additionally, the mix of crops produced would adjust to relative changes in net returns—while plantings of most crops would fall, acreage planted to soybeans rose in our results as their production costs are less affected by higher energy costs than most other crops. As a consequence of these acreage and production changes, prices for most crops would increase, the exceptions being prices for soybeans and soybean products.

With higher corn prices and only moderately lower soybean meal prices, feed costs in the livestock sector would rise in addition to increases in energy-related production costs for livestock. As a result, livestock production would fall and prices would increase. Although impacts in our scenarios are not large, pork and beef are affected more than poultry, mostly due to relative shares of corn and soybean meal in typical feed rations.

While these adjustments in agricultural commodity markets raise cash receipts, increases in production expenses are greater, leading to overall reductions in net farm income.

Effects are not distributed equally across all sectors within agriculture or across all regions of the country. Relative impacts reflect the importance of energy inputs in production costs of different commodities, the relative importance of different commodities in different regions, and other market characteristics. Nonetheless, farm sector impacts were modest for the scenarios examined.

Retail food prices also increase in response to higher energy prices, by less than 1 percent in the scenarios analyzed. Not only are farm commodity prices higher, but energy-related processing, distribution, and marketing costs are higher throughout the food marketing chain from the farmgate through wholesale and retail levels. Most of the retail food price impact is from the effect of higher energy prices in the food marketing system rather than from agricultural commodity price impacts.

Agricultural sector impacts of the higher energy prices in the scenarios studied in this report are not likely to have large effects overall on farm county economies and populations because their education and employment levels are generally high compared with other nonmetro counties. Some counties in the Mississippi Portal region, where estimated energy-related farm income losses are largest, would likely be relatively more affected.

Few nonmetro counties derive a substantial share of nonfarm employment from energy production, so rural impacts from energy production adjustments due to emissions pricing would be small. Nonetheless, employment impacts will be larger in nonmetro counties mainly because counties that specialize in energy production are overwhelmingly rural and some counties would be particularly affected. Coal mining counties in eastern Kentucky and West Virginia may have particular difficulty adjusting to significant job loss because of lower education and economywide employment levels in these areas.

Longer run increases in energy prices would lead to further adjustments in the agricultural sector. Importantly, the development and adoption of new technologies would facilitate changes in production practices and energy use in agriculture, potentially mitigating economic impacts of higher energy prices. Agricultural production practices would be modified to improve energy-use efficiency. Energy use per unit of output in the agricultural sector would be likely to continue its decades-long decline, also reducing energy price impacts.

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Appendix A

Greenhouse Gas Pricing Mechanisms

Two primary mechanisms can be used that would result in the introduction of prices for greenhouse gas emissions. First, a system of taxes on emissions could be used, which would be directly added to the prices of associated fossil fuels. Second, an emissions cap-and-trade system could be implemented, where quantity limits on emissions are established and costs for the required emission permits would indirectly add to prices of fossil fuels. While in many ways these two alternatives are similar in their effects on energy markets, there are also significant differences between them administratively, operationally, and analytically.

Pricing of Emissions Through Taxes

A system of taxes on greenhouse gas emissions would affect prices for fossil fuels. This approach can be illustrated in the accompanying figures. Figure A.1 starts with a simplified depiction of the U.S. energy market, as an aggregate, with no system for pricing greenhouse gas emissions. The market equilibrium is determined by the intersection of the supply curve (S) and the demand curve (D) and is at point e. The equilibrium energy quantity is q_e with p_e the equilibrium price.

Figure A.2 adds a tax on greenhouse gas emissions. The amount of the tax would be equal to the vertical shift in the supply curve, the distance from point e to point a. The new equilibrium would be at point e’ with a price of $p_{e'}$ and an equilibrium quantity of $q_{e'}$. Note that the increase in the equilibrium price ($p_{e'}$ - p_e) is less than the amount of the tax.

The situation depicted in figure A.2 is for the aggregate market for energy, but implications would vary among different fuels. For individual fuel markets, the upward shift of the supply curve would reflect the tax rate set for

Figure A.1
U.S. energy market, no emissions pricing

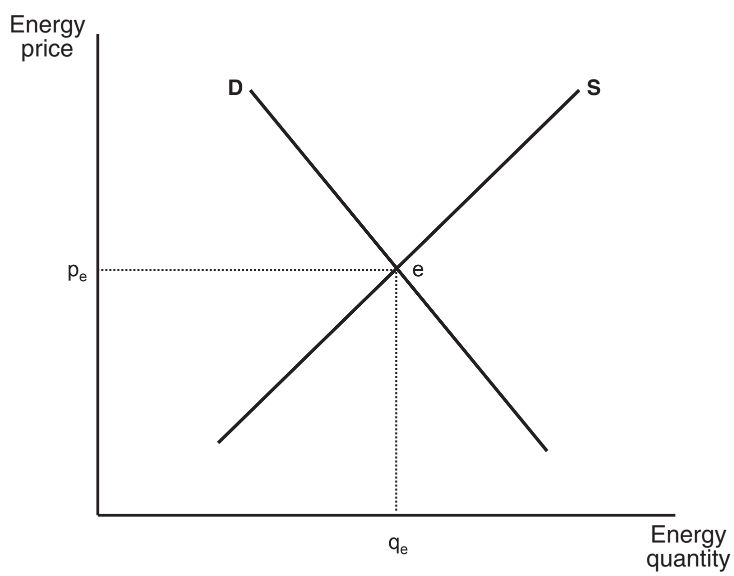
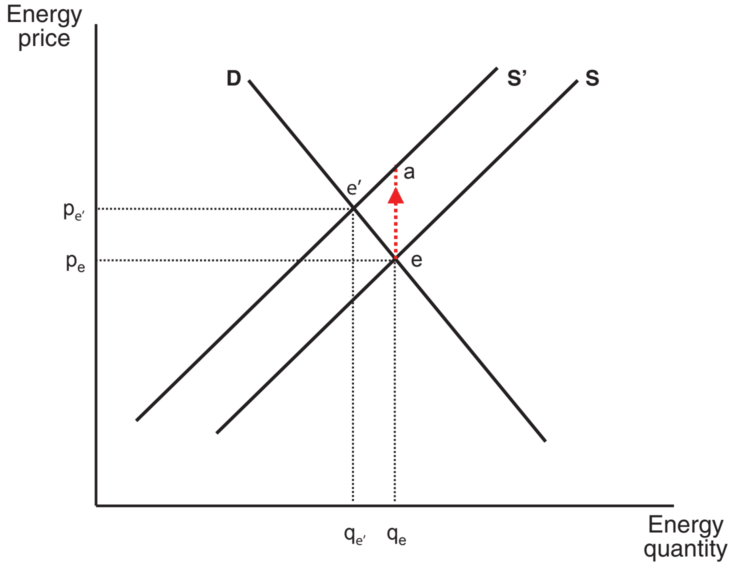


Figure A.2
U.S. energy market with emissions tax



emissions as well as the amount of emissions associated with each specific energy source. For fuels with higher emissions, this vertical shift would be greater. If demands across the different fuels are similar, the greater shift in the supply curve for larger emitting fuels would imply larger reductions in equilibrium quantities for those fuels. However, at least theoretically, this might not occur if, for example, demand for the fuel with higher greenhouse gas emissions was significantly more inelastic (less price responsive, or steeper).

Emissions Pricing Through a Cap-and-Trade System

A cap-and-trade system puts a cap on greenhouse gas emissions and allows trading of emission permits among different fuels. For example, a cap may reduce emissions by some specified amount (say 10 percent) from a base level. Trading of permits may result in more than a 10-percent reduction in emissions from one energy source and less than 10 percent from another source.

The requirement for holding emission permits associated with an emissions cap can be placed at various stages in the production processes within an economy, ranging from the original energy source to the industries that use energy. Here, it is assumed that the emission permits are held at the original energy source.

Analytically, it is also useful to look at the parts of a cap-and-trade system separately, first the cap component and then the permit trading aspects. As with the emissions tax framework, the aggregate energy market is discussed first.

Framework for a Cap Under a Cap-and-Trade System

For a particular technology, emissions are related to production. Thus, a cap on emissions places a constraint on production of energy proportional to the required emissions reduction.

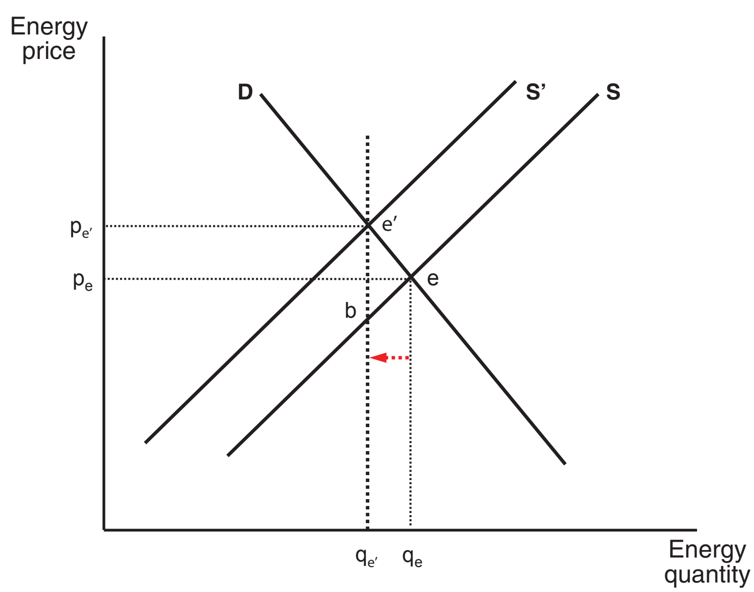
This mechanism is depicted in figure A.3. Starting with the same initial supply and demand framework shown in figure A.1, the reduction in output corresponding to the emissions cap is shown in figure A.3 by moving along the supply curve from point e to point b, lowering permitted production to the level needed to achieve the specified emissions reduction.

At point b, the market is not in equilibrium since the price at point b on the supply curve is below the price on the demand curve at this quantity. However, under a cap-and-trade system, suppliers must hold permits for emissions and would be willing to pay as much as the initial price gap for those permits. This cost for the emission permits is represented by raising the supply curve to S', resulting in a new equilibrium point at e'. The equilibrium quantity ($q_{e'}$) is the energy use level associated with the required emissions reduction (the cap), and the new equilibrium price is $p_{e'}$.

Energy Market Differences Between an Emissions Tax and an Emissions Cap

At this stage of developing the analytical framework, an emissions tax and an emissions cap (as part of a cap-and-trade system) appear to be analytically identical or closely similar, despite the operational differences in the underlying policy mechanism. However, there are differences between the two systems beyond the operational and administrative aspects of the approaches because the tax works through the pricing of emissions while the cap operates by setting the permitted quantity of emissions.

Figure A.3
U.S. energy market with emissions cap



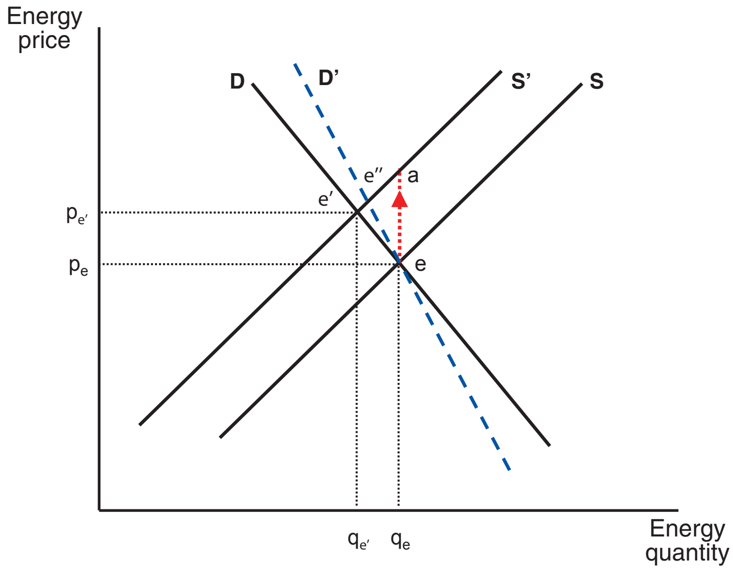
We now discuss implications of these differences and illustrate them by building on the analytical frameworks of figures A.2 and A.3. Both an emissions tax and an emissions cap result in the pricing of greenhouse gas emissions, either through the tax or the cost of emission permits under the cap. In both cases, the emission pricing system raises the price of energy from fossil fuels and reduces the overall use of energy.

However, important differences result from the different mechanism used in each approach. A tax specifies the price of emissions, but the equilibrium quantity (and the associated emissions reduction) is unknown in advance and will be determined in the marketplace. In contrast, a cap-and-trade system specifies the emissions reduction (and implicitly associated equilibrium quantity), but the equilibrium emissions price is unknown in advance.

This difference can be illustrated by augmenting the analytical frameworks of figures A.2 and A.3 with an alternative demand curve. For the emissions tax, figure A.4 adds a more inelastic (less price responsive, or steeper) demand curve, D'. While the vertical shift of the supply function associated with the specified tax remains the same, the new, more inelastic demand function intersects the shifted supply function at a new equilibrium point, e''. At this new equilibrium, the tax is the same, but the price and quantity are higher than at point e'. This implies that while the tax rate can be specified, the corresponding decrease in quantity and the associated reduction in emissions is not known ahead of time and will be determined in the marketplace, depending critically on the properties of the demand and supply functions.

In contrast, Figure A.5 adds a more inelastic demand curve to the initial framework figure A.3 for cap and trade. As before, the point b on the supply curve (S) that reflects the implementation of the cap is not in equilibrium. With more inelastic demand, the price gap from point b to the new demand function is larger. Under a cap-and-trade system, suppliers would now be willing to pay more for the required emissions. As represented in figure A.6,

Figure A.4
U.S. energy market with emissions tax, alternative demand



this higher cost for permits is represented by an additional upward shift of the supply function to S'', resulting in a new equilibrium point at e''.

In contrast with the emissions tax case, here the equilibrium quantity is unchanged with the alternative demand, and the associated level of emissions remains at the cap. Only the price for emissions permits and the associated equilibrium price for energy change.

Figure A.5
U.S. energy market with emissions cap, alternative demand

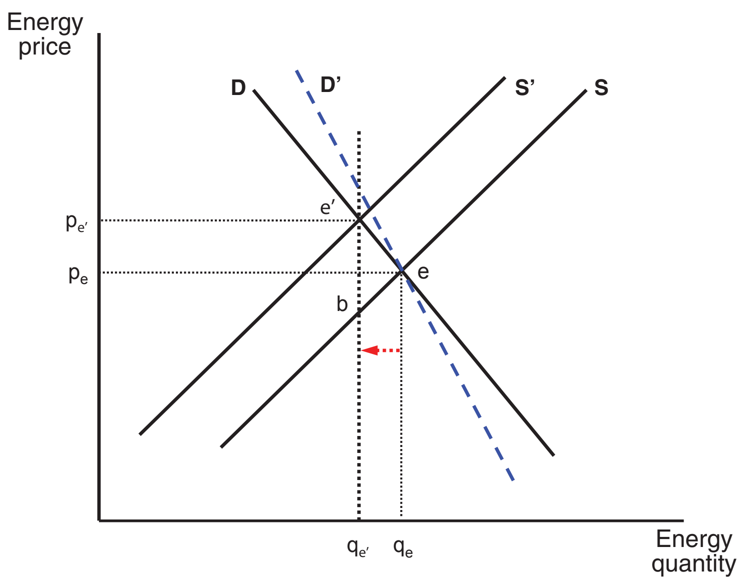
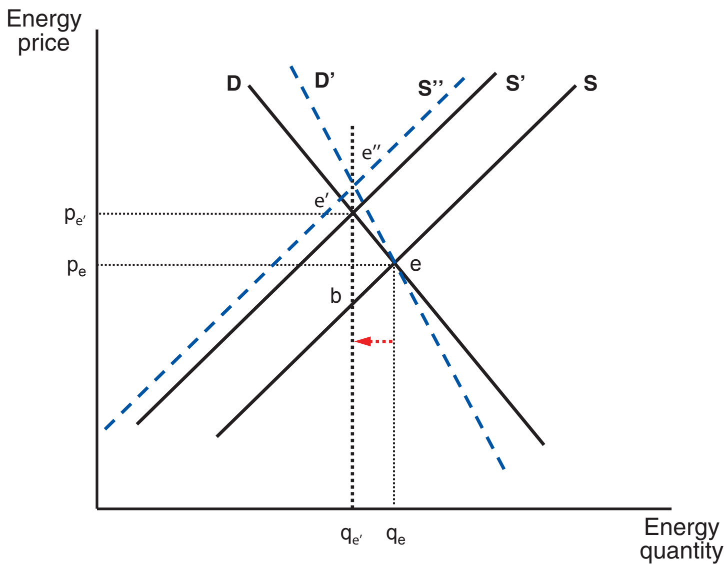


Figure A.6
U.S. energy market with emissions cap, alternative demand and resulting supply shift



Adding Emissions Permit Trading to the Cap-and-Trade System

To add trading of emissions permits to the analytical framework of figure A.3, the aggregate energy sector is disaggregated into two (or more) energy sources, as depicted in figures A.7 and A.8. In each figure, q_b represents the reduced level of energy output corresponding to the emissions cap, if each sector had the same percentage reduction in output.

However, an emissions cap does not affect all energy sources equally since each fuel has different carbon emissions per unit of energy. Consequently, the number of permits needed and associated costs vary across energy sources to reflect their different emissions. Thus, for a relatively high-emissions energy source, more permits would be needed, raising the supply curve more than for a low-emissions energy source.

Thus, two cases can occur. The first situation, represented in figure A.7, is when the cost of permits at the output level of q_b raises the supply curve above the demand curve at that output level. This means the costs of the permits raises the supply price above what the market demand will pay. This is depicted by the permit cost, d - b, being larger than the increase in the market demand value of the energy source at a quantity of q_b, c – b. At this output level, the demand price of p_c is less than the price, p_d, that suppliers would need to cover their added cost of permits. In this situation, production would be lowered, moving downward along the supply curve, S', from point d to the intersection of the demand curve at point e'. At this point, the increase in the market value for the quantity $q_{e'}$ of the energy source matches the cost of the emission permits, so the market is in equilibrium, with a market clearing price of $p_{e'}$. This reduction in output, shown as moving along the supply curve from point d to point e', is facilitated by the trading of emis-

Figure A.7
U.S. energy market with cap and trade, two energy sources: market for higher emissions energy source

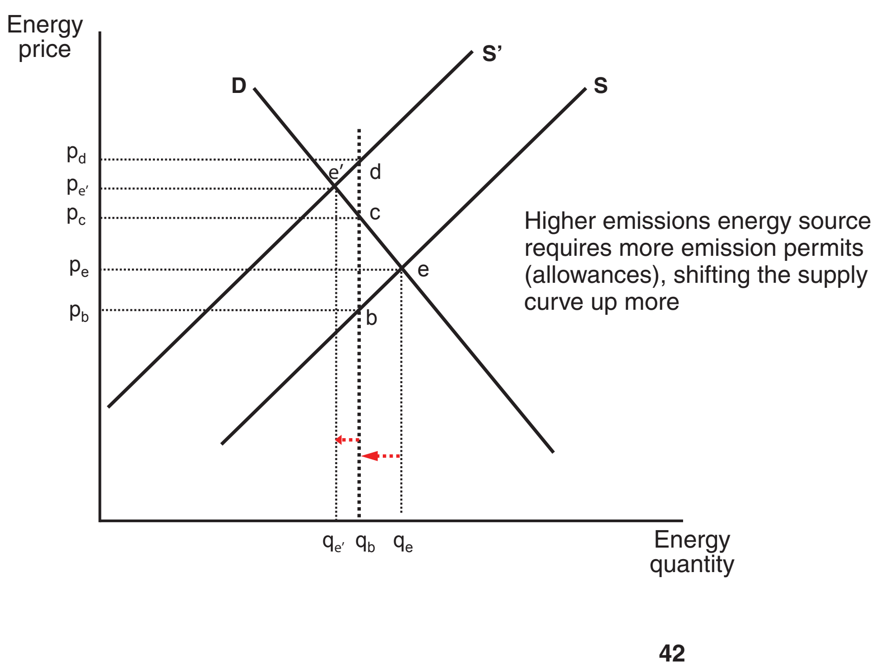
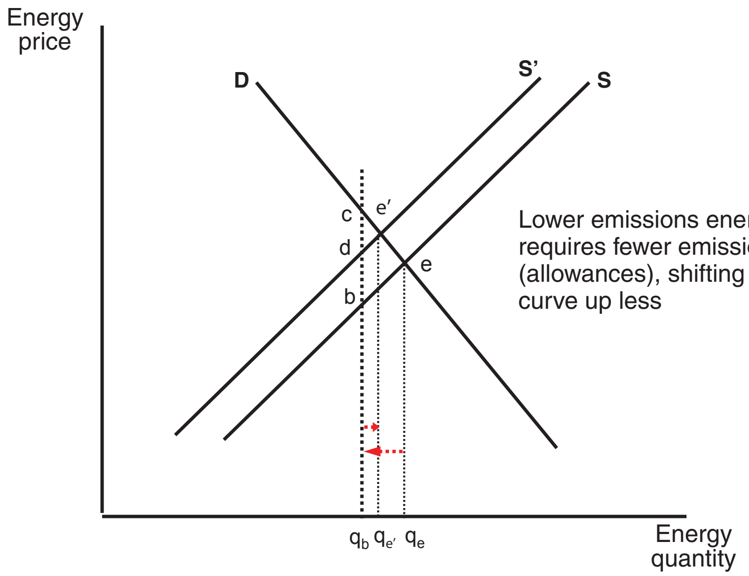


Figure A.8

U.S. energy market with cap and trade, two energy sources: market for lower emissions energy source



sion permits. Permits held by these suppliers are either sold to other markets or fewer permits are initially acquired.

For the second situation, shown in figure A.8, the cost of permits at the output level of q_b does not increase the supply curve as high as the demand curve. This is again depicted by comparing the permit cost, d - b, with the increase in the market demand value of the energy source at q_b, c - b. Now the former is less than the latter. In this situation, production would increase by moving upward along the S' supply curve from point d to the intersection of the demand curve at point e'. The market is in equilibrium at this point since the increase in the market value of the quantity $q_{e'}$ of the energy source equals the cost of the emission permits. This change in output from point d to point e' is again facilitated by the trading of emission permits, with additional permits bought by these suppliers.

The different situations under a cap-and-trade system as depicted here illustrate the economic incentives for greater reductions in use of higher emission energy sources and smaller reductions for the lower emission energy sources compared with the overall reduction in emissions set by the cap. While this would tend to be the case, price impacts also depend on the underlying supply and demand elasticities, so other situations can occur.

Appendix B

From Greenhouse Gas Emission Prices to Energy Prices

The relationship between a price for greenhouse gas emissions and prices of fossil fuels depends on the carbon content of the fuel. Prices for emissions are typically reported in prices per metric ton of carbon dioxide (CO_2), or carbon dioxide equivalent (CO_2-eq) for other greenhouse gases. The impact of a CO_2 price on the price of a fuel is additive:

(B1) $$P^1_{fuel} = P^0_{fuel} + P_{CO_2} \times k_{fuel}$$ where

P^0_{fuel} is the original fuel price;

P^1_{fuel} is the fuel price adjusted for a price on carbon dioxide;

P_{CO_2} is the emissions price in units of U.S. dollars per metric ton of carbon dioxide; and

k_{fuel} is the carbon emissions factor, which varies by fuel.

Carbon emissions factors for different fuels are available from the U.S. Energy Information Administration (EIA) website as a spreadsheet. Emissions factors are in units of million metric tons of CO_2 per quadrillion Btu, or Mt-CO_2 per quadrillion Btu. This unit is the same as kilograms CO_2 per million Btu (kg-CO_2 per MBtu).

For converting Btu to units consumers are more familiar with, the following *thermal* conversion factors are needed:[1]

Crude oil:	MBtu per barrel (bbl)
Natural gas:	Btu per cubic foot
Coal:	MBtu per short ton
Electricity:	Btu per kWh (heat rate).

A useful *physical conversion factor* is:

1 barrel = 42 U.S. gallons (exactly).[2]

Next, we provide sample calculations for motor gasoline, fuel oil, natural gas, and electricity. The change in electricity price depends on the generating technology and fuel. This methodology can be applied to any given CO_2 price.

[1] Thermal conversion factors are found in Appendix A of *Annual Energy Review 2007*, available on the U.S. Energy Information Administration website.

[2] This and other physical conversion factors are found in Appendix B of the *Annual Energy Review 2007*, available on the U.S. Energy Information Administration website.

Sample Calculation for Motor Gasoline (Gallons)

Assume the price of motor gasoline is measured as dollars per U.S. gallon. We can calculate the additive portion due to a CO_2 price as:

$$P_{CO_2} \times k_{fuel} \quad .$$

This seems simple, but we need to convert the carbon emissions factor for motor gasoline into units of metric tons CO_2 per U.S. gallon. Conventional motor gasoline has a carbon emissions factor of 70.88 kg-CO_2 per MBtu, and a thermal conversion factor of 5.253 MBtu per bbl.

(B2) $$k_{fuel} = \frac{t}{1,000\ kg} \times \frac{70.88\ kgCO_2}{MBtu} \times \frac{5.253\ MBtu}{bbl} \times \frac{bbl}{42\ gallons} = 0.00887 \frac{tCO_2}{gallon}$$

A price of $100 per t-$CO_2$, translates to an additional 88.7 cents per gallon of motor gasoline.

Distillate Fuel Oil (Gallons)

Distillate fuel oil, which includes diesel fuel, has a carbon emissions factor of 73.15 kg-CO_2 per MBtu, and a thermal conversion factor of 5.825 MBtu per bbl.

(B3) $$k_{fuel} = \frac{t}{1,000kg} \times \frac{73.15kgCO_2}{MBtu} \times \frac{5.825MBtu}{bbl} \times \frac{bbl}{42gallons} = 0.01015 \frac{tCO_2}{gallon}$$

A price of $100 per t-$CO_2$ translates to an additional $1.02 per gallon of distillate fuel oil.

Natural Gas (1,000 Cubic Feet)

(B4) $$k_{fuel} = \frac{t}{1,000\ kg} \times \frac{53.06\ kgCO_2}{MBtu} \times \frac{1,028\ Btu}{cu.ft.} \times \frac{MBtu}{(10)^6\ Btu} = 0.05455 \frac{tCO_2}{(10)^3 cu.ft.}$$

A price of $100 per t-$CO_2$ translates to an additional $5.46 per 1,000 cubic feet of natural gas.

Electricity Generated from Coal, Steam Turbine (Megawatt-Hours)[3]

(B5) $$k_{fuel} = \frac{t}{(10)^6 g} \times \frac{973\ gCO_2}{kWh} \times \frac{(10)^3 kWh}{MWh} = 0.973 \frac{tCO_2}{MWh}$$

A price of $100 per t-$CO_2$ translates to an additional $97.30 per megawatt-hour, or 9.7 cents per kilowatt-hour, for electricity generated from coal.

[3] Source: IPCC, 2007c. "Energy Supply," in *Climate Change 2007: Mitigation of Climate Change. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, p. 295.

Appendix C

Energy Price Impacts on Retail Food Prices

In this analysis, we investigate the effect of predicted changes in energy prices working through the food marketing system to retail food prices. These projected impacts are conditional on a number of modeling and marketing system assumptions and are based on the estimation of historical energy pass-through rates between food processing stages. A brief description of the analysis process, the data considered, and detailed results follow.

To model the historical pass-through relationship for energy, we generally used an Error Correction Model that is inclusive of any co-integrating relationships between food prices within the data. Variations of this setup have been used widely in examining pass-through relationships among agricultural production levels of particular commodities.[1] The model employed in this analysis follows a basic two-stage setup as originally proposed by Engle and Granger (1987) in which the long term or co-integrating relationship is first estimated:

[1]See, for example, Meyer and von Cramon-Taubadel (2004) for a survey of studies using Error Correction Models.

(C1) $$P_{O,t} = \beta_0 + \beta_1 P_{I,t} + u_t \; .$$

then the complete Error Correction Model is estimated, incorporating the residuals of equation C1:

(C2) $$\Delta P_{O,t} = \phi_0 + \sum_{i=1}^{Q} \phi_{1,i} \Delta P_{O,t-i} + \sum_{i=1}^{R} \phi_{2,i} \Delta P_{I,t-i} + \gamma u_{t-1} + \nu_t$$

The variables $P_{O,t}$ and $P_{I,t}$ in the above equations represent the output and input price levels, respectively. If the necessary conditions are not met for such a relationship (the individual series are not integrated of order 1 or the test for co-integration fails at 10 percent) then a basic Autoregressive Distributed Lag (ARDL) Model is used to estimate the pass-through relationship. In equations C1 and C2, the output price is considered to be the downstream food price series and the input price is the upstream food price series. Energy price changes are considered only as short-term variables in equation C2 due to the unlikelihood of a direct and consistent long-term relationship with the dependent variable.

The data used for the pass-through estimation were non-seasonally adjusted, monthly Bureau of Labor Statistics CPI and Producer Price Index (PPI) data. All price series were converted to their natural logs before use. The time period considered in this part of the analysis was 1983 to 2009, which was the longest time period available with consistent data. Aggregate price measures were used to represent commodity, processed, and retail food prices, while energy prices for electric power, diesel fuel, and natural gas were represented by their respective wholesale price series. Models including variables for energy price changes were estimated for the farm-to-wholesale, wholesale-to-FAH (food at home), and wholesale-to-FAFH (food away from home) marketing stages.[2] To derive retail price implications of the farm-to-wholesale energy pass-through, results from those models were multiplied by the estimated pass-through relationships of wholesale food prices to the two different retail price categories, FAH and FAFH.

[2] All of the energy types were used in each pass-through model except in the case of processed food to FAH, where the effect of a change in the price of natural gas was not considered.

Thus, the total estimated impacts of the predicted changes working through the food marketing chain to the FAH CPI and FAFH CPI can be described by the following equations:

(C3) $$E(\Delta CPI\_FAH_j) = \hat{e}_{FAH} \times (\hat{c}_j \times E(\Delta P_{I,j})) + (\hat{a}_{FAH,j} \times E(\Delta P_{I,j}))$$

(C4) $$E(\Delta CPI\_FAFH_j) = \hat{e}_{FAFH} \times (\hat{c}_j \times E(\Delta P_{I,j})) + (\hat{a}_{FAFH,j} \times E(\Delta P_{I,j}))$$

In the above equations, $E(\Delta CPI\_FAH_j)$ and $E(\Delta CPI\_FAFH_j)$ represent the estimated changes in the FAH CPI and FAFH CPI, respectively, from a change in energy input j; $\hat{e}$ represents the estimated historical pass-through relationship between processed food and retail food prices; $\hat{c}_j$ represents the estimated historical pass-through rate for energy input j at the farm-to-processed food stage; $\hat{a}_j$ represents the estimated pass-through rate for energy input j from processed food to retail food (separate estimates for food at home and food away from home); and $E(\Delta P_{I,j})$ represents a price change for energy input j.

Estimated pass-through rates for energy inputs are shown in table C1, with the following correspondence to parameters and terms in equations C3 and C4:

- Farm to processed foods, $\hat{c}_j$
- Farm to processed foods, passed through to FAH CPI, $\hat{c}_j$ x $\hat{e}_{FAH}$
- Farm to processed foods, passed through to FAFH CPI, $\hat{c}_j$ x $\hat{e}_{FAFH}$
- Processed foods to FAH CPI, $\hat{a}_{FAH,j}$
- Processed foods to FAFH CPI, $\hat{a}_{FAFH,j}$.

A number of assumptions should be noted with the predicted impacts on retail food prices. The pass-through models use variables that are thought to be analogous to the descriptions provided for the predicted energy price changes, and the model setup focuses only on direct connections between the price series. The pass-through relationships in the future are assumed to be consistent with what was found using historical data, and the estimated historical pass-through relationships are subject to the limitations inherent in using CPI and PPI data. Also, long-term substitutability in factor inputs has not been considered in the analysis.

Table C1

Estimated historical pass-through rates for energy inputs in the food marketing system

Production level	Electricity	Diesel fuel	Natural gas
		Percent	
Farm to processed foods	4.942	1.296	0.885
Passed through to FAH CPI	1.738	0.456	0.311
Passed through to FAFH CPI	0.466	0.122	0.084
Processed foods to FAH CPI	6.865	1.246	-
Processed foods to FAFH CPI	0.672	NA	0.186

Note: All pass-through rates were statistically significant at the 10% level except for the case of diesel fuel in the processed foods to FAH CPI production level.

The estimated historical energy pass-through rates from the models are presented in table C1. These rates are then applied to energy price changes from table 3.1 to obtain the energy-related impacts on the CPI for FAH and FAFH in the food marketing chain that are part of results shown in table 4.8. Impacts for total food are constructed with weights of 0.558 for food at home and 0.442 for food away from home.

The majority of the effect on retail food prices appears to be from the predicted increases in electricity prices in the FAH production chain. The large impact from electricity price changes is likely due to the high values of the predicted changes and the relatively high estimated pass-through rate. The high estimated pass-through rate for electricity price changes could indicate that this variable may be serving as a proxy for other macroeconomic variables as the trend of this series is observed to be very similar to that of the FAH and FAFH CPIs.