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Energy Demand and Capacity to Adjust in U.S. Agricultural Production

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Background

What are the drivers of energy demand in US agriculture and how responsive is the sector these drivers? Alternatively, we might think of responsiveness as the capacity to adjust to changing economic forces. The demand for refined petroleum products, natural gas, and electricity in farm production activities is a derived demand explained by the price of energy, the price of the crop, the prices of other inputs, acres planted and harvested, and the weather.

All prices are taken into account by the producer before making production decisions. The demands for energy, both direct and indirect, are largely a function of prices, crops grown, and acres planted and determined prior to the beginning of the production cycle. Throughout the growing season, adjustments may be made due to weather conditions, health problems, and pest problems. As real energy prices increase or decrease, the derived demand for energy in agriculture will decrease or increase. Higher energy prices will not only mean adjustments in production, but also higher production costs and decreased returns, at least in the short run. Real energy prices drive not only direct energy demands in agriculture, but also indirect energy demands embodied in fertilizers and pesticides.

What are the objectives of this paper on energy demand and capacity to adjust in the agricultural sector? First, establish a baseline for energy demand in agricultural production in the aggregate, by region, and by major type of crop and livestock farm. Second, evaluate the capacity of agricultural producers to adjust to real energy price changes and shocks as well as supply disruptions through input substitution and output adjustments. Fourth, assess how changing technology, improving energy efficiency, and growing agriculture productivity alter the capacity to adjust over time. Finally, discuss the potential roles of government to achieve food and energy security.

Aggregate direct and indirect farm energy demand

Different types of energy are demanded for different production activities on farms. Direct energy demand, including diesel fuel, gasoline, natural gas, and liquid petroleum (LP) gas, is used for planting, tillage, harvesting, drying, and transportation. Electricity is used for irrigation, operation of livestock facilities, dairy operations, and other stationary production activities. Indirect energy demand is derived from the demand for fertilizers and pesticides used on farms. As indicated in Figure 1, both direct and indirect farm energy consumed about 1.7 quadrillion British thermal units (Btu), or 1.7% of energy consumed in the U.S. in 2002 (Duffield, 2004). US farmers directly consume about one percent of US motor gasoline, six percent of diesel and distillate fuels, 2.3% of LP gas, 0.25% of natural gas, and about one percent of electricity annually.

Changes in direct and indirect energy use over time

From Figure 2, we see that energy use grew throughout the 1960s and 1970s and peaked at about 2.4 quadrillion Btu (quad) in 1978 (Duffield, 2004). In the late 1970s and 1980s, farmers responded to higher prices resulting from the oil crises of 1974, 1975, and 1979. They substituted relatively cheaper inputs for the relatively more costly energy inputs. Thus, farm production became more energy-efficient. Farm energy use declined throughout most of the 1980s, increased slightly in the early 1990s due to declining real energy prices, and returned to late 1980s levels during the last five years. Over time, farmers have substituted less fuel-efficient gasoline- for more fuel-efficient diesel-powered engines, adopted energy-conserving tillage practices, sized machines more appropriately to tasks, and adopted energy-saving methods for crop drying and irrigation. Energy-saving measures and productivity growth in agriculture have reduced on-farm direct energy use by 30% since 1978 and indirect on-farm energy use (i.e., fertilizer and pesticide use) by about 38% since 1980.

Chemical manufacturers use natural gas, electricity, fuel oil, and other fossil fuels to produce fertilizers and pesticides (See indirect energy use in Figure 3). Commercial fertilizers (nitrogen, phosphate, and potash) are the most energy-intensive farm inputs, accounting for 29% of total energy consumed in farm production in 2002 (Duffield, 2004). Fertilizer consumption by farmers increased throughout the 1960s and 1970s, and peaked at 23.7 million nutrient tons in 1981 (Economic Research Service, 2003). Since the mid-1980s, fertilizer use has remained relatively steady, ranging from 18 million tons in 1983 to 21 million tons in 2001 (H. Taylor, US Department of Agriculture, Economic Research Service, Washington, DC, 2001, personal communication; see also Taylor, 1994). After the mid-1980's, fertilizer prices increased relative to crop prices, and fewer acres were planted to fertilizer-intensive crops. The fertilizer industry also experienced major technological breakthroughs in the 1980s, reducing indirect energy use through more energy efficient nitrogen and phosphorous fertilizer production technologies (Bhat *et al.*, 1994). From 1979 to 1987, the energy consumed in producing nitrogen fertilizer declined about 11%, and the energy requirements for producing phosphorous fertilizer decreased 27%. Even though current fertilizer application rates are similar to the mid-1980s, the energy embodied in this fertilizer has declined significantly over the past 20 years (Fertilizer Institute, 2004; Shapouri *et al.*, 2002).

About 108 trillion Btu of petroleum and natural gas were required to produce, process, package, and distribute pesticides (including herbicides, insecticides, fungicides, and other pesticides) used on-farm in 2002 (Duffield, 2004). Pesticide use, especially herbicides, increased rapidly between 1960 and 1980 (Economic Research Service, 1994, 1997, 2003). Pesticide use decreased from about 1.05 billion pounds in 1980 to 846 million pounds in 1987. Although the pesticide use trend was reversed in the early 1990s, it has been stable at around 955 million pounds since 1996 (Duffield, 2004; Office of Prevention, Pesticides, and Toxic Substances, 1999). Like the fertilizer industry, the pesticide manufacturing process has become more energy-efficient over time (Bureau of the Census, 2004).

ARMS database and farm energy expenses

An important source of on-farm energy expenditure data is the Agriculture Resource Management Survey (ARMS), conducted by the US Department of Agriculture's National Agricultural Statistics Service (NASS). NASS collects farm-level expenditure data on farms classified by field crop, farm animal, fruit and nut, vegetable, and nursery and greenhouse farms. These data are not collected by crop or animal enterprise, but rather, for the whole farming operation. A farm is then classified as a particular farm type if over 50% of the value of production (not used on the farm) can be attributed to a particular crop or animal enterprise. For example, a farm with over half of the value of production from corn would be classified as a corn farm. On-farm direct-energy cash expense and total cash expense estimates based on the unpublished ARMS data were compiled and summarized for 2002, as well as direct- and indirect-energy expense estimates for the 10 farm production regions1. It is not possible to report ARMS estimates of fuel and electricity expenses per acre or per animal because they represent a composite of livestock and crop expenses for a type of farm as opposed to enterprise type. Thus, the ARMS energy expense estimates are reported on per dollar value of production and on share of total cash expenses for farm types.

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1 These estimates were compiled by Robert Dubman, US Department of Agriculture, Economic Research Service, from unpublished data from the annual ARMS survey conducted by US Department of Agriculture, National Agricultural Statistics Service. Estimates were prepared for 2002 energy expenditures by form of energy and by farm type. Although not compiled for this chapter, similar energy expenditure data are available for 1991 to the present.

Share of energy expenses in total cash farm expenses

In assessing agriculture's capacity to adjust to real energy price increases and supply disruptions, it is useful to evaluate energy cost shares in agricultural production. Our hypothesis is that the higher the expense shares of energy inputs in total cash production expenses, the more producers utilize energy intensive practices, and the less capacity they have to adjust to price and supply shocks. Direct and indirect energy expenditures are a significant share of farm expenses accounting for 12% (excluding electricity) of total farm production expenses in 2002 (NASS, 2004). On-farm fuel (gasoline, diesel, LP gas, and natural gas) expenses were 3.3% of total farm production expenditures. Expenditures on fertilizers, pesticides, and other indirect energy consumption accounted for 9.2% of total farm expenditures. Since farmers are dependent on direct and indirect energy inputs, energy prices can have a significant effect on farm expenses. For example, during the energy crises of the 1970s, energy price increases led energy's share of total farm production expenses to increase from 11.2% in 1972 to 15.9% in 1981 (Figure3). Direct energy costs increased from 3.3% of total farm production expenditures in 1972 to 6.1% in 1981. As fuel supplies stabilized, direct energy costs decreased to 3% to 4% of total farm production expenditures after 1985 and have remained in that range through 2002 (Duffield, 2004).

The farm costs of indirect energy increased significantly in the 1970s. The share of indirect energy in total farm production expenditures went from 8.0% in 1972 to 11.3% in 1975. The share of indirect energy expenditures decreased to 7.8% in 1983 and has been in the 9% to 11% range since. In 2002, the share of indirect energy expenses was 9.2% (Duffield, 2004).

In 2002, US farmers spent about $10.4 billion on direct energy use. Farmers spent about $7.0 billion on fuels, oils and lubricants and almost $3.4 billion on electricity (Table 1). Of the $7.0 billion spent of fuels, oils, and lubricants, crop farms spent $4.5 billion and livestock farms spent $2.5 billion. Crop farms spent almost $1.9 billion on electricity while livestock farms spent $1.4 billion. As illustrated in Table 1, farmers' expenses were highest for diesel fuel, followed by electricity and gasoline.

Share of direct energy expenses on crop farms

Fuel and electricity expenditures per unit of output and the share of fuel and electricity expenses in total cash expenses for crop farm types are reported in Figure 4. Peanut farms had the highest energy expenditure per dollar of output at $0.15 or 11.6% of cash expenses for fuel and electricity, rice farms were second at $0.149 per dollar of output or 12.8% of cash expenses, cotton farms were third at $0.11 per dollar of output or 9.5% of cash expenses, tobacco farms were fourth at $0.10 per dollar of output or 12.8% of cash expenses, followed by wheat farms at $0.092 per dollar of output or 9.3% of cash expenses, maize farms at $0.07 per dollar of output or 8.5% of cash expenses, and soybean farms at $0.073 per dollar of output or 7.4% of cash expenses. It is important to note that these estimates do not include indirect energy expenditures that would have changed the relative ranking of some crop farms, especially corn farms.

Share of direct energy expenses on animal farms

For livestock farm types reported in Figure 5, producers relied on electricity, natural and LP gas for heating and cooling poultry and swine facilities. Dairy farms relied heavily on electricity to power their milking, cooling, and handling equipment. Livestock farms accounted for $2.72 billion of fuel and lubricant and $1.59 billion of electricity expenditures, or 39% of total farm fuel purchases and 47% of electricity purchases (Table 1). In terms of cash expenses per unit of output and share of cash total expenses, beef operations were highest at $0.062 per dollar of output or 6.6% of cash expenses for fuel and electricity purchases, dairy farms were second with $0.047 per dollar of output or 5.5% of cash expenses, then poultry farms with $0.038 per dollar of output or 15.2% of cash expenses, and last were hog farms with $0.032 per dollar of output or 6.2% of total cash expenses.

Share of direct energy expenses on nursery, greenhouse, fruit/nut, and vegetable farms

In addition to fuels and lubricants, the greenhouse industry has significant natural gas and electricity expenses for climate control throughout the growing season. In 2002, fruit and tree nut farms expended

$208 million on fuels and lubricants, $218 million on electricity, and $0.042 per dollar of output on fuels and electricity (Table 1). Fuels and electricity accounted for 5.7% of their total cash expenses. Vegetable farms purchased $280 million of fuels and lubricants and $236 million of electricity, and $0.043 per dollar of output on fuels and electricity as indicated in Figure 6. Fuels and electricity accounted for 6.1% of total cash expenses. Fruit and nut farms, and vegetable farms spent the most on electricity followed by diesel fuel. Nursery and greenhouse producers spent $514 million on fuels and lubricants, $256 million on electricity, and $0.061 per dollar of output on fuels and electricity. These items accounted for 6.0% of cash expenses, with electricity and natural gas being the two key energy inputs. Energy is obviously a significant expense for specialty crop farms. Although nursery and greenhouse farms are more vulnerable to weather which increases their outlays for natural gas relative to fruit and vegetable farms, natural gas only accounts for about $0.01 per dollar of output.

Share of farm energy expenses by production regions

Individual state ARMS data were aggregated into 10 farm production regions by Dubman (2004). Expense share categories are reported for two forms of direct energy - fuel and lubricant expense share and electricity expense share, and indirect energy – fertilizer and pesticide expense, are reported in Table 2. In assessing agriculture's capacity to adjust to real energy price increases and supply disruptions, it is helpful to evaluate energy cost shares in agricultural production. Our hypothesis is that the higher the expense shares of energy inputs in total cash production expenses, the more dependent are farmers on energy intensive practices and the less capacity producers have to adjust to price and supply shocks. Above, we have assessed energy expense shares by "type" of farm. In addition to energy input use varying by farm type, we hypothesize that energy shares may vary by region. Some regions may be more energy dependent than others because farms produced outputs that use more energy, farms are more dependent on irrigation to produce crops, pest and nutrient problems require the use of more indirect energy, and/or animals may require more environmental management to achieve optimal production levels.

Based on the results reported in Table 2, expense shares for different energy forms exhibit unique regional patterns. For example, fuel expense shares were highest in the Delta (7.6%) and Southern Plains (7.4%) in 2002 and lowest in the Pacific (2.8%) and Northeast (3.8%). Electricity expense shares were highest in Pacific (5.3%) and Mountain States (5.2%) and lowest in the Corn Belt (2.2%) and Lake States (2.7%). Indirect energy (fertilizer and pesticide) expense shares were highest in the Delta States (19.1%) and Corn Belt (16.5%) in 2002 and lowest in the Northeast (6.8%) and Mountain States (8.0%). It is interesting and important to note that expense shares are not consistently high or low for different energy forms. For example, if one region had the highest energy expense share for all three energy forms in 2002, energy would have accounted for 1/3 of all cash expenses and imply a low capacity to adjust to energy price shocks and supply disruptions. Alternatively, if a region had the lowest energy expense share for all three energy forms in 2002, their energy expense share would have been less than 12% and we could infer a rather high capacity to adjust or respond to energy price increases and supply disruptions.

Regional expense share rankings do vary by year but the same regions ten to be ranked higher or lower over time. These results are sensitive to the mix of crops grown, climatic factors, and inherent fertility and pest problems. Also, we need to exercise caution in interpreting these results because particular farm types may be more vulnerable to energy price increases even though the region is not. It is interesting to compare these results with those reported in Table 1 disaggregated by farm type. In general, these results can be interpreted to indicate that there is adjustment capacity in production agriculture, especially when considering that indirect energy expense shares are overstated. Although significant in the production of most fertilizers and pesticides, other non-energy inputs are an important component.

Do producers respond to energy price increases?

In the short run, farmers have limited options to mitigate the effects of higher energy prices. Some producers may reduce field operations by switching from conventional to reduced tillage practices; by adjusting fertilizer application rates when nitrogen price exceeds the value of the marginal output; or by harvesting later and allowing crops to dry naturally in the field.

Over the long run, farmers have more flexibility and can utilize more energy efficient practices. This adjustment occurred following the real energy price increases of the mid 1970s and early 1980s. Currently, more advanced technologies and farming practices such as precision farming (e.g., yield monitoring, global positioning system, calibrated application of pesticides and fertilizers) are available and may be competitive and adopted in response to a higher real energy price era.

Although it is common to talk about higher nominal energy prices at the gasoline pump, producers and consumers react primarily to real energy prices (i.e., prices corrected for inflation). Nominal and real energy prices are reported in Figures 8-9 for all fuels, diesel, gasoline, natural gas, and electricity. Although nominal energy prices peaked in early 2000, real prices for major energy inputs peaked in the early 1980s. With the exception of natural gas, real energy prices are similar to real prices in 1970. When real energy prices are lower, producers and consumers have less incentive to conserve energy inputs in agriculture, industry, services, or consumption. Although there are a number of ways of achieving energy conservation, including moral suasion, posted energy efficiency ratings, EPA fleet mileage standards, and other voluntary and mandatory approaches, real market prices are the most effective inducement. Current real energy prices provide limited incentives to improve energy efficiency.

To approximate the energy demand responsiveness of farmers to higher real prices, we estimate the capacity to adjust or the own price elasticity of energy demand, and the capacity to substitute between energy and other relatively less expensive inputs, or the elasticity of substitution, and report these in Table 3. In the aggregate, these estimates indicate that a ten percent increase in real energy prices will result in a six percent decrease in energy use in agriculture, assuming all other prices are unchanged. The off-diagonal coefficients indicate that if energy prices are higher relative to other input prices, that all other inputs considered in the analysis will be substituted for the then relatively more expensive energy input. Further, to the extent indirect energy inputs embody more costly energy inputs, all other inputs will substitute for fertilizers and pesticides. Given sufficient planning time, we infer that there is a fair amount of capacity in agriculture to adjust to higher real energy prices. Non-energy inputs would be substituted for direct and indirect energy inputs without significant reductions in output.

In more intuitive terms, what does an increase in real energy prices mean for the typical corn-soybean producer? The early adoption of reduced tillage provides an intuitive illustration of the important role that real energy prices can have in agricultural production decisions. Because reduced- and no-till practices reduce soil loss, efforts were made to encourage adoption of the technology in the 1970s but were of limited success. The adoption of reduced- and no-till practices on major field crops, such as corn and soybeans, took off about 1980, largely in response to the significantly higher real and relative energy prices faced by farmers at that time (Miranowski, 1980). Using conventional-till required several (5-7) trips over the field, consumed a significant amount of energy, buried most of the plant residue, and left the soil prone to erosion. Reduced-tillage used less energy because it required less field preparation trips. Reduced-till and no-till adoption increased significantly into the 1990s.

What is happening to farm energy efficiency over time?

Energy use increased in production agriculture during the 1960s and 1970s, peaking at 2.4 quads in 1978. After 1978, total farm energy consumption declined 30% by 2002. Other input use decreased as well, but agricultural output increased 45%. As a result, total factor productivity grew at two percent annually (Figure 11). US agriculture became more energy-efficient. The sustained productivity growth in the agricultural sector combined with reductions in energy and other input use, led to significant improvements in energy efficiency. Real energy price increases from the mid 1970s through 1982 provided incentives for farmers to become more energy efficient. Producers switched from gasoline-powered to more fuel-efficient diesel-powered engines, adopted reduced tillage practices, matched power to equipment, shifted to more efficient machines, and adopted energy-saving methods of crop drying, irrigation, heating, and ventilation. As a result, farmers reduced direct energy use 30% and indirect energy use 38% from 1978 to 2002 (Figure 3). The combined effects of growing agricultural productivity and increasing fuel (and other input) efficiency was that energy use per unit of agricultural output decreased by 7% between 1978 and 2002 (Figure 12).

Information and biotechnology impacts on energy efficiency

Since 1990, revolutionary advances have been made in biotechnology and information. These advances are having dramatic impacts on agriculture as well as the rest of our economy. Important breakthroughs in plant and animal biotechnology are producing a wide range of new products, including pharmaceuticals and plants resistant to pests, diseases, and herbicides. Information advances are mapping plant and animal genomes, manipulating genetic materials, improving the efficiency of production and service systems, advancing precision agriculture, and reducing the cost of information to producers and consumers.

What are some of the implications for energy efficiency in plant production? First, by inserting genes in the plant to control plant pests, the need for pesticides, a major consumer of indirect energy, will be reduced in production agriculture. Second, herbicide-resistant plants will reduce the need for multiple herbicide treatments and will reduce overall herbicide use and save energy as well. Third, research is underway to improve nutrient utilization in plants and to allow the plant itself to fix nitrogen in the soil, reducing commercial fertilizer and indirect energy consumption. Fourth, GPS, yield and soil monitors, and geographic information system (GIS) data are key components of precision farming systems. Such systems have the potential to more efficiently use nutrients and control pests and ultimately save on both direct and indirect energy needs in crop production.

Likewise, animal agriculture is making important breakthroughs that improve productivity and reduce energy needs. For example, if fewer cows can produce the same amount of milk using *rbST*, then energy is saved in dairy production. Further, the information revolution has transitioned meat animal production from an era of “attentive” husbandry to an era of “knowledge” or “informed” husbandry. Computers are now used to monitor health condition of hogs in finishing facilities based on feed and water consumption, providing a preventive approach to animal health care and reduced overall energy demand.

Opportunities to integrate farm energy use and farm energy production

Higher real energy prices, desire to reduce U.S. dependence on imported oil, and concern about rural energy security may provide incentives for agriculture to move toward integrated farming systems that supply at least part of their own energy. Crops, crop residue, forest residue, and energy crops planted on idle or marginal cropland can serve as feedstocks for ethanol, biodiesel, and methane production. Ethanol from grains accounts for most of US biofuel production. In 2002, close to two billion gallons of ethanol were produced in the US and production capacity is rapidly expanding. Yet, the US has been slow to integrate farm systems that consume energy based on farm produced feedstocks. Smaller-scale facilities, such as ethanol plants, lack scale economies realized by commercial plants in the 100- to 200-million gallon annual capacity range.

Wind energy and methane have more potential for on-farm production and consumption. Wind energy has significant potential in farming regions with appropriate wind conditions and farming systems dependent on stationary sources of power such as electricity, e.g., dairy operations. Commercial wind technology is rapidly advancing and becoming competitive in electric power production. Towers with annual capacity of 1.5 megawatt wind turbines are becoming the norm in the US industry with indications that 5.0 megawatt capacity may be feasible and most competitive in the not too distant future. At the same time, integration into the farm production system will be more viable if producers can tie into the electric grid to obtain energy when they have deficiencies and sell energy when they have surpluses while receiving what is considered “fair” terms-of-trade.

Methane technology offers promise as an integrated source of farm energy, especially when livestock farms are faced with residual disposal problems. In some cases methane digestion may be the most cost-effective solution while providing power to the farm operation.

Advances in solar energy technology are providing important on-farm substitution opportunities, including providing water to remote livestock, powering electric fencing not in proximity to another power source, and providing lighting in more isolated areas. As technology improves, other substitution opportunities are anticipated on farms and ranches.

Rural energy security and disruption costs in field crop, specialty crop, and animal agriculture

Data on seasonal energy use in agriculture are not available. Field crop production is less prone to energy disruptions except during the planting and harvesting periods when direct and indirect energy disruptions could reduce crop yields and increase product loss due to delayed planting or planting without a full complement of inputs. Also crop production could be disrupted during harvesting and drying when delays may lead to increased field loss and increased crop damage from inadequate drying.

Livestock, poultry and dairy operations are active year-around and account for significant on-farm energy use on livestock farms. , or if energy is not available to harvest animals, processing may develop a backlog. For example, large-confined hog operations have very different energy demands over the production cycle. During the cold months, farrowing requires supplemental heat to insure the survival of piglets, but during the heat of the summer months, millions of finishing hogs may perish without proper ventilation. The producer may be able to stockpile large amounts of LP gas in large storage tanks on-farm to protect piglets in the winter but has more limited options to store electricity to run fans during peak heat periods unless the producer has back-up generators.

The area with the greatest potential for energy disruption impacts may be the processing sector, much of which is a continuous process throughout the year in modern livestock agriculture and in important fruit and vegetable areas. To the extent that energy disruptions impair transportation and storage, a disruption could substantially reduce perishable food supplies. The magnitude of these effects would depend on the nature and magnitude of the energy disruption. Processed dairy products, such as cheese, butter, ice cream, and yogurt require energy to maintain proper temperatures during processing and storage. With energy disruptions and without proper refrigeration, a large amount of milk and other dairy products will perish or spoil. Similar impacts could occur in perishable fruits and vegetables if an energy disruption occurs at harvest time, these crops may spoil in the field or on trees and vines. Likewise, perishable crops must be processed soon after harvest. If energy is not available, such crops will deteriorate and spoil. As another example, the U.S. pork processing industry operates with very limited excess capacity. When the number of hogs sent to slaughter exceeded harvesting capacity in December 1998 and January 1999, market prices fell to depression-era levels until the excess supply was eliminated. If energy disruptions shut down pork harvesting, even at only a few large plants for a short period, the backlog could cause significant declines in pork prices. At present, it is impossible to measure these potential impacts in terms of critical disruption points, avoidance costs, and market impacts.

Nitrogen fertilizer production tends to be located near sources of natural gas. Natural gas is the primary feedstock for anhydrous ammonia, the most common form of nitrogen fertilizer as well as a feedstock for other fertilizer products. Fertilizer plants are clustered in the natural gas producing states, including Texas, Oklahoma, and Louisiana. Significant amounts of nitrogen fertilizer are now being imported as well. Florida has the largest concentration of phosphorus producers. The U.S. imports potassium from Canada. Fertilizers come primarily in solid, gaseous, and liquid forms and are shipped by trains, trucks, barges, pipelines, and ocean vessels. Given the concentrated production of fertilizer in the South and abroad, the use of pipelines and major carriers to transport the solid, liquid and gaseous forms, rail, highway, and pipeline disruptions could impact fertilizer availability during critical application windows. Such disruptions could have a significant impact on fertilizer prices, fertilizer availability, and crop yields.

An important energy disruption point could be the processing of field crops if major facilities are forced to shut down due to energy disruptions. For example, large food and bioproduct corn processing plants, such as high fructose corn syrup (HFCS) and ethanol plants operate on a continuous process and consume large quantities (e.g., 350,000 bushels) of corn per day. If such plants are forced to temporarily shut down for an energy disruption, it could have major impacts on HFCS, ethanol, and feed markets. Some of these facilities have their own energy sources but others are more vulnerable. Because of large-scale economies, the food, feed, and biofuel production is highly concentrated in centrally-located, large-scale plants.

Conclusions and implications for energy consumption in US agriculture

Energy conservation should be a goal for agriculture as well as all sectors of the US economy. Improving energy efficiency reduces our vulnerability to energy price shocks, adverse impacts of long-term real energy price increases, and environmental impacts of fossil fuel consumption. As agriculture becomes more technologically sophisticated through the use of precision farming systems, biotech inputs, and enhanced information systems, greater energy efficiency will be achieved in agriculture. If real energy prices increase over time, price incentives will speed the adoption of new information and biotech inputs, encourage investment in more energy-saving capital and information, and continue the productivity growth and structural transition in American agriculture.

Real price incentives are typically the most affective inducement to promote energy conservation and efficiency. Direct regulation and government intervention is an inefficient approach to achieving energy conservation. Yet, since the late 1970s and early 1980s, real prices have provided little consistent information and few incentives to producers to pursue more energy efficiency. If producers are behaving rationally and maximizing profits of their operations, they have few incentives to improve energy efficiency.

Finally, I have adhered to market-based incentives to achieve energy efficiency. Energy demand and efficiency in agriculture are driven by real and relative energy prices, but I also recognize that energy efficiency improvements may be achieve through agricultural productivity growth, especially in the absence of real and relative price incentives. Because the agricultural sector has achieved improved energy efficiency through productivity growth, the sector is less vulnerable to energy price shocks and real energy price increases but possibly more vulnerable to energy disruptions. For most crops and farms, energy expenditures are a small share of the value of output and cash expenses so price shocks and real energy price increases should be absorbed without significant disruption. Energy supply disruptions could prove far more costly to field crop, animal, horticultural, and greenhouse operation, especially during critical periods in the production and harvesting process.

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Figure 1. Total Energy Consumed
in U.S. Farms in 2002
Total = 1.7 Quadrillion BTUs

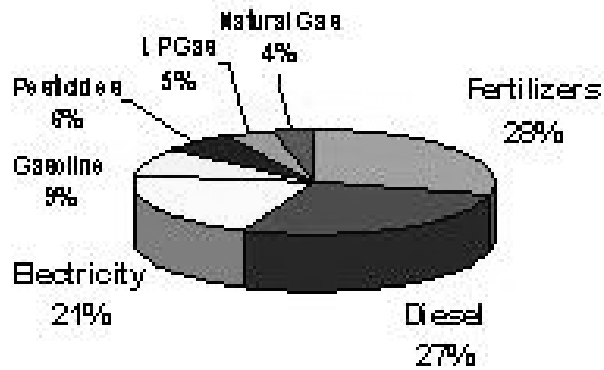


Figure 2. Total Energy Consumed on U.S. Farms,
1965-2002

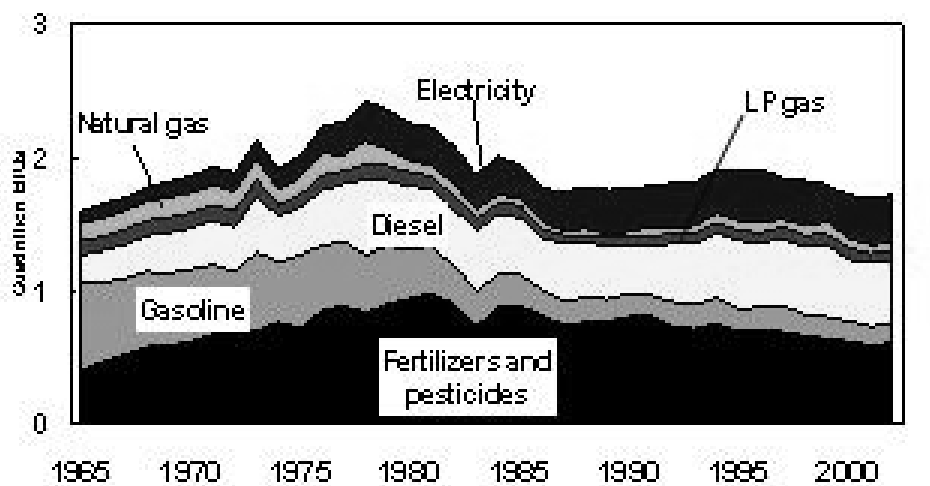


Figure 3. Direct and Indirect Energy Consumed on U.S. Farms, 1965-2002

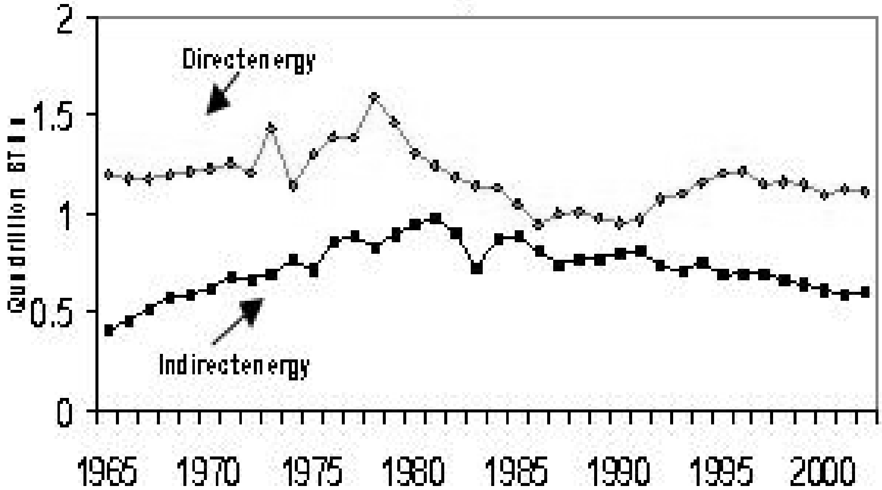


Figure 4. Direct Energy Expenses per Dollar Cash Expenses and Output in 2002: Major Crop Farms

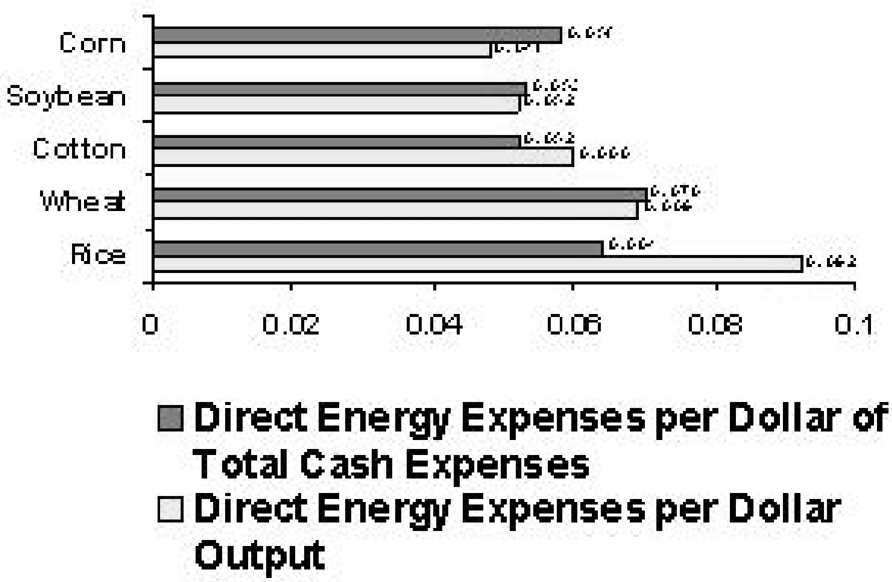


Figure 5. Direct Energy Expenses per Dollar Cash Expenses and Output in 2002: Livestock Farms

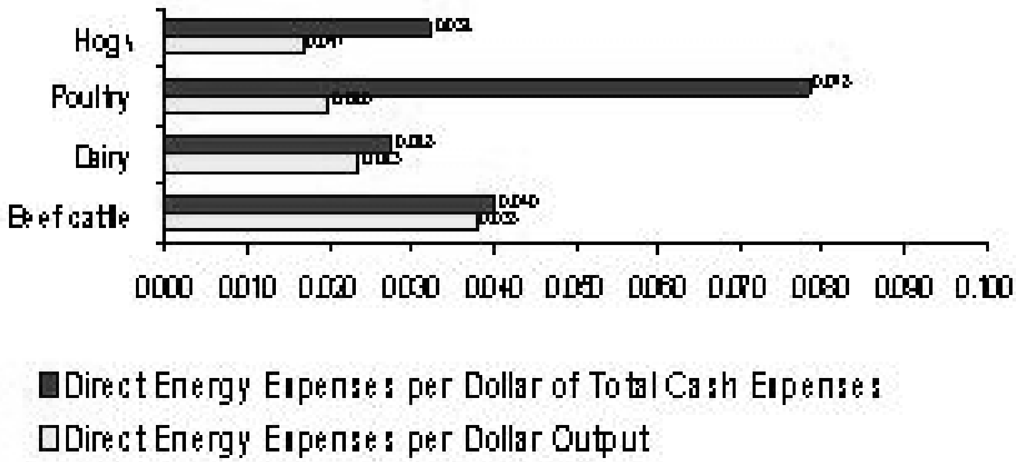


Figure 6. Direct Energy Expenses per Dollar Cash Expenses and Output in 2002: Speciality Crop Farms

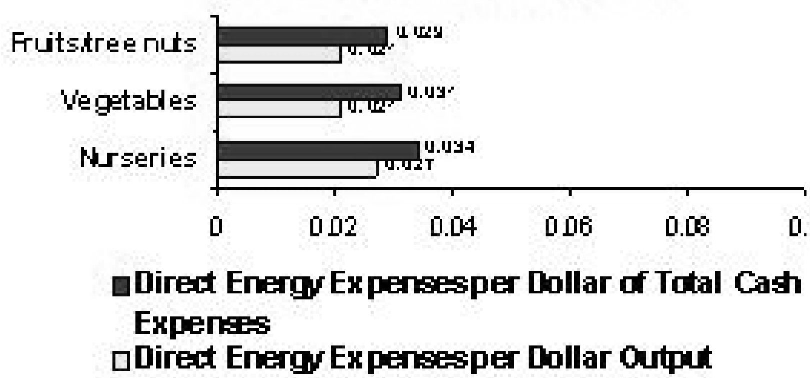


Figure 7. Energy's Share of Farm Production Expenses

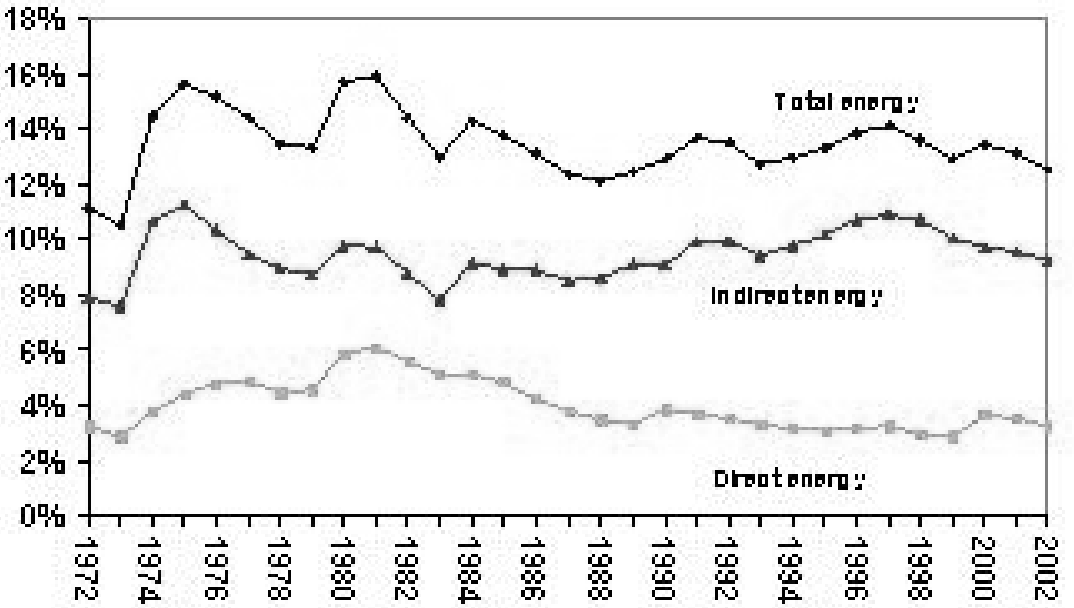


Figure 8. Nominal Prices of Major Farm Fuel Sources: 1970-2002

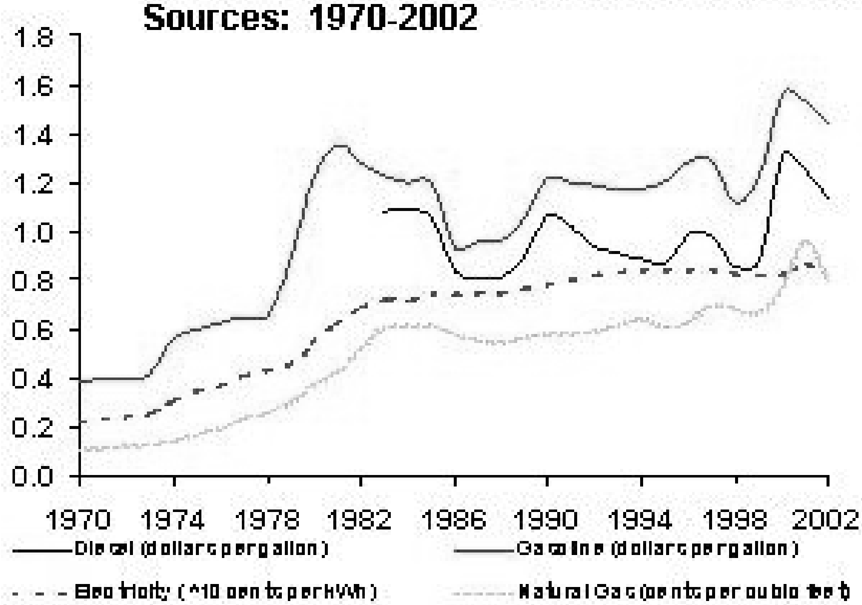


Figure 9. Real Prices of Major Farm Fuel Sources 1970-2002 (1996 dollars):

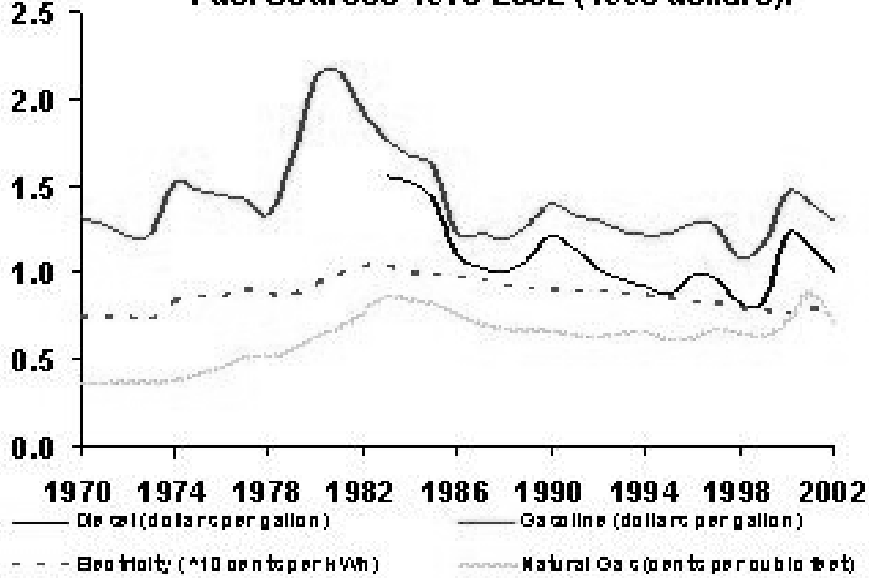


Figure 10. Indices of Farm Output, Input Use and Productivity in U.S. Agriculture

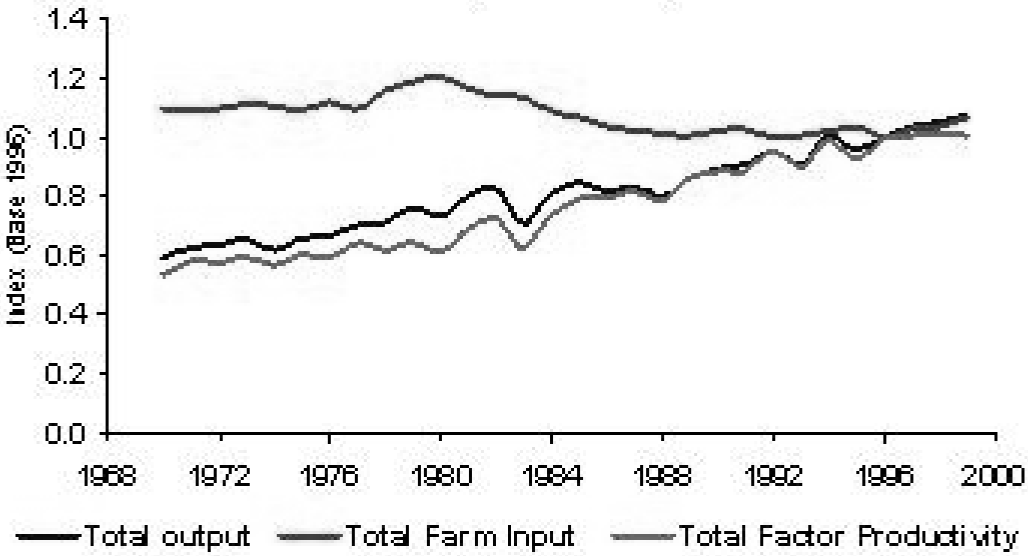


Figure 11. Indices of Major Inputs Used in U.S. Agriculture

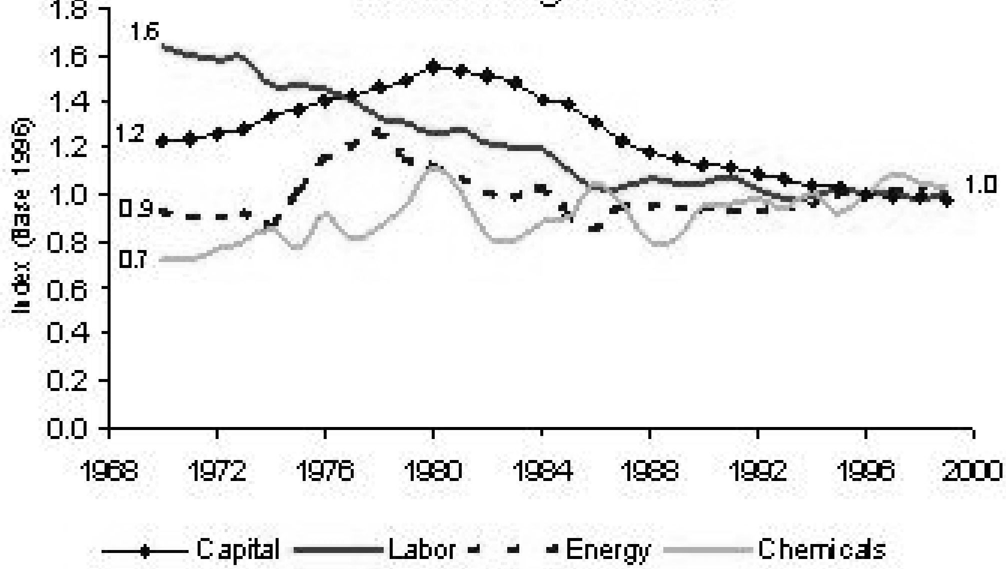


Figure 12. Partial Productivity Indices for U.S. Agriculture

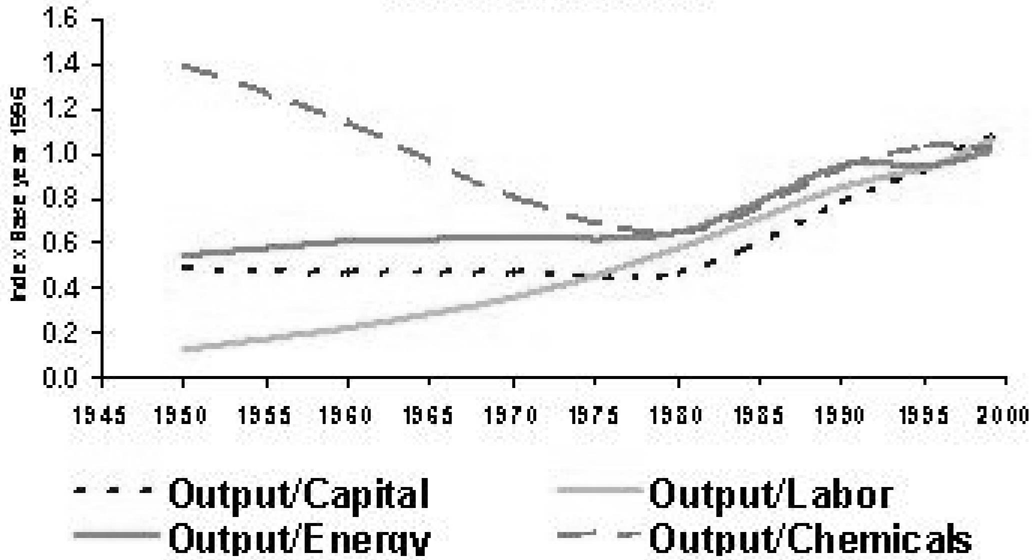


Table 1: Farm Business Fuel Expenses, by Farm Type Defined with Value of Production, 2002

Item	General cash grain	Wheat	Corn	Soybean	Rice	Tobacco	Cotton	Peanut	General crop
	Farm type defined with value of production								
Number of farms	75,746	36,300	124,695	68,886	4,321	49,347	12,885	3,382	426,229
Percent of farms	3.5	1.7	5.8	3.2	0.2	2.3	0.6	0.2	19.8
Sample size	575	406	668	297	56	158	173	37	1,416
Average expansion factor	80	82	125	128	47	254	56	86	280
	Thousand dollars								
Total Fuel/lubes purchases									
Gasoline/gasohol	107,606	54,244	126,500	48,726	10,919	44,293	33,818	9,353	184,732
Diesel	356,547	137,259	485,427	159,098	53,481	65,406	112,006	22,278	409,160
Natural gas	45,996	9,372	148,782	1,964	1,300	4,061	22,661	2,596	28,725
LP gas (propane,butane)	73,996	6,424	134,306	17,792	2,355	72,935	5,134	1,060	40,395
Oils and lubricants	38,658	15,120	44,777	15,972	7,057	12,401	17,643	2,776	57,088
All other fuels	733	605	388	345	L	1,408	856	0	23,865
All purchased fuels/lubes	623,534	223,024	940,181	243,896	75,466	200,505	192,118	38,064	743,966
Electricity	154,727	41,203	232,350	50,206	20,930	46,962	104,419	22,523	413,171
	Dollars								
Average Fuel/lubes purchases									
Gasoline/gasohol	1,421	1,494	1,014	707	2,527	898	2,625	2,766	433
Diesel	4,707	3,781	3,893	2,310	12,376	1,325	8,693	6,588	960
Natural gas	607	258	1,193	29	301	82	1,759	768	67
LP gas (propane,butane)	977	177	1,077	258	545	1,478	398	314	95
Oils and lubricants	510	417	359	232	1,633	251	1,369	821	134
All other fuels	10	17	3	5	L	29	66	0	56

All purchased fuels/lubes	8,232	6,144	7,540	3,541	17,463	4,063	14,911	11,255	1,745
Electricity	2,043	1,135	1,863	729	4,843	952	8,104	6,660	969

Table 1 (continued)

Item	*General cash grain*	*Wheat*	*Corn*	*Soybean*	*Rice*	*Tobacco*	*Cotton*	*Peanut*	*General crop*
					Percent				
Fuel purchases distribution									
Gasoline/gasohol distribution	6.78	3.42	7.97	3.07	0.69	2.79	2.13	0.59	11.64
Diesel distribution	10.51	4.05	14.31	4.69	1.58	1.93	3.30	0.66	12.06
Natural gas distribution	7.56	1.54	24.44	0.32	0.21	0.67	3.72	0.43	4.72
LP gas (propane, butane) distribution	8.23	0.71	14.93	1.98	0.26	8.11	0.57	0.12	4.49
Oils and lubricants distribution	8.67	3.39	10.04	3.58	1.58	2.78	3.96	0.62	12.80
All other fuels distribution	1.12	0.93	0.59	0.53	L	2.16	1.31	0.00	36.53
All purchased fuels distribution	8.91	3.19	13.43	3.48	1.08	2.86	2.74	0.54	10.63
Electricity distribution	4.57	1.22	6.87	1.48	0.62	1.39	3.09	0.67	12.21
					Farm numbers				
Number of farms reporting fuel expense									
Gasoline/gasohol	59,690	29,096	83,696	43,622	2,951	36,115	9,040	2,824	201,114
Diesel	73,316	33,598	111,634	55,725	4,085	41,235	11,994	3,382	241,103
Natural gas	5,282	2,032	8,129	931	236	1,958	2,596	264	5,587
LP gas (propane, butane)	28,736	7,279	55,223	13,900	681	8,958	3,001	503	30,633
Oils and lubricants	63,798	31,965	87,759	44,567	4,019	42,655	10,919	3,064	201,245
All other fuels	3,534	1,745	2,972	1,329	459	3,843	1,323	0	9,944
All purchased fuels	75,472	34,866	120,996	59,275	4,225	48,791	12,373	3,382	319,716
Electricity	66,792	27,021	102,492	39,759	3,257	38,600	8,563	2,464	171,853

Table 1 (continued)

Item	General cash grain	Wheat	Corn	Soybean	Rice	Tobacco	Cotton	Peanut	General crop
					Fuel use ratios				
Fuel purchases/value of production 1/									
Gasoline/value of production	0.0097	0.0192	0.0076	0.0121	0.0158	0.0183	0.0126	0.0231	0.0099
Diesel/value of production	0.0320	0.0487	0.0290	0.0394	0.0772	0.0270	0.0419	0.0550	0.0218
Natural gas/value of production	0.0041	0.0033	0.0089	0.0005	0.0019	0.0017	0.0085	0.0064	0.0015
LP gas (propane, butane)/value of production	0.0066	0.0023	0.0080	0.0044	0.0034	0.0302	0.0019	0.0026	0.0022
Oils and lubricants/value of production	0.0035	0.0054	0.0027	0.0040	0.0102	0.0051	0.0066	0.0068	0.0030
All other fuels/value of production	0.0001	0.0002	0.0000	0.0001	0.0005	0.0006	0.0003	0.0000	0.0013
All purchased fuels/value of production	0.0560	0.0791	0.0561	0.0603	0.1089	0.0829	0.0718	0.0939	0.0397
Electricity/value of production	0.0139	0.0146	0.0139	0.0124	0.0302	0.0194	0.0390	0.0556	0.0221
Fuel purchases/total cash expenses 2/									
Gasoline/total cash expenses	0.0110	0.0194	0.0091	0.0123	0.0111	0.0211	0.0109	0.0180	0.0143
Diesel/total cash expenses	0.0363	0.0491	0.0351	0.0401	0.0541	0.0312	0.0360	0.0430	0.0318
Natural gas/total cash expenses	0.0047	0.0034	0.0108	0.0005	0.0013	0.0019	0.0073	0.0050	0.0022
LP gas (propane, butane)/total cash expenses	0.0075	0.0023	0.0097	0.0045	0.0024	0.0348	0.0017	0.0020	0.0031
Oils and lubricants/total cash expenses	0.0039	0.0054	0.0032	0.0040	0.0071	0.0059	0.0057	0.0054	0.0044
All other fuels/total cash expenses	0.0001	0.0002	0.0000	0.0001	0.0004	0.0007	0.0003	0.0000	0.0019
All purchased fuels/total cash expenses	0.0635	0.0798	0.0680	0.0614	0.0764	0.0956	0.0618	0.0734	0.0577
Electricity/total cash expenses	0.0158	0.0147	0.0168	0.0126	0.0212	0.0224	0.0336	0.0434	0.0321

1/ Value of production is the value of all crops and livestock produced and not used on the farm.

2/ Cash expenses are all expenses except depreciation and non-cash hired labor expenses.
Source: 2002 USDA Agricultural Resource Management Survey. Table processed by Bob Dubman.

Table 1 --Farm Business Fuel Expenses, by Farm Type Defined with Value of Production, 2002

Item	Fruits and tree nuts	Vegetables	Nursery and greenhouse	Beef cattle	Hogs	Poultry	Dairy	General livestock	All
	Farm type defined with value of production								
Number of farms	61,633	28,145	47,217	704,177	35,287	43,562	76,187	354,413	2,152,411
Percent of farms	2.9	1.3	2.2	32.7	1.6	2.0	3.5	16.5	100.0
Sample size	502	293	480	2,536	267	665	1,062	773	10,364
Average expansion factor	123	87	97	263	96	61	64	429	178
	Thousand dollars								
Total Fuel/lubes purchases									
Gasoline/gasohol	69,666	72,109	100,185	428,876	39,634	44,385	101,890	109,955	1,586,892
Diesel	99,600	170,797	128,794	616,315	75,799	51,148	320,220	129,803	3,393,139
Natural gas	L	5,482	178,692	51,958	13,271	65,446	11,358	5,070	608,785
LP gas (propane,butane)	12,813	14,422	66,214	74,486	75,207	227,528	49,150	25,395	899,611
Oils and lubricants	13,579	16,290	17,392	103,824	9,631	12,053	39,286	22,342	445,888
All other fuels	L	1,108	22,274	4,300	1,184	470	4,572	2,377	65,325
All purchased fuels/lubes	208,195	280,207	513,551	1,279,758	214,725	401,031	526,476	294,943	6,999,640
Electricity	218,645	235,991	255,891	466,031	139,121	275,657	516,006	189,491	3,383,323
	Dollars								
Average Fuel/lubes purchases									
Gasoline/gasohol	1,130	2,562	2,122	609	1,123	1,019	1,337	310	737
Diesel	1,616	6,068	2,728	875	2,148	1,174	4,203	366	1,576
Natural gas	L	195	3,784	74	376	1,502	149	14	283
LP gas (propane,butane)	208	512	1,402	106	2,131	5,223	645	72	418
Oils and lubricants	220	579	368	147	273	277	516	63	207
All other fuels	L	39	472	6	34	11	60	7	30

All purchased fuels/lubes	3,378	9,956	10,876	1,817	6,085	9,206	6,910	832	3,252

Table 1 (continued)

Item	*Fruits and tree nuts*	*Vegetables*	*Nursery and greenhouse*	*Beef cattle*	*Hogs*	*Poultry*	*Dairy*	*General livestock*	*All*
Electricity	3,548	8,385	5,419	662	3,943	6,328	6,773	535	1,572
Fuel purchases distribution									
Gasoline/gasohol distribution	4.39	4.54	6.31	27.03	2.50	2.80	6.42	6.93	100.00
Diesel distribution	2.94	5.03	3.80	18.16	2.23	1.51	9.44	3.83	100.00
Natural gas distribution	L	0.90	29.35	8.53	2.18	10.75	1.87	0.83	100.00
LP gas (propane, butane) distribution	1.42	1.60	7.36	8.28	8.36	25.29	5.46	2.82	100.00
Oils and lubricants distribution	3.05	3.65	3.90	23.28	2.16	2.70	8.81	5.01	100.00
All other fuels distribution	L	1.70	34.10	6.58	1.81	0.72	7.00	3.64	100.00
All purchased fuels distribution	2.97	4.00	7.34	18.28	3.07	5.73	7.52	4.21	100.00
Electricity distribution	6.46	6.98	7.56	13.77	4.11	8.15	15.25	5.60	100.00
					Farm numbers				
Number of farms reporting fuel expense									
Gasoline/gasohol	40,299	23,784	33,888	429,721	25,116	31,901	57,512	184,877	1,295,244
Diesel	41,826	17,156	26,152	526,557	24,631	33,874	72,533	159,874	1,478,675
Natural gas	993	911	6,612	11,424	1,162	5,154	4,151	5,033	62,456
LP gas (propane, butane)	10,082	6,127	17,571	79,347	15,559	23,326	26,181	21,824	348,933
Oils and lubricants	38,966	20,929	27,311	484,099	20,687	32,062	59,320	164,992	1,338,357
All other fuels	806	2,485	5,135	16,620	2,255	651	6,520	11,050	70,671
All purchased fuels	53,568	27,216	45,634	638,629	32,393	42,536	75,457	269,823	1,864,351
Electricity	44,482	19,273	39,150	445,439	30,335	41,789	70,508	204,019	1,355,795

Table 1 (continued)

Item	Fruits and tree nuts	Vegetables	Nursery and greenhouse	Beef cattle	Hogs	Poultry	Dairy	General livestock	All
	Fuel use ratios								
Fuel purchases/value of production 1/									
Gasoline/value of production	0.0068	0.0059	0.0063	0.0152	0.0036	0.0025	0.0046	0.0233	0.0087
Diesel/value of production	0.0098	0.0141	0.0080	0.0219	0.0069	0.0029	0.0143	0.0275	0.0187
Natural gas/value of production	0.0012	0.0005	0.0112	0.0018	0.0012	0.0037	0.0005	0.0011	0.0033
LP gas (propane, butane)/value of production	0.0013	0.0012	0.0041	0.0026	0.0068	0.0129	0.0022	0.0054	0.0049
Oils and lubricants/value of production	0.0013	0.0013	0.0011	0.0037	0.0009	0.0007	0.0018	0.0047	0.0025
All other fuels/value of production	0.0000	0.0001	0.0014	0.0002	0.0001	0.0000	0.0002	0.0005	0.0004
All purchased fuels/value of production	0.0204	0.0231	0.0321	0.0455	0.0195	0.0228	0.0236	0.0624	0.0385
Electricity/value of production	0.0214	0.0195	0.0160	0.0166	0.0126	0.0157	0.0231	0.0401	0.0186
Fuel purchases/total cash expenses 2/									
Gasoline/total cash expenses	0.0093	0.0085	0.0079	0.0162	0.0069	0.0099	0.0054	0.0129	0.0111
Diesel/total cash expenses	0.0133	0.0202	0.0102	0.0233	0.0132	0.0115	0.0170	0.0153	0.0238
Natural gas/total cash expenses	0.0016	0.0006	0.0141	0.0020	0.0023	0.0147	0.0006	0.0006	0.0043
LP gas (propane, butane)/total cash expenses	0.0017	0.0017	0.0052	0.0028	0.0131	0.0510	0.0026	0.0030	0.0063
Oils and lubricants/total cash expenses	0.0018	0.0019	0.0014	0.0039	0.0017	0.0027	0.0021	0.0026	0.0031
All other fuels/total cash expenses	0.0001	0.0001	0.0018	0.0002	0.0002	0.0001	0.0002	0.0003	0.0005
All purchased fuels/total cash expenses	0.0279	0.0332	0.0405	0.0484	0.0375	0.0899	0.0279	0.0347	0.0491
Electricity/total cash expenses	0.0293	0.0280	0.0202	0.0176	0.0243	0.0618	0.0273	0.0223	0.0237

1/ Value of production is the value of all crops and livestock produced and not used on the farm.

2/ Cash expenses are all expenses except depreciation and non-cash hired labor expenses.
Source: 2002 USDA Agricultural Resource Management Survey. Table processed by Bob Dubman.

Table 2. Ratios of Direct and Indirect Energy Expenses to Total Cash Expenses by Production Regions 1991-2002

Northeast		1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	ALL
Fertilizer ratios	% of cash Expenses	10.5%	8.9%	7.8%	8.3%	8.9%	8.1%	9.1%	7.9%	7.2%	7.7%	9.2%	6.8%	8.3%
	% of gross cash income	8.8%	7.7%	6.6%	7.1%	7.3%	6.6%	8.0%	6.5%	6.1%	6.1%	7.8%	6.1%	7.0%
Fuel ratios	% of cash Expenses	4.5%	4.3%	4.5%	4.6%	4.3%	4.1%	4.4%	3.6%	3.4%	4.4%	5.0%	3.8%	4.2%
	% of gross cash income	3.8%	3.7%	3.8%	3.9%	3.5%	3.3%	3.9%	3.0%	2.9%	3.5%	4.3%	3.4%	3.6%
Utilities ratios	% of cash Expenses	3.5%	3.7%	4.4%	3.7%	3.7%	3.4%	3.7%	3.0%	3.7%	3.9%	3.9%	3.5%	3.7%
	% of gross cash income	2.9%	3.2%	3.7%	3.1%	3.0%	2.8%	3.2%	2.5%	3.1%	3.0%	3.4%	3.2%	3.1%
Lake states														
Fertilizer ratios	% of cash Expenses	12.7%	12.2%	12.6%	12.9%	12.8%	13.7%	12.6%	13.5%	12.4%	12.0%	11.6%	12.1%	12.6%
	% of gross cash income	9.9%	9.6%	10.4%	10.5%	10.5%	10.6%	10.3%	10.1%	9.2%	9.8%	9.3%	9.6%	10.0%
Fuel ratios	% of cash Expenses	6.6%	6.8%	6.2%	5.9%	5.5%	5.8%	5.7%	5.4%	5.3%	6.1%	7.4%	6.3%	6.1%
	% of gross cash income	3.8%	4.0%	3.8%	3.6%	3.4%	3.4%	3.5%	3.0%	2.9%	3.7%	4.4%	3.7%	3.6%
Utilities ratios	% of cash Expenses	2.9%	3.0%	3.1%	2.6%	2.7%	2.7%	2.4%	2.4%	2.7%	2.5%	2.6%	2.7%	2.7%
	% of gross cash income	2.3%	2.4%	2.6%	2.1%	2.2%	2.1%	2.0%	1.8%	2.0%	2.1%	2.1%	2.2%	2.1%
Corn Belt														
Fertilizer ratios	% of cash Expenses	17.3%	16.2%	15.9%	16.6%	19.2%	20.2%	19.3%	19.2%	17.4%	17.5%	17.4%	16.5%	17.7%
	% of gross cash income	13.9%	13.1%	12.2%	13.5%	15.4%	15.4%	14.9%	14.6%	13.7%	13.9%	13.5%	14.0%	14.0%
Fuel ratios	% of cash Expenses	5.2%	5.4%	5.0%	4.6%	4.2%	4.8%	4.9%	4.1%	3.9%	4.9%	4.6%	4.4%	4.7%
	% of gross cash income	4.2%	4.4%	3.8%	3.7%	3.4%	3.7%	3.8%	3.1%	3.1%	3.9%	3.6%	3.7%	3.7%
Utilities ratios	% of cash Expenses	2.4%	2.4%	2.8%	2.2%	2.3%	2.3%	2.3%	2.0%	2.3%	2.2%	2.2%	2.2%	2.3%
	% of gross cash income	1.9%	1.9%	2.1%	1.8%	1.9%	1.7%	1.8%	1.5%	1.8%	1.7%	1.7%	1.9%	1.8%
Northern Plains														
Fertilizer ratios	% of cash Expenses	9.8%	12.4%	11.7%	13.8%	13.0%	14.6%	13.9%	13.7%	12.6%	14.3%	12.6%	13.3%	13.0%
	% of gross cash income	7.8%	9.6%	9.3%	10.7%	10.5%	11.5%	11.5%	11.1%	9.9%	11.4%	10.0%	11.0%	10.4%
Fuel ratios	% of cash Expenses	6.0%	7.0%	5.7%	6.0%	5.6%	5.7%	5.9%	4.9%	4.4%	6.4%	5.8%	5.7%	5.7%
	% of gross cash income	4.8%	5.3%	4.6%	4.6%	4.5%	4.5%	4.9%	4.0%	3.5%	5.1%	4.6%	4.7%	4.6%
Utilities ratios	% of cash Expenses	2.8%	2.9%	2.8%	2.9%	2.5%	2.6%	2.3%	2.4%	2.3%	2.4%	2.4%	3.0%	2.6%
	% of gross cash income	2.2%	2.2%	2.2%	2.3%	2.0%	2.1%	1.9%	2.0%	1.8%	1.9%	1.9%	2.5%	2.1%
Appalachia														
Fertilizer ratios	% of cash Expenses	14.9%	15.6%	16.2%	14.8%	16.0%	17.4%	16.0%	16.0%	15.4%	14.5%	17.1%	13.7%	15.6%

	% of gross cash income	12.6%	11.9%	13.1%	12.4%	12.7%	15.1%	13.0%	12.5%	13.1%	11.7%	13.7%	11.6%	12.8%
Fuel ratios	% of cash Expenses	6.1%	6.4%	6.0%	6.6%	6.8%	5.1%	6.5%	5.4%	5.2%	7.4%	6.8%	6.4%	6.2%
	% of gross cash income	5.1%	4.9%	4.8%	5.5%	5.4%	4.4%	5.3%	4.3%	4.4%	5.9%	5.5%	5.4%	5.1%
Utilities ratios	% of cash Expenses	2.8%	2.8%	3.9%	2.9%	3.0%	2.8%	3.0%	2.8%	2.7%	3.1%	3.4%	3.3%	3.0%
	% of gross cash income	2.4%	2.1%	3.2%	2.4%	2.4%	2.5%	2.4%	2.2%	2.3%	2.5%	2.7%	2.8%	2.5%
Southeast														
Fertilizer ratios	% of cash Expenses	19.6%	18.2%	17.5%	17.2%	17.1%	20.1%	19.6%	18.2%	16.7%	13.4%	17.3%	13.9%	17.4%
	% of gross cash income	16.1%	14.5%	15.4%	14.8%	14.6%	17.1%	15.9%	15.8%	14.1%	11.4%	14.6%	11.4%	14.7%
Fuel ratios	% of cash Expenses	5.6%	5.0%	4.5%	4.2%	4.7%	4.2%	5.5%	4.5%	4.7%	5.1%	6.0%	5.5%	4.9%
	% of gross cash income	4.6%	4.0%	3.9%	3.6%	4.0%	3.6%	4.4%	3.9%	4.0%	4.3%	5.1%	4.5%	4.1%
Utilities ratios	% of cash Expenses	2.4%	2.6%	2.8%	2.3%	3.1%	2.1%	2.3%	2.8%	3.0%	2.9%	3.7%	3.4%	2.8%
	% of gross cash income	2.0%	2.1%	2.4%	1.9%	2.7%	1.8%	1.9%	2.4%	2.6%	2.5%	3.1%	2.8%	2.3%
Delta														
Fertilizer ratios	% of cash Expenses	20.9%	22.7%	18.2%	21.7%	22.1%	23.6%	22.1%	22.9%	20.8%	21.7%	18.2%	19.1%	21.1%
	% of gross cash income	16.8%	17.9%	15.6%	16.3%	19.5%	17.8%	17.5%	18.6%	17.3%	18.4%	14.8%	16.5%	17.2%
Fuel ratios	% of cash Expenses	7.1%	6.4%	6.3%	6.8%	6.7%	6.0%	7.5%	6.7%	6.4%	8.9%	7.2%	7.6%	7.0%
	% of gross cash income	5.7%	5.1%	5.4%	5.1%	5.9%	4.5%	6.0%	5.5%	5.3%	7.6%	5.9%	6.5%	5.7%
Utilities ratios	% of cash Expenses	2.6%	2.8%	3.9%	2.7%	4.1%	3.0%	3.3%	3.2%	3.2%	3.4%	3.3%	3.8%	3.3%
	% of gross cash income	2.1%	2.2%	3.3%	2.0%	3.6%	2.2%	2.6%	2.6%	2.7%	2.9%	2.7%	3.3%	2.7%
Southern Plains														
Fertilizer ratios	% of cash Expenses	10.4%	10.1%	9.4%	9.9%	10.0%	10.3%	10.5%	10.2%	9.8%	10.1%	9.8%	10.6%	10.1%
	% of gross cash income	9.3%	8.5%	8.4%	9.1%	9.1%	9.8%	9.3%	8.6%	8.3%	9.1%	9.8%	10.1%	9.1%
Fuel ratios	% of cash Expenses	6.7%	6.0%	6.0%	6.0%	5.8%	5.7%	7.5%	5.6%	4.9%	6.3%	7.1%	7.4%	6.3%
	% of gross cash income	6.1%	5.1%	5.4%	5.5%	5.3%	5.4%	6.7%	4.8%	4.2%	5.7%	7.2%	7.0%	5.7%
Utilities ratios	% of cash Expenses	3.3%	2.7%	3.2%	3.0%	3.4%	3.4%	3.5%	3.6%	3.5%	3.7%	3.6%	3.5%	3.4%
	% of gross cash income	3.0%	2.3%	2.9%	2.7%	3.1%	3.2%	3.1%	3.0%	3.0%	3.3%	3.6%	3.3%	3.1%
Mountain														
Fertilizer ratios	% of cash Expenses	8.3%	8.1%	8.2%	8.5%	8.1%	9.8%	9.9%	10.6%	10.0%	7.4%	7.5%	8.0%	8.7%
	% of gross cash income	6.8%	6.9%	6.8%	7.1%	6.5%	7.9%	8.5%	8.7%	7.9%	6.6%	5.8%	6.5%	7.1%
Fuel ratios	% of cash Expenses	6.1%	5.3%	4.7%	4.7%	4.5%	4.5%	5.2%	4.7%	4.4%	4.9%	4.5%	4.5%	4.8%
	% of gross cash income	5.0%	4.5%	3.9%	4.0%	3.6%	3.7%	4.5%	3.9%	3.5%	4.3%	3.5%	3.6%	3.9%
Utilities ratios	% of cash Expenses	5.6%	5.1%	4.8%	4.6%	4.5%	5.2%	4.9%	4.8%	4.5%	4.3%	4.4%	5.2%	4.8%

	% of gross cash income	4.6%	4.3%	4.0%	3.9%	3.6%	4.2%	4.2%	4.0%	3.6%	3.8%	3.4%	4.2%	3.9%
Pacific														
Fertilizer ratios	% of cash Expenses	9.6%	11.0%	8.1%	10.5%	9.8%	11.3%	10.5%	11.2%	8.8%	8.3%	8.5%	8.6%	9.6%
	% of gross cash income	8.3%	8.8%	7.1%	9.0%	8.4%	9.4%	8.0%	9.1%	7.4%	6.8%	6.6%	7.3%	7.9%
Fuel ratios	% of cash Expenses	3.6%	3.3%	2.5%	2.8%	2.5%	3.6%	3.1%	2.7%	2.9%	3.3%	3.6%	2.8%	3.1%
	% of gross cash income	3.1%	2.6%	2.2%	2.4%	2.1%	3.0%	2.4%	2.2%	2.5%	2.7%	2.8%	2.4%	2.5%
Utilities ratios	% of cash Expenses	7.5%	6.1%	5.2%	6.0%	4.8%	5.7%	5.3%	5.1%	5.0%	5.7%	6.0%	5.3%	5.6%
	% of gross cash income	6.5%	4.8%	4.5%	5.1%	4.1%	4.7%	4.0%	4.2%	4.2%	4.7%	4.6%	4.5%	4.6%
Pacific 2														
Fertilizer ratios	% of cash Expenses	12.9%	13.2%	12.1%	13.1%	13.3%	14.7%	13.8%	14.0%	12.6%	12.2%	12.3%	12.0%	13.0%
	% of gross cash income	10.6%	10.6%	10.0%	10.8%	11.0%	11.9%	11.2%	11.2%	10.2%	10.1%	9.9%	10.2%	10.6%
Fuel ratios	% of cash Expenses	5.3%	5.3%	4.7%	4.7%	4.5%	4.7%	5.0%	4.3%	4.1%	5.1%	5.2%	4.8%	4.8%
	% of gross cash income	4.3%	4.2%	3.9%	3.9%	3.7%	3.8%	4.1%	3.4%	3.3%	4.2%	4.2%	4.1%	3.9%
Utilities ratios	% of cash Expenses	3.8%	3.5%	3.7%	3.4%	3.4%	3.4%	3.4%	3.2%	3.4%	3.5%	3.6%	3.6%	3.5%
	% of gross cash income	3.2%	2.8%	3.0%	2.8%	2.8%	2.8%	2.8%	2.6%	2.7%	2.9%	2.9%	3.1%	2.9%
Major Farm														
Fertilizer ratios	% of cash Expenses	12.9%	13.2%	12.1%	13.1%	13.3%	14.7%	13.8%	14.0%	12.6%	12.2%	12.3%	12.0%	
	% of gross cash income	10.6%	10.6%	10.0%	10.8%	11.0%	11.9%	11.2%	11.2%	10.2%	10.1%	9.9%	10.2%	
Fuel ratios	% of cash Expenses	5.3%	5.3%	4.7%	4.7%	4.5%	4.7%	5.0%	4.3%	4.1%	5.1%	5.2%	4.8%	
	% of gross cash income	4.3%	4.2%	3.9%	3.9%	3.7%	3.8%	4.1%	3.4%	3.3%	4.2%	4.2%	4.1%	
Utilities ratios	% of cash Expenses	3.8%	3.5%	3.7%	3.4%	3.4%	3.4%	3.4%	3.2%	3.4%	3.5%	3.6%	3.6%	
	% of gross cash income	3.2%	2.8%	3.0%	2.8%	2.8%	2.8%	2.8%	2.6%	2.7%	2.9%	2.9%	3.1%	

Table 3. Own Price Elasticities and Allen Input Substitution Elasticities

Input	Land	Labor	Capital	Energy	Fertilizer	Pesticide
Land	-0.28					
Labor	-0.27	-0.39				
Capital	0.73	0.65	-0.86			
Energy	0.35	0.59	1.13	-0.60		
Fertilizer	0.20	0.82	0.97	0.60	-0.66	
Pesticide	0.08	0.66	0.82	0.70	1.04	-0.53

Energy Demand and Capacity to Adjust in Agricultural Production

John A. Miranowski
Professor of Economics
Iowa State University

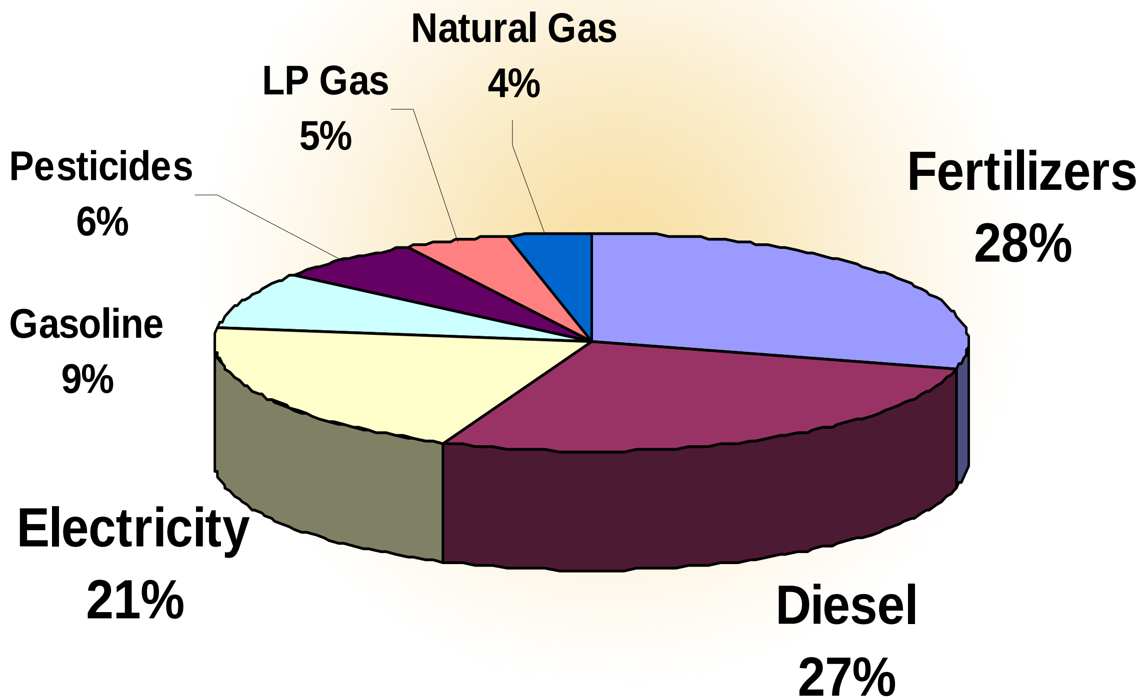
Objectives

- Establish farm energy demand baseline
- Evaluate capacity to adjust to real energy prices and supply disruptions
- Evaluate impacts of productivity growth and technical change on capacity to adjust
- Consider impact of rural energy disruptions and energy security
- Discuss on-farm energy production as option to enhance adjustment capacity

Underlying Issues

- Energy demand is driven by **real** energy prices and relative prices
- Shares of energy expenses impact the capacity to adjust to price increases
- Timing of real price increases is critical to adjustment capacity in production agriculture
- Agricultural productivity growth enhances agriculture's capacity to adjust to energy prices

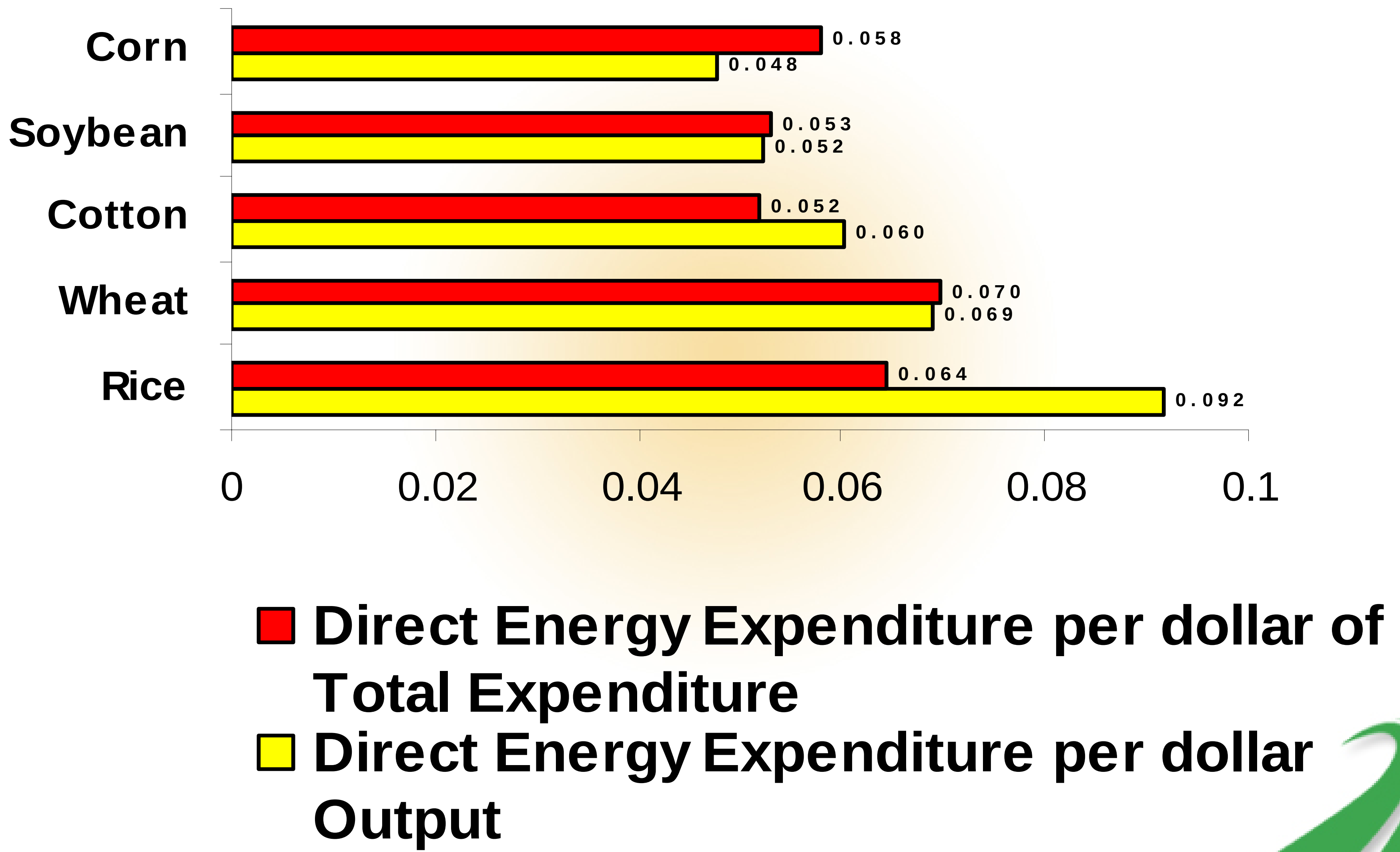
Total Energy Used on US Farms in 2002
Total = 1.7 Quadrillion BTUs



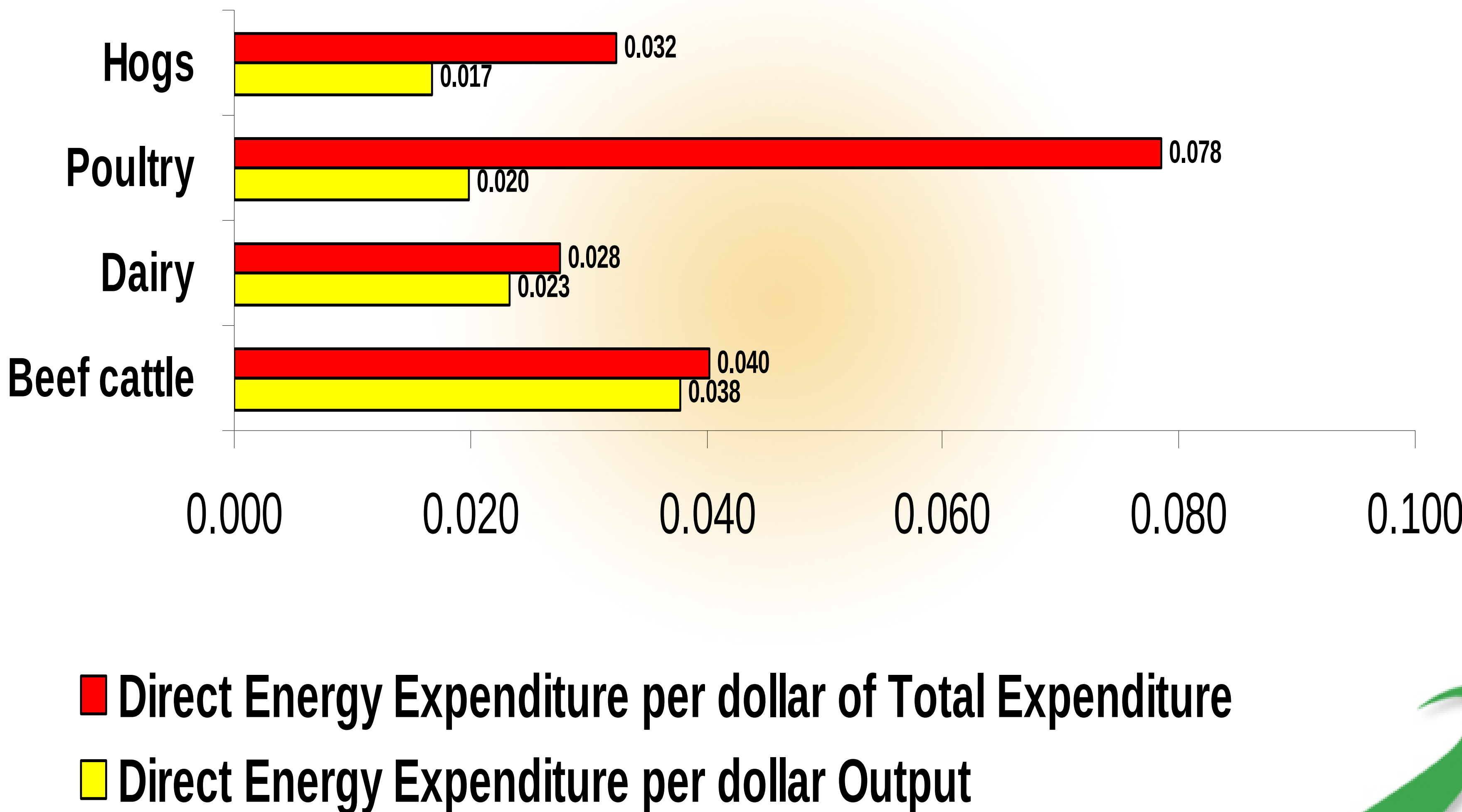
Energy Use and Farm Production Expenses

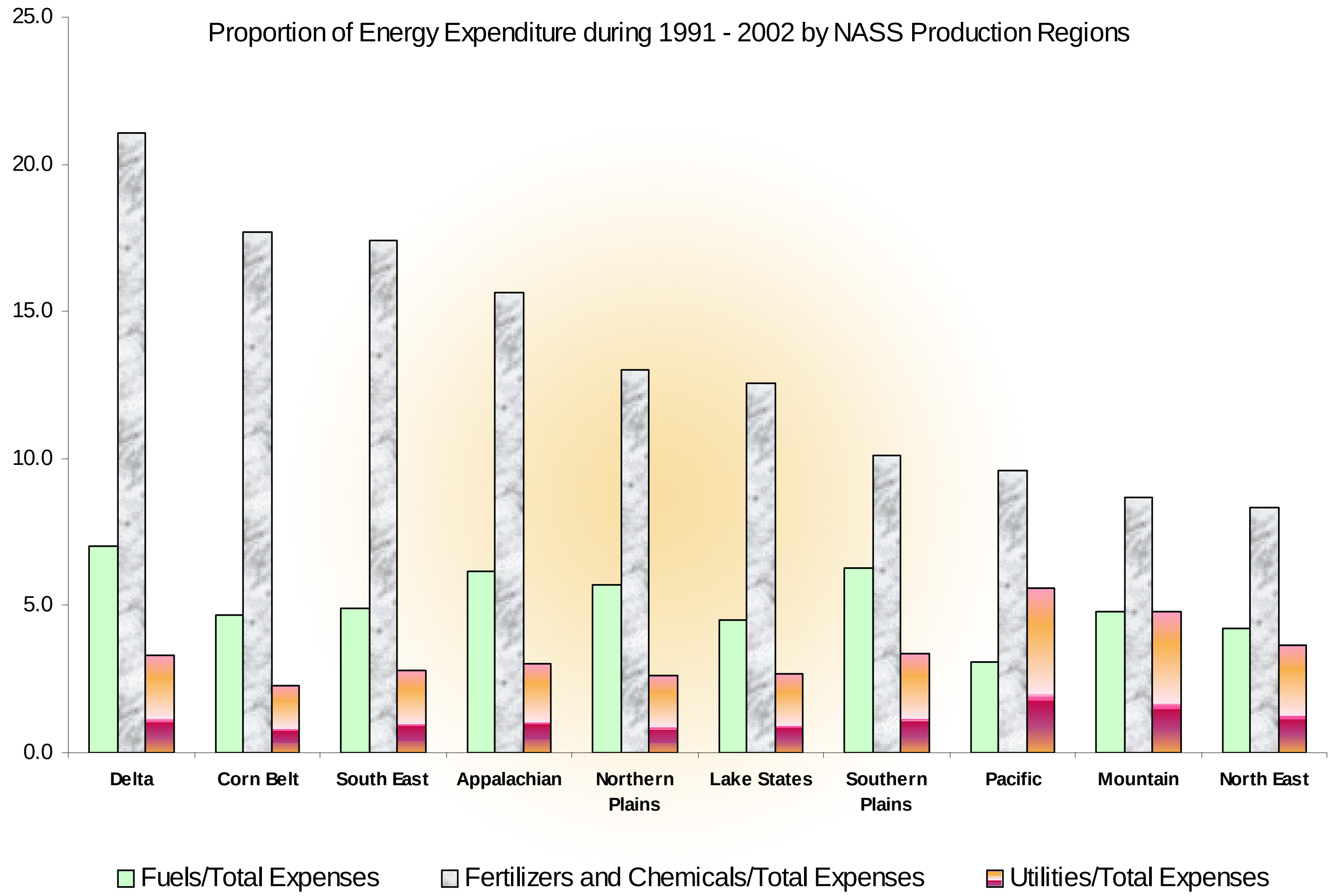
- Direct energy consumes twice as many BTUs as indirect energy, but
- Direct energy accounts for 3-4% of farm cash expenses
- Indirect energy inputs (fertilizer and pesticides) account for 9-10% of farm cash expenses
- How important are energy expenses in crop, animal, and specialty-crop type farms and by regions:

Direct Energy Expenditure per Dollar Expenditure and Output in 2002: Major Crop Farms



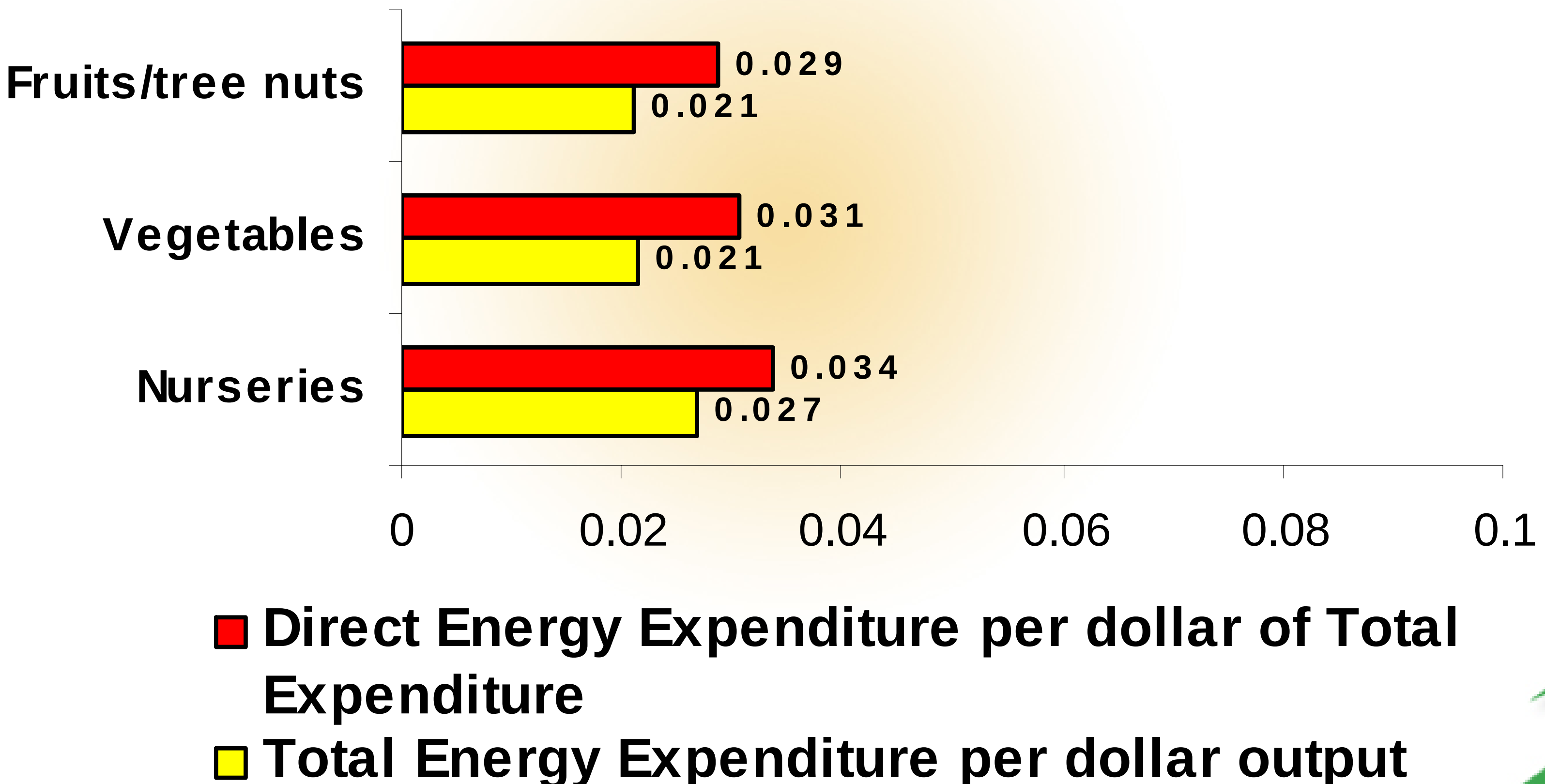
Direct Energy Expenditure per Dollar Expenditure and Output in 2002: Livestock





Proportion of Energy Expenditure during 1991 - 2002 by NASS Production Regions
25.0
20.0
15.0
10.0
5.0
0.0
Delta
Corn Belt
South East
Appalachian
Northern Plains
Lake States
Southern Plains
Pacific
Mountain
North East
Fuels/Total Expenses
Fertilizers and Chemicals/Total Expenses
Utilities/Total Expenses

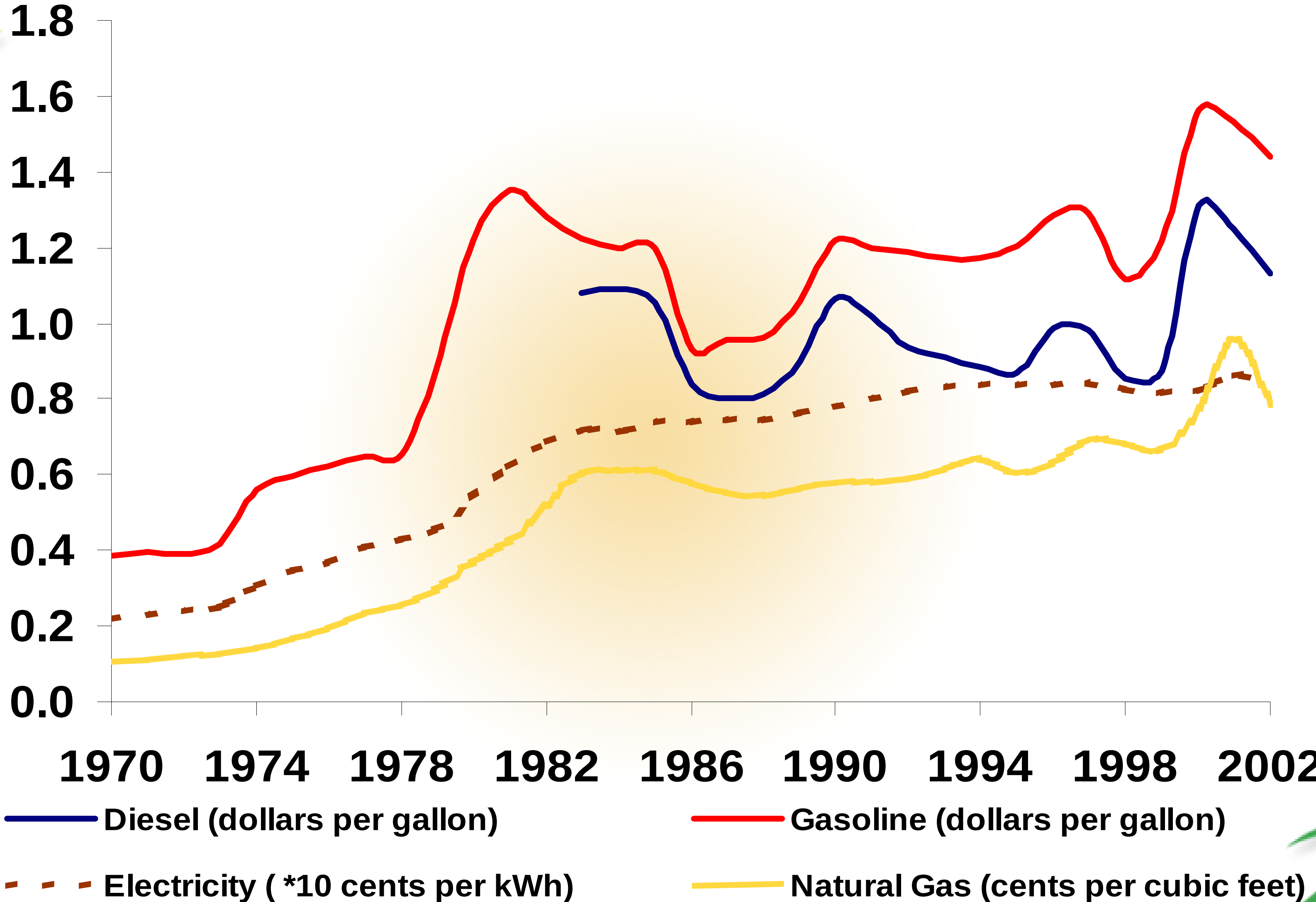
Direct Energy Expenditure per Dollar Expenditure and Output in 2002: Speciality Crops



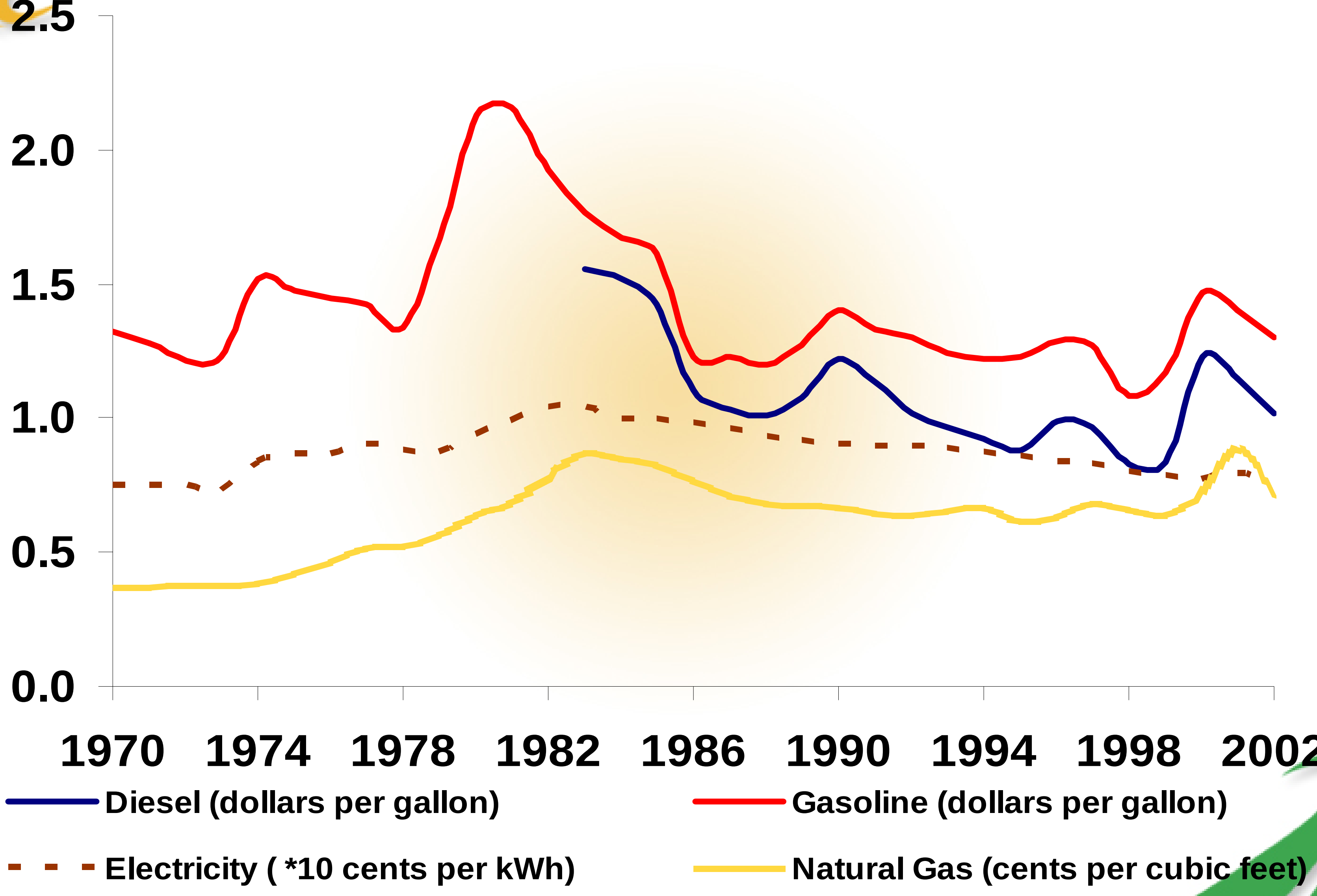
How do Producers Adjust to Energy Price Increases?

- What is happening to nominal and **real** energy prices?
- What adjustments to real energy price increases may we anticipate from producers?
- With relative energy price increases what substitution opportunities are available?

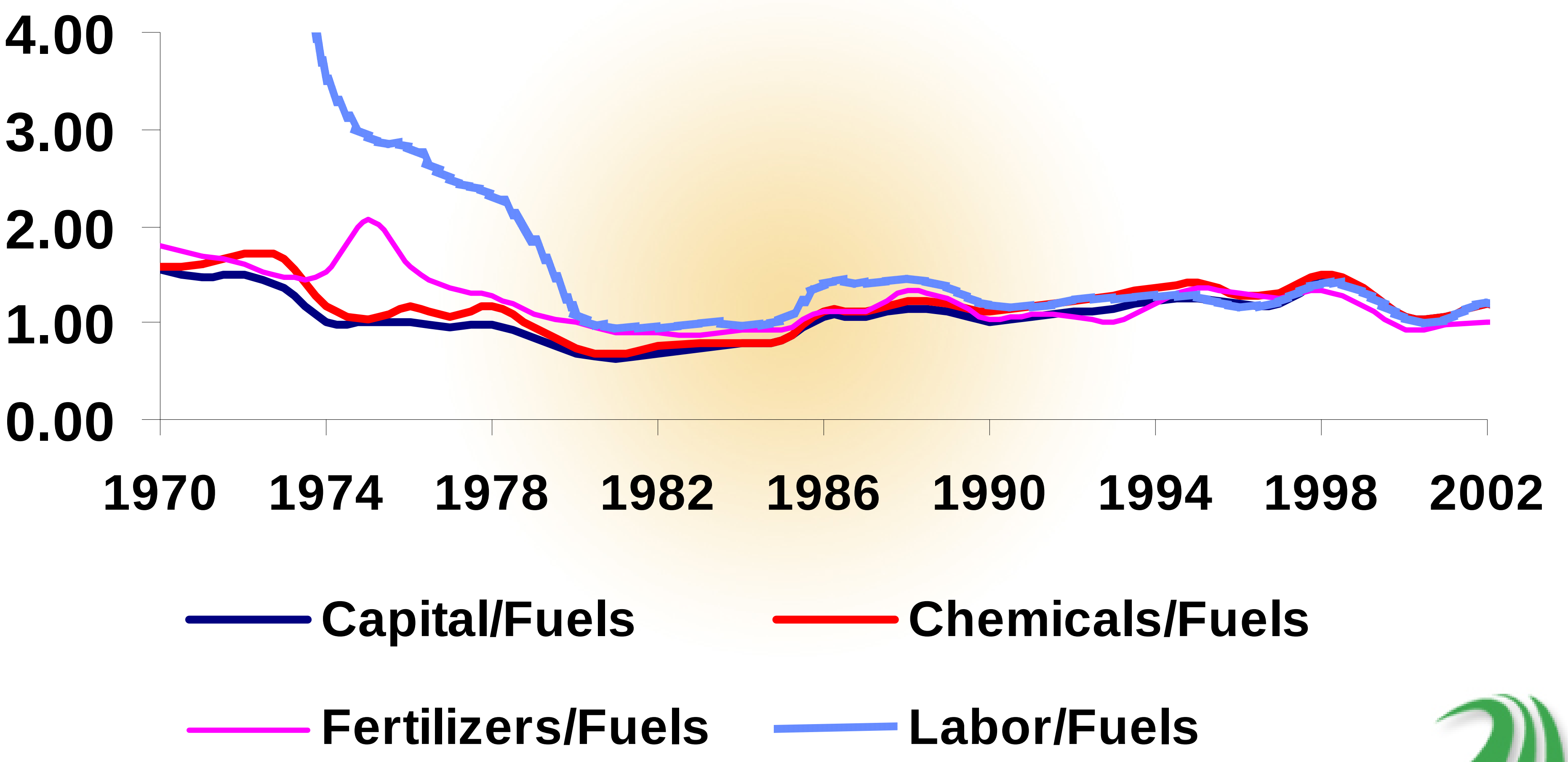
Nominal Prices of major fuel sources: 1970-2002



Real Prices of major fuel sources 1970-2002 (1996 dollars):



Relative Input Price Ratios



Own Price and Cross Price Elasticity Estimates

- Own price elasticity of direct and indirect energy inputs - -0.5 to -0.9

- A 10% increase in real energy prices will cause a 5-9% decrease in energy input use

- Short verses long-run elasticity estimates and farmer responsiveness

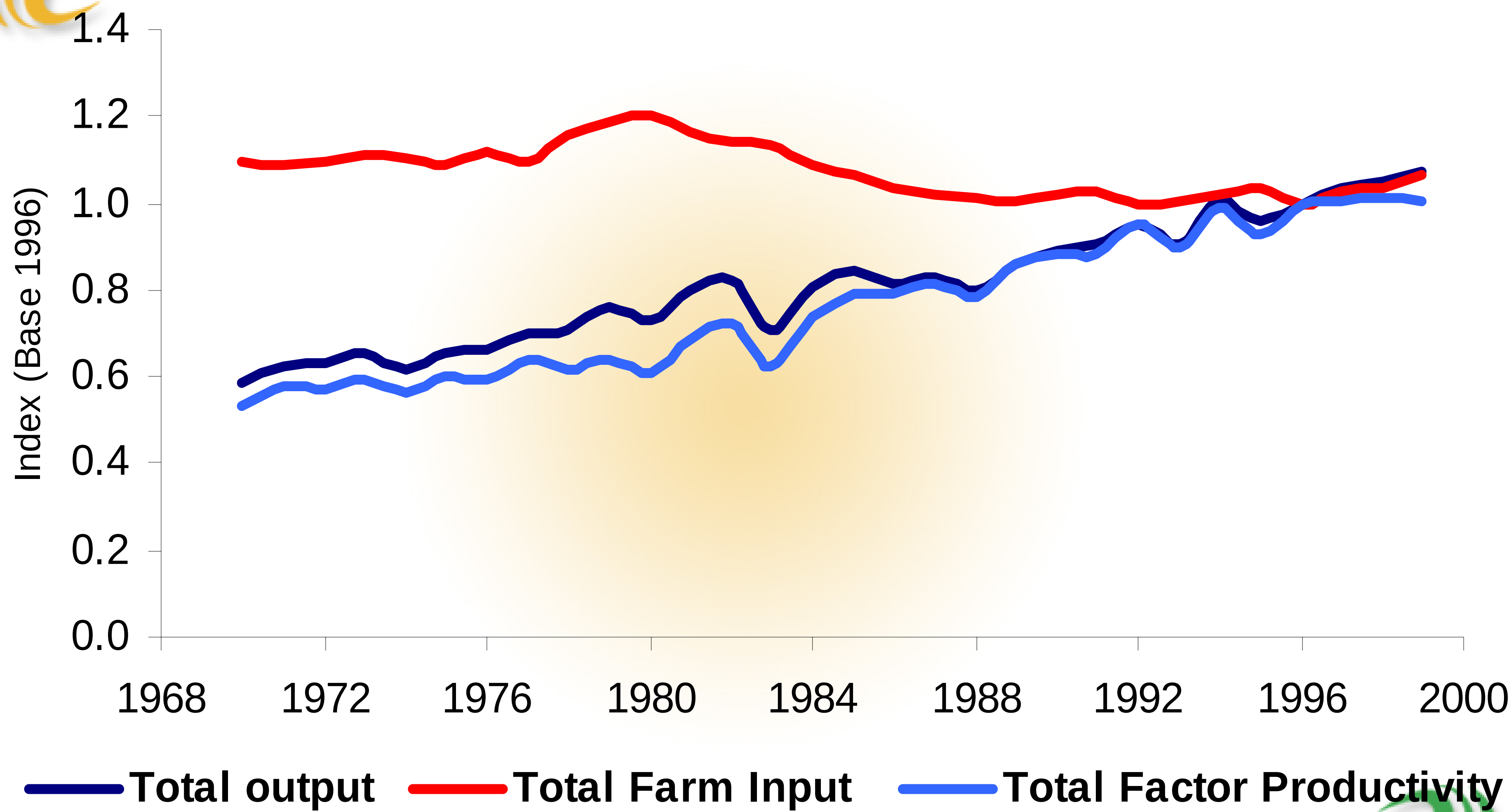
- Cross price elasticity estimates:
  - Energy/capital – 0.8
  - Energy/pesticides – 0.8

- No important input complementarities with energy

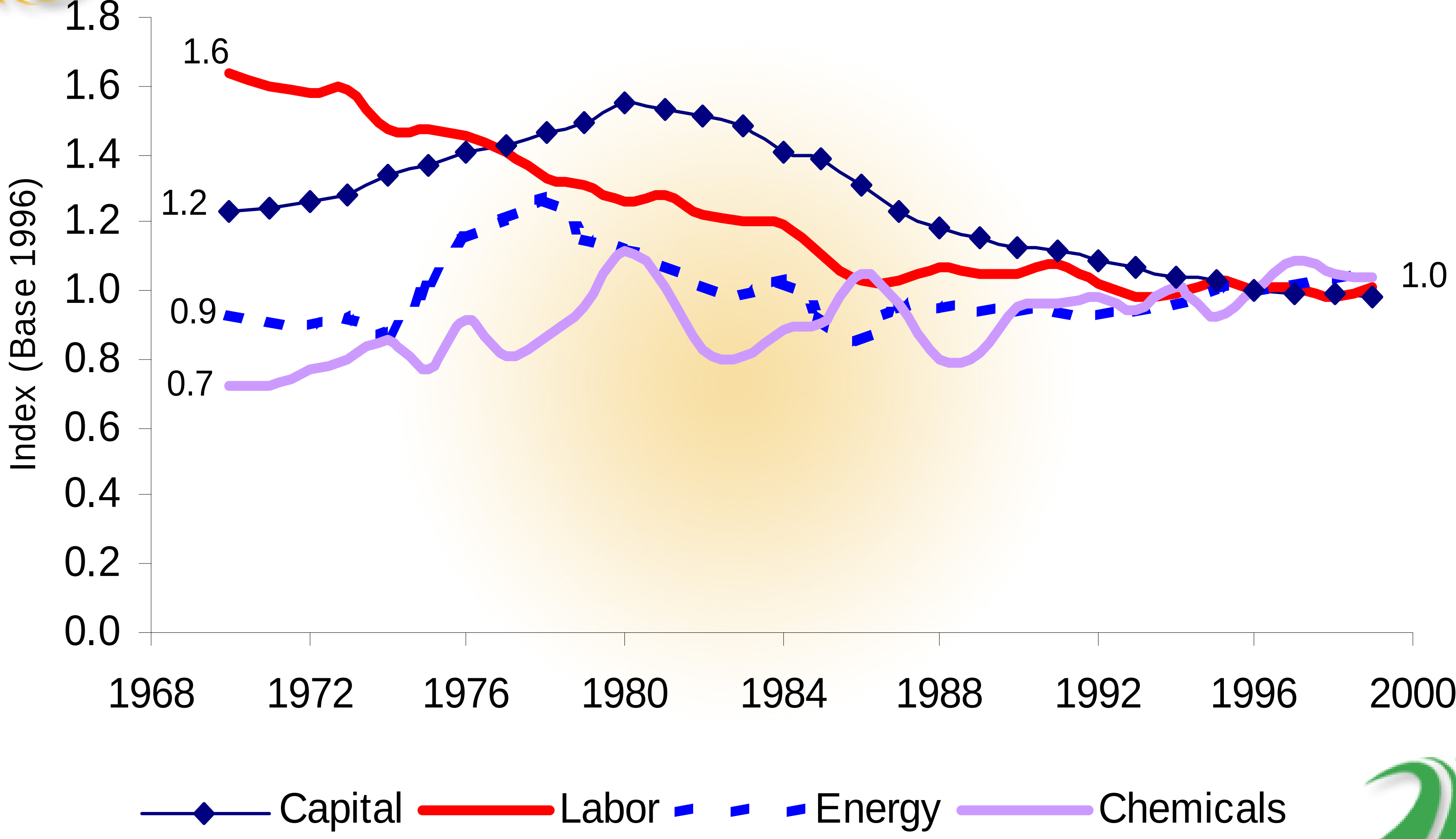
Farm Productivity and Efficiency

- 2% annual productivity growth in production agriculture
- Total input use is flat, but productivity and output are growing
- Individual input use declining except energy and chemicals after early 1990s
- Partial input productivity measures all increasing

Indices of Farm Output, Input Use and Productivity in US Agriculture



Indices of Major Farm Inputs Usage in US



Information and Technology Impacts on Energy Efficiency

- Continuation of productivity growth
- Substituting information for other inputs
- Substituting biotechnology for fertilizer, pesticides, energy, and pharmaceuticals
- Substituting information and knowledge for traditional breeding and husbandry

Rural Energy Security and Energy Supply Disruption Costs

- Energy disruption costs at points in production and processing
  - Specialty crop harvesting
  - Crop processing
  - Animal production
  - Animal harvesting
  - Dairy production
  - Fertilizer production
  - Ethanol production

- Seasonal energy use data would be required to assess such disruption costs

Integrating Farm Energy Demand and Supply

- Wind energy offers opportunities for on-farm or integrated energy production and use
- Bio-fuels have more limited on-farm potential due scale problems unless co-operative effort
- Solar offers potential power alternatives for livestock watering, electric fencing, and lighting in remote areas

Implications for Farm Energy Demand

- Important user of direct and indirect energy in crop and animal production
- Given sufficient time, producers do respond to real energy price incentives and make input and output adjustments
- Productivity growth enhances capacity to adjust
- Vulnerability to energy supply disruptions may be more critical, especially in short run

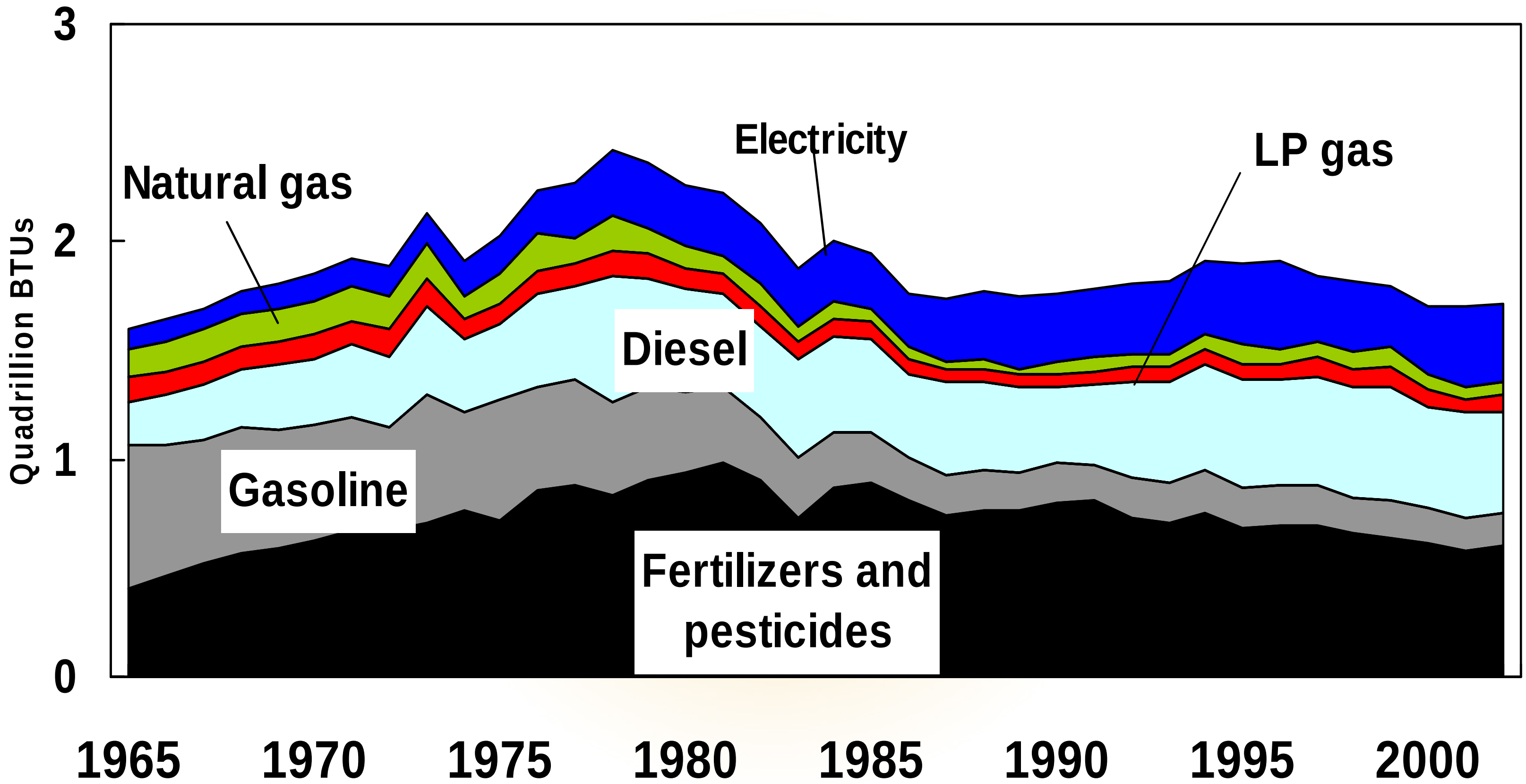
Conclusion

- Producers will mitigate impacts of real energy price increases and supply disruptions by modifying production practices given time to adjust
- Producers may invest in renewable energy and avoidance strategies
- Agriculture is resilient!

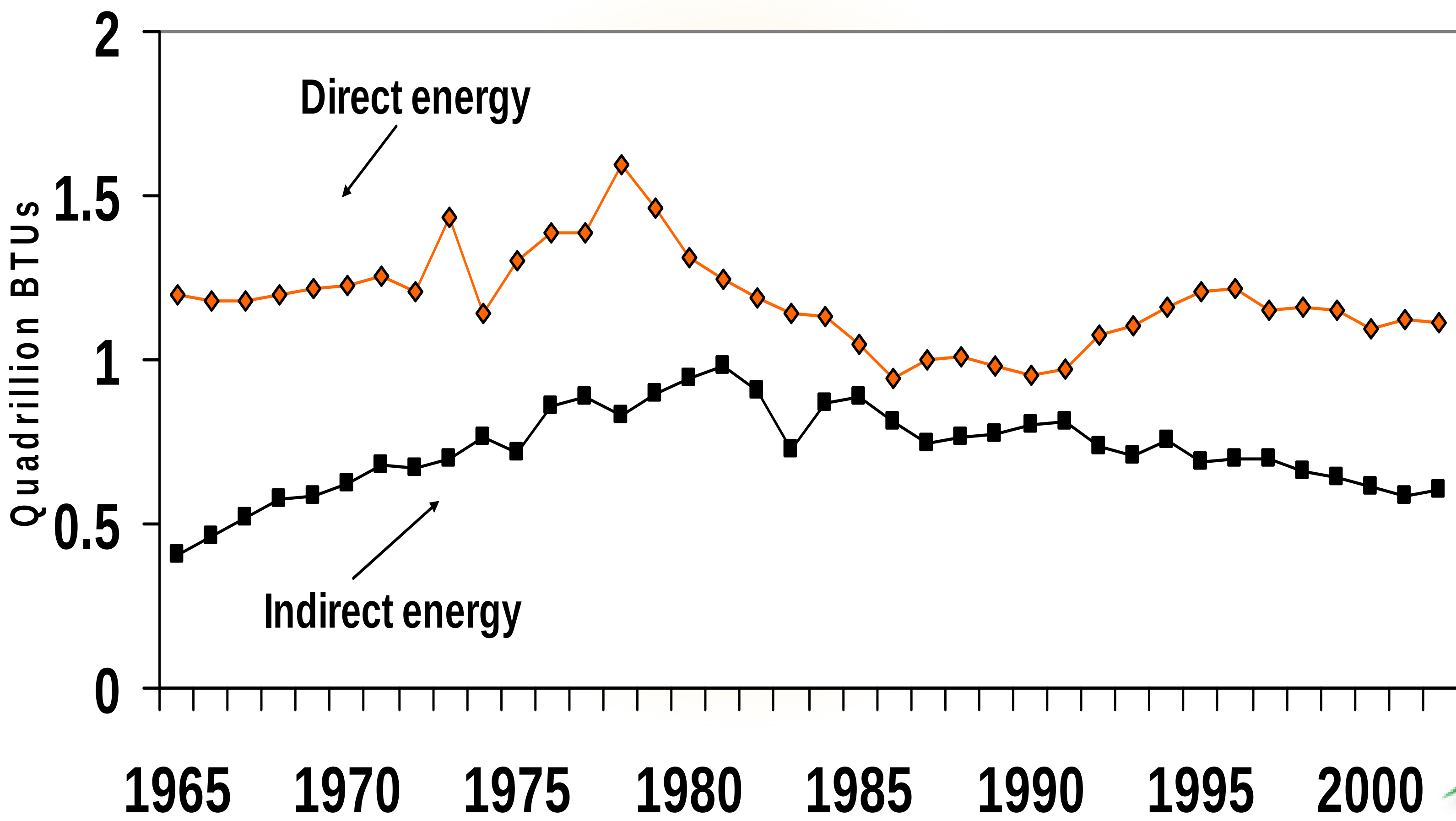
Thank You!

Supporting Slides

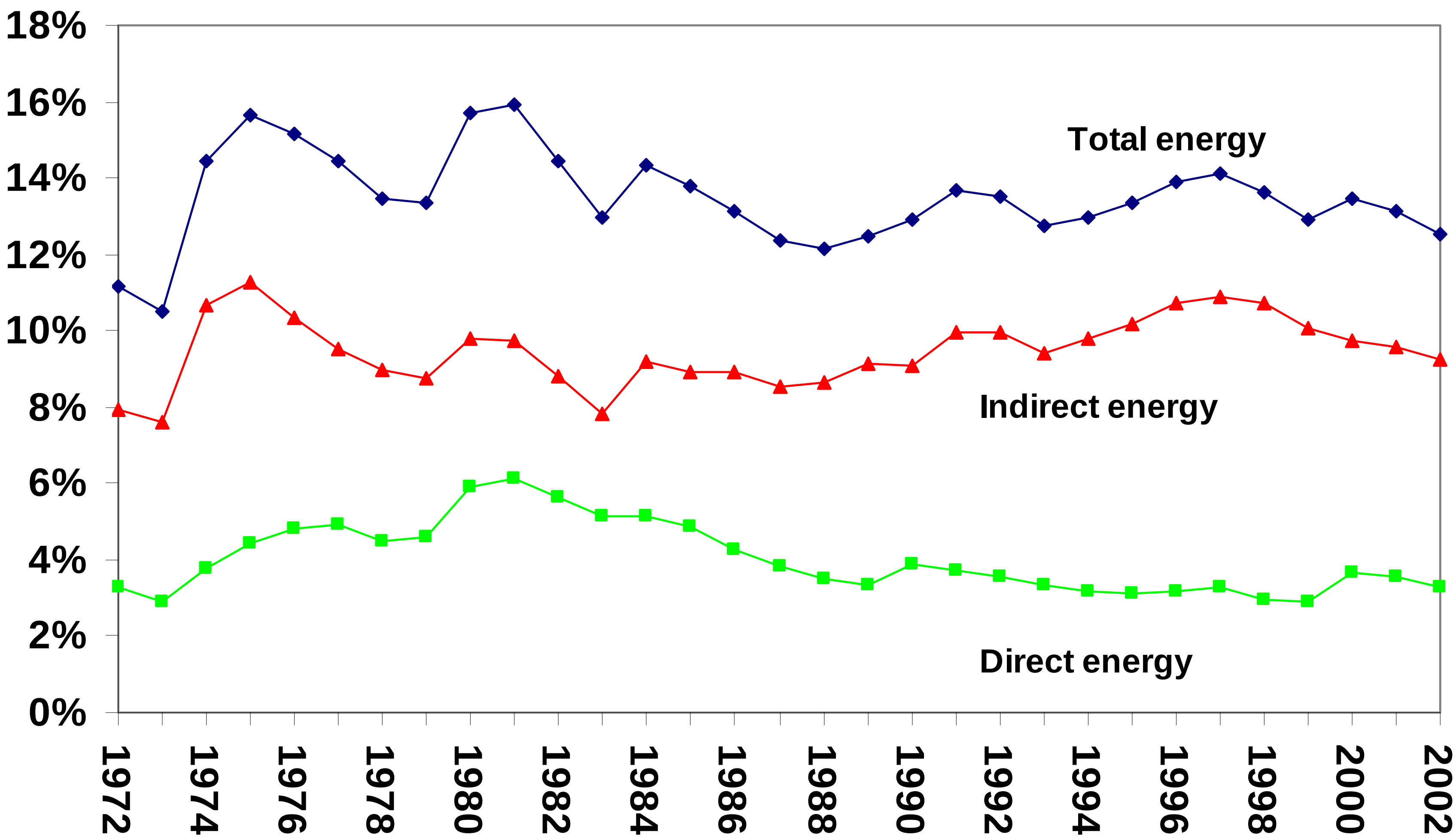
Total Energy Used on US Farms, 1965-2002



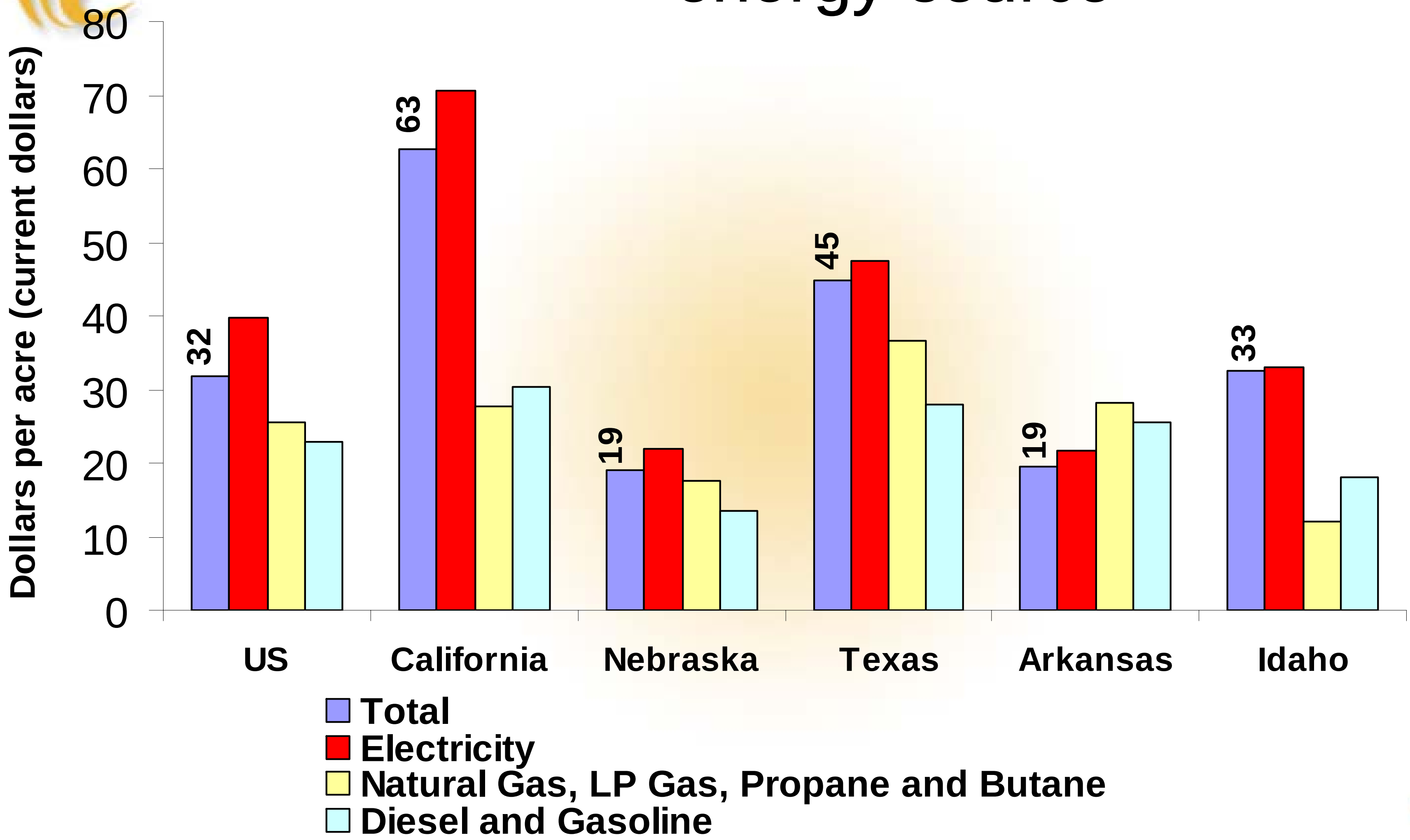
Direct and Indirect Energy Consumed on U.S. Farms, 1965-2002



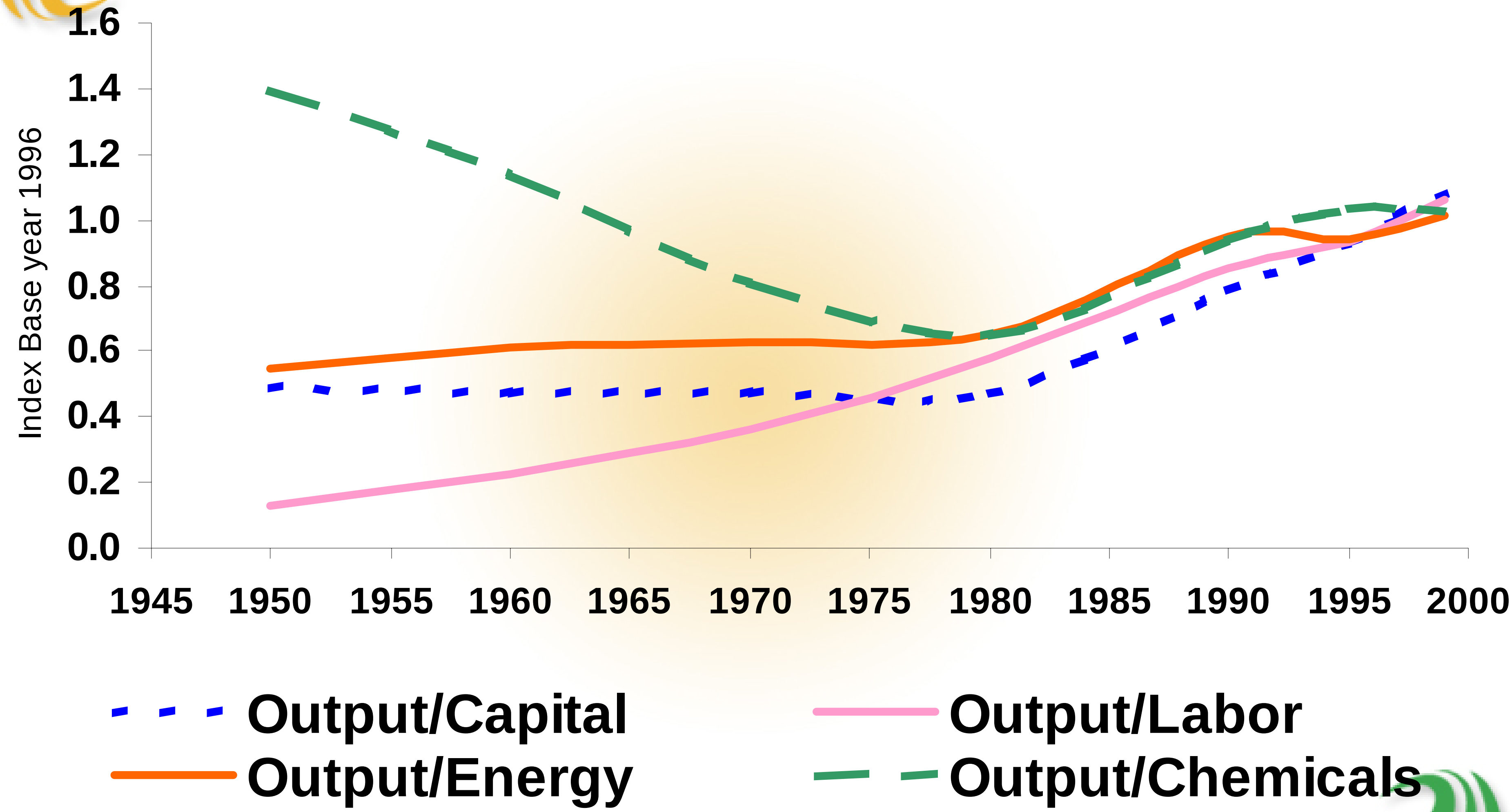
Energy's Share of Farm Production Expenses



Average Irrigation Costs Per Acre – by energy source



Partial Productivity indexes in US Agriculture:



Regional Energy Expense Shares in Farm Production

- Fuels and lubricants (direct)
  - Delta (7.6%) – Pacific (2.8%)
- Electricity (direct)
  - Pacific (5.8%) – Corn Belt (2.2%)
- Fertilizer and pesticides (indirect)
  - Delta (19.1%) – Northeast (6.8%)
- Summing top (32%) – bottom (12%)

Own Price Elasticity and Input Substitution Elasticities

Input	*Land*	*Labor*	*Capital*	*Energy*	*Fertilizers*	*Pesticide*
Land	-0.28					
Labor	-0.27	-0.39				
Capital	0.73	0.65	-0.86			
Energy	0.35	0.59	1.13	-0.60		
Fertilizers	*0.20*	*0.82*	*0.97*	*0.60*	*-0.66*	
Pesticides	*0.08*	*0.66*	*0.82*	*0.70*	*1.04*	*-0.53*

Energy Intensity (BTUs consumed per dollar) in US Agriculture, Food Manufacturing, Industry, and U.S. Economy