ADJUSTMENTS OF MIDWEST GRAIN FARM BUSINESSES IN RESPONSE TO INCREASES IN PETROLEUM ENERGY PRICES*

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INTRODUCTION

Since the early 1970s, the increasingly tight energy situation has introduced a new emphasis, if not a wholly new concern, into the economics of agriculture. Assuming the tight energy situation continues, or even intensifies in the future, it is likely to require economic adjustment in U.S. agriculture—an agriculture heavily dependent on fossil fuels [10, 11 and 12].

Dvoskin and Heady have shown that when maximizing farm profits is the primary goal, energy price levels have a minimal impact on acres of crops produced under reduced tillage methods in the U.S. [4]. However, when energy minimization was the primary goal, there was a substantial shift from conventional to reduced tillage. An ERS study proposes that forms of reduced tillage can be a major means of achieving fuel savings [5]. Reduced tillage methods do reduce fuel requirements, but these are accompanied by higher chemical requirements. Eidman, Dobbins and Mapp found that with current energy prices, a form of reduced tillage for corn production was preferable to conventional tillage methods [6]. In a recent study, Musser and Marable concluded that with respect to machinery purchases, energy cost increases are providing incentives for substitution of labor for capital [9].

One analytical method of looking at potential adjustments is comparison of cultural systems. One source of data is developing countries where production systems contrast sharply. Warnken has shown that energy price increases in Nicaragua are eroding comparative advantages that energy intensive farms have had in the past [13]. And yet, it would take a substantial energy price increase to completely eliminate comparative advantages which energy intensive farms have enjoyed. Warnken suggests that extreme changes in energy prices would have to occur before energy intensive farming would revert. Short of that, changes would be in degree only.

A recent study was made of potential adjustments profit-maximizing Midwest grain farms would make in responding to relatively higher energy prices [1]. The objective was to estimate changes in selected production practices, resource uses and enterprises which would accompany energy price changes at levels ranging from zero (free energy) to five times 1975 prices. Prices for products produced were assumed to remain constant at all energy price levels.[1] Thus, in relative terms, the energy price increase represented a wide range. Results are applicable to relative input-output prices and not necessarily to absolute energy price levels.

The four input factors tied directly to petroleum energy price changes were fuel, propane, chemicals and nitrogen fertilizer. Each of these inputs is highly dependent upon fossil fuels as the base stock and there was assumed to be a direct relationship between these input prices and the price for fossil fuels. For example, it was assumed that a doubling of the energy price would lead to a doubling of the price of

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[1] Given this assumption of constant product prices, the energy price range of zero to five times 1975 prices represents a substantial price range. Over the long run, energy price increases would force up prices for products produced. For these reasons, projected crop mix adjustments for relatively high energy prices should be treated with caution.

each of the four inputs. It is recognized that this assumption is influenced by changing short run and long run demand and supply conditions for each product, as a result of changing input and output price levels. In addition, the amount of further processing of each product will affect this relationship. Prices for products such as chemicals and fertilizers, which typically have a relatively greater amount of further processing than do fuel or propane, would be affected to a smaller degree by a given change in energy prices.

MODEL DEVELOPMENT

A firm-level linear programming (LP) model was used to analyze potential production adjustments to energy price changes.[2] The model was structured to maximize income over variable costs, subject to given resource constraints and selected input and output prices. An implicit assumption is that the production mix chosen would not affect other (fixed) costs. Costs such as machinery depreciation and land charges are treated as fixed.

As a modeling tool, LP permits selected information within the model to be changed parametrically. In the study, the energy price was varied parametrically while holding other information and assumptions constant. Observed solutions were used to determine potential impacts of energy price relationships on production mixes and technologies.

Production activities studied were those typically found on a Midwest grain farm. Crops were corn, soybeans and wheat. Pasture, silage and hay production along with selected livestock operations were also taken into consideration. Production practice alternatives centered around fertilization, tillage and chemical treatments. Data were obtained from farmers, technical specialists and cost of production studies. Prices received for products were average projected prices for the 1976-78 Midwest production period and were as follows: corn, $2.15 per bushel; soybeans, $4.75 per bushel; and wheat, $3.00 per bushel. It was assumed that the farm included 400 acres of land with the labor and machinery complement equivalent to that commonly found in the Midwest. Labor was divided into two-month segments, with 480 hours of labor available over each segment. All land was capable of continuous row cropping. Selected input requirements per acre for those activities selected by the model are presented in Table 1.[3]

The basic difference between double cropping activities shown in Table 1 is the amount of chemicals applied. Activity I is no-tillage with a high level of chemical useage while activities II and III are minimum tillage with a medium and low level of chemical application, respectively. In addition, 30 inch rows, or those capable of manual cultivation, are used in double cropping activity III. In all double cropping rotations wheat was produced under minimum tillage.

For corn, the basic difference hinges on amount and type of nitrogen fertilizer. When chemical fertilizers are applied, no-tillage is used as compared to conventional tillage for organic fertilizer. With organic fertilization, the amount of diesel fuel needed per unit increases substantially. This fuel is needed to work the organic fertilizer into the soil.

RESULTS

Impact on Cropping Patterns

As relative energy price index levels increase, a noticeable acreage substitution occurs first from corn and double cropped soybeans-wheat to single-crop soybeans, then to single-crop wheat (Figure 1).[4] Corn, a large user of energy, is well suited to relatively low energy prices; whereas soybeans, which use relatively less energy, compete better at relative average energy prices (index of 100-300, 1975=100). Wheat, a relatively low energy-demanding crop, displaces both at the highest relative energy price levels (index of 300-500).

Although single-crop soybeans entered the plan only at the intermediate energy price level, soybeans double cropped with wheat came in at all energy price levels. However, double cropping became relatively less important at the higher energy prices.

At relatively high energy prices, corn acreage became small with all the corn produced being utilized by a cattle feeding enterprise. In addition, at energy price index levels of 300-500, all corn fertilization was organic, coming from the associated cattle feeding enterprise. No provision was made in the problem for manure purchase. Without availability of livestock feeding, it is doubtful any corn would remain at the highest energy price index levels.

As an example of how relative energy prices

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[2] For a mathematical interpretation of linear programming check reference sources [2, 3 and 7].

[3] For a more lucid discussion of all activities included in the model see Chavas [1]. In total, there were 25 corn growing activities, six soybean growing activities, four double cropping (wheat-soybeans) activities and two wheat growing activities. Activities varied by tillage practices, fertilization levels and chemical treatments. There were 13 beef cattle livestock enterprises ranging from cow-calf to feeding enterprises.

[4] Energy price and energy price index are used as synonomous terms.

TABLE 1. INPUT REQUIREMENTS AND PRODUCTION TECHNIQUES FOR THE PRODUCTION ACTIVITIES SELECTED

Activity	Diesel Gals.	Propane Gals.	Nitrogen lbs.	Chemicals Dollars	Row Width Inches	Tillage[a] Method	Yield Bu./Ton
Double Cropping (Wheat-Soybeans)							
I	7.66		60	35.00	15	NT	50-23 bu.[b]
II	7.74		60	24.00	15	MT	50-23 bu.[b]
III	7.84		60	9.00	30	MT	50-20 bu.[b]
Corn							
I	5.23	18.3	200	20.50	30	NT	110 bu.
II	4.95	16.7	150	20.50	30	NT	100 bu.
III	4.65	15.0	110	20.50	30	NT	90 bu.
IV	14.00	16.7	300[c]	9.00	30	CT	100 bu.
Soybeans	5.27			24.00	15	MT	35 bu.
Wheat	5.00		60			MT	50 bu.
Silage	17.65		150	9.00	30	CT	15.5 ton
Hay	9.15						2.5 ton

[a]CT = Conventional tillage—tillage is with a moldboard plow, disk, harrow, cultivator or similar tool
MT = Minimum tillage—tillage is with a chisel plow and one other operation
NT = No tillage—seed is planted in undisturbed soil with no-till planter.

[b]Wheat yields are 50 bushels per acre and soybean yields are 23 and 20 bushels per acre.

[c]This represents 20 tons of manure per acre as the source of fertilizer. On the average, a ton of fresh manure will contain about 15 pounds of nitrogen.

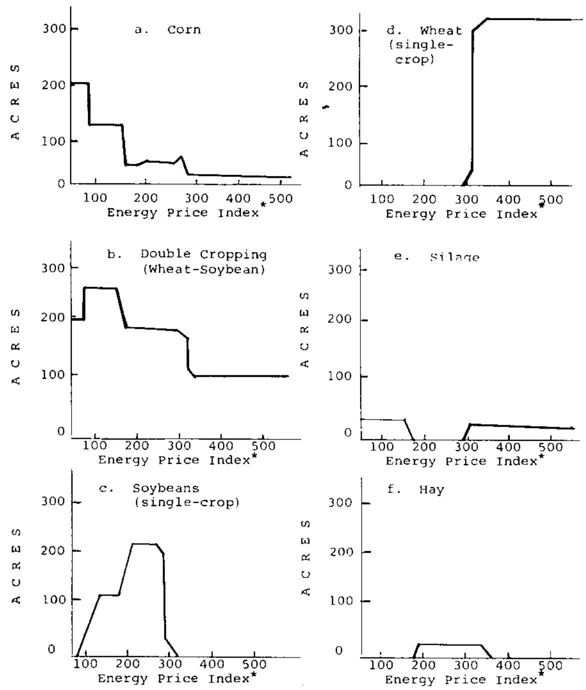
affect rates of mineral fertilization and tillage practices, "best" solutions were calculated for corn and single-crop soybeans. Table 2 presents some fertilization and tillage adjustments for corn through use per acre implicit values. Implicit values per acre represent a change in the objective function resulting from forcing one more acre of the crop into the production mix. Therefore, the lowest implicit value with respect to each relative energy price represents the best corn fertilization level and tillage method for that respective energy price. However, if no values are zero, it means other crops enter the optimal crop mix at those respective energy price levels. For example, when the relative energy price is 100, the best corn production combination is no-tillage with a high level of fertilization. Furthermore, for every acre of corn produced under conventional tillage methods with low fertilization rates at this same relative energy price (100), returns over variable costs are reduced by $79.

In making comparisons of implicit values, relative relationships are more important than absolute relationships. Thus, from a relative standpoint, no-tillage corn with high fertilization is the best corn production option up through an energy price index of 300. At indexes of 400 and 500, the best production option for corn is a low level of fertilization with conventional tillage. This movement from high to low levels of fertilization as energy prices increase is consistent with findings of Miranowski, Pidgeon and Peterson [8] and Dvoskin and Heady [4].

Thus, there is a movement in corn production technology from no-tillage to conventional tillage as relative energy prices increase. Also, the rather obvious movement away from the high fertilization level is present, but not until relative energy prices have tripled over those prevalent in 1975.

Implicit values for single-crop soybeans are shown in Table 3. With single-crop soybeans, production technology moves from no-tillage to minimum tillage as relative energy prices increase.[5] In fact, minimum tillage is the preferred production method at all energy price levels and both row widths except for the zero energy price level. No-tillage is the

[5]Implicit values for double crop soybeans (wheat-soybeans) follow quite closely this same pattern.



*1975 Energy Price = 100

FIGURE 1. ENERGY PRICE EFFECT ON THE CROP PRODUCTION MIX OF A 400 ACRE MIDWEST GRAIN FARM

TABLE 2. IMPLICIT VALUES FOR THE REAL ACTIVITY CORN[a]

Tillage Method	ENERGY PRICE INDEX 0	100[b]	200	300	400	500
	HIGH CHEMICAL FERTILIZATION[c]					
CT[d]	12	17	18	20	43	69
MT	3	12	17	23	50	80
NT	0	0	1	9	49	93
	LOW CHEMICAL FERTILIZATION[e]					
CT	105	79	60	44	36	47
MT	100	78	63	51	55	62
NT	97	66	47	36	56	76

[a]Implicit values for Real Activities are sometimes called "shadow prices." In effect, these values represent the change in the objective function resulting from forcing one more acre of the crop into the optimal solution. Or, it represents how much the per acre returns for that respective activity would need to increase before it would enter to optimal crop mix.

[b]1975 energy prices = 100.

[c]Fertilization rate is 200-80-100 of NPK, respectively, per acre.

[d]CT = Conventional tillage; MT = Minimum tillage; NT = No tillage.

[e]Fertilization rate is 20-8-10 of NPK, respectively, per acre.

TABLE 3. IMPLICIT VALUES FOR THE REAL ACTIVITY SINGLE-CROP SOYBEANS[a]

Tillage Method	ENERGY PRICE INDEX 0	100[b]	200	300	400	500
	15 INCH ROWS					
CT[c]	20	3	2	5	27	48
MT	16	0	0	3	24	45
NT	14	9	20	34	66	98
	30 INCH ROWS					
CT	43	23	14	5	7	8
MT	40	19	10	1	2	4
NT	37	30	41	54	87	120

[a]Implicit values for Real Activities are sometimes called "shadow prices." In effect, these values represent the change in the objective function resulting from forcing one more acre of the crop into the optimal solution. Or, it represents how much the per acre returns for that respective activity would need to increase before it would enter to optimal crop mix.

[b]1975 energy price = 100.

[c]CT = Conventional tillage; MT = Minimum tillage; NT = No tillage.

preferred method at the zero energy price level. For soybeans the more important criterion seemed to be chemical treatment, which in turn determined row width. Preferred row width was 15 inches up through an energy price index of 200 and 30 inches for the energy price indexes above 200. Movement to 30 inch rows allows mechanical cultivation as a means of weed control.

Impact on Resource Value and Useage

As an example of how relative energy price increases affect resource useage and resource values, shadow prices for resources are presented in Table 4. These values can be interpreted as imputed marginal value products (MVPs) for each respective resource at the respective relative energy prices. Any input not completely utilized will have a shadow price of zero.

Labor for the months January through June was never fully utilized and therefore had a MVP of zero. However, July through August labor had a relatively high MVP that increases up to $41.37 per hour with increases in energy price up to an index of 300 and then declined rather sharply with further energy price increases. Labor for September through October follows somewhat the same pattern but had a substantially lower MVP. The MVP for additional labor in November-December is directly correlated to the corn producing activity with a relatively high value when energy prices are low and decreasing rapidly with increases in energy prices. In general,

TABLE 4. SHADOW PRICES FOR RESOURCES

	ENERGY PRICE INDEX					
Resource	0	100[a]	200	300	400	500
Labor						
July-Aug		21.89	34.93	41.37	30.20	19.41
Sept-Oct	1.78	4.77	6.19	7.23	4.90	3.11
Nov-Dec	36.96	18.84	5.83	0.00	0.00	0.00
Land	140.40	89.44	54.97	32.85	34.72	35.64
Double Crop	17.79	24.10	25.10	25.38	24.27	23.29

[a]1975 energy price = 100.

total annual labor hours utilized increased up through an energy price index of 300 and thereafter decreased.

The shadow price for land decreased rather rapidly from $140 per acre with free energy to $30 per acre with an energy index of 300, and increased slightly thereafter. This was expected as production costs increased relative to output prices. The result is a lower rent value for fixed factors, or in this case, land. However, magnitude of the change is relevant in indicating potential impacts of increased energy prices on land values. The shadow price for double crop acres remained relatively stable as energy prices were increased. To some degree this explains why wheat double cropped with soybeans entered the crop mix at all energy price levels.

Impact on Energy Consumption

Energy consumption varied by type of energy product used (Figure 2). For example, utilization of fuel (gasoline, diesel and L-P for tractors, trucks and combines) is affected minimally by energy prices. Propane use (primarily crop drying) on the other hand, is highly responsive to energy prices. For example, at an energy price index of 500, fuel consumption is about 85 percent of 1975 consumption, while at the same price index, propane consumption is only about eight percent of 1975 consumption.

Estimated utilization of chemicals also proved to be quite responsive to price. Chemical usage, of course, varies with tillage practices; and at relatively higher costs, less chemical-intensive production practices were chosen.

There appears to be two points in the price curve for energy where quantity of energy used responds rather sharply to price. One is at a level about 50 percent above 1975 prices. The other is at energy prices about three and one-half times above those of 1975.

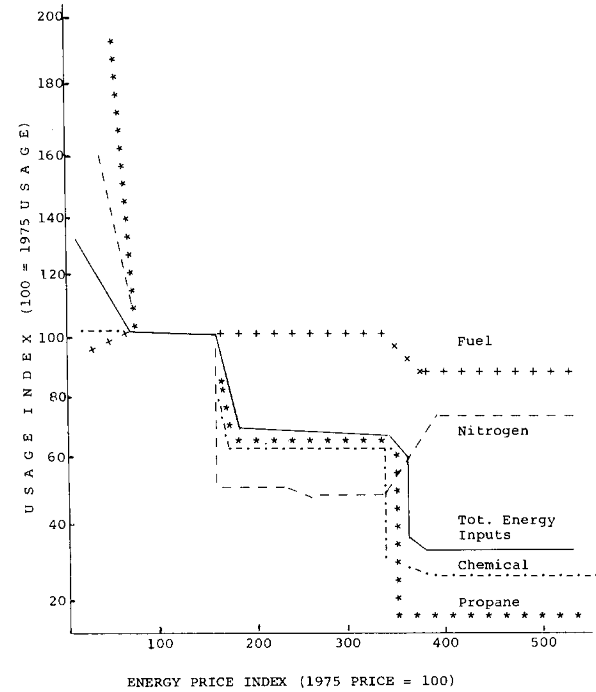


FIGURE 2. RESPONSE OF FUEL, NITROGEN, CHEMICAL AND PROPANE USAGE TO ENERGY PRICES

SUMMARY

If there is no significant breakthrough in energy technology in the years ahead, the world is likely to see rather regular increases in the price of energy in its various forms. Farm input industries that use fossil fuels as feed-stock will unavoidably be affected; and their cost increases will at least in part be passed on to the farmer. Therefore the question is raised as to how farmers can and will adjust their production to changing cost-price relationships.

Potential adjustments for a Midwest grain farm would be successive substitution from corn to single-crop soybeans to wheat. Adjustments for soybeans were from no-tillage with 15 inch rows to minimum tillage with 30 inch rows as energy price increased. Shadow prices for land fell sharply as energy prices increased up to three times 1975 prices.

Chemical and propane consumption was quite responsive to price changes while fuel consumption was less so. Energy demand was most responsive to relative energy prices 50 percent above and three and one-half times above 1975 prices.

The usual *caveat* must be added. The study was limited in scope, and only the more general indications are trustworthy. Nevertheless, the changing energy situation is likely to involve important shifts in economic relationships among the energy industry, the farm input industry, and farmers—and ultimately the food industry and consumers. Some changes in production on Midwest grain farms may go in the general directions described here.

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