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Energy, Agriculture and Crop Surpluses

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This paper examines the impacts of potential higher prices and short supplies for energy inputs used in the production of agricultural commodities. We focus specifically on the issue of the extent to which the cost or availability of energy inputs might lead to a situation in which the United States would no longer be a surplus producer and net exporter of agricultural commodities.

From the 1950's through the 1970's, American agriculture was able not only to fulfill domestic food demands, but also to provide a significant portion of the food needed as a result of shortages that occurred in a number of developing nations. This overcapacity of American agriculture occurred both because of only a modest increase in domestic food demands and because of high rates of growth in productivity. For example, birth rates in the U.S. decreased markedly in most of the U.S. between 1960 and 1980. Moreover, output per acre for many individual crops in the U.S. is high relative to many other countries. However, in some instances, output per unit of cropland is low in comparison to small, intensely cultivated plots in some developing countries. And the rate of growth in agricultural productivity in the U.S. during the last thirty years has averaged only 1.7 percent per year. This compares with 2.4 percent per year for many other developed and some developing countries (Binswanger and Ruttan, Hayami and Ruttan, Ruttan).

The productivity of American Agriculture has traditionally been traced to three primary factors:

(a). The mechanical revolution which relied heavily on the replacement of labor with machinery and low cost liquid fuels to run mobile power plants.

(b). The availability of chemical fertilizers and pesticides at low cost.

(c). The genetic revolution, which substantially increased ratios of output to input for crops and livestock.

We argue here that one of the most important components of productivity growth can be traced to the reduction in the real prices of energy inputs that took place. The reduction in the cost of energy in the form of gasoline, diesel fuel, and natural gas, (a) induced the substitution of mechanical power, (b) made possible irrigation of previously arid lands, (c) made high levels of fertilization possible which resulted in continuous cropping in much of the U.S. and increased per acre yields, and (d) sustained soil productivity at the level such that the promise of the genetic revolution with respect to crop yield increases could be fulfilled. Farm programs limiting crop acreage further induced the use of fertilizer and pesticides. As the real price of energy increases, a similar substitution may take place which will induce energy saving technologies.

A Hierarchy of Energy-Related Concerns

Four major energy and input-related issues are important.

(a). What impact will increasing energy prices have in aggregate agricultural productivity and output in the United States?

(b). What will happen to fertilizer prices? What crop price levels will be necessary to sustain fertilizer use and crop yields at or near current levels? Will production technology change as a result of higher fertilizer prices in real terms?

(c). What about other inputs, particularly energy-related inputs used in crop production?

(d). What impact might the production of a alcohol from agricultural sources have on supplies of agricultural crops. Can crop yields be sustained if residuals are removed and used in the production of alcohol?

We will examine in detail each of these issues.

An Aggregate Supply Function

An econometric analysis of aggregate supply captures the interrelationships in the agricultural sector between input and commodity prices and provides an estimate of resultant aggregate supply response in the face of increased energy prices. We estimate an aggregate supply function for U.S. crops by incorporating two energy related measures as key explanatory variables into a specification originally proposed by Tweeten and Quance. The model specification is:

$$AGGSC_t/IPD_t = f(PR_t; PG_t/IPD_t; PNG_t/IPD_t)$$

The aggregate supply of crops for the U.S. weighted by the dollar value for each crop ($AGGSC_t$) deflated by the implicit price deflator (IPD_t) is a function of the prices received index (PR_t), the price of gasoline deflated by the implicit price deflator (PG_t/IPD_t) and the price of natural gas deflated by the implicit price deflator (PGN_t/IPD_t). The model was estimated as a multiplicative function and, as a result, coefficients are directly interpretable as elasticities (Trabelsi). The results were as follows:

$$AGGSC_t/IPD_t = .00844PR_t^{\,.87}\,(PG_t/IPD_t)^{-.23}\,(PNG_t/IPD_t)^{-.29}$$

A one percent increase in the prices received index (PR_t) will result in a .87 percent increase in aggregate supply ($AGGSC_t$). A one percent decrease in the real price of gasoline (PG_t/IPD_t) will result in a .23 percent increase in the aggregate supply of crops. A similar one percent decrease in the real price of natural gas will result in a .29 percent increase in the aggregate supply of crops. All coefficients were significant at the .05 level. While these elasticites are all less than one, they do suggest that much of the productivity of American agriculture can be directly traced to declining real energy prices. Only recently have real energy prices started to increase. Whether increases in real energy prices will lead to as substantive reductions in aggregate crops supply as this equation would suggest is an empirical question which will only be resolved through observation over the next decade.

Fertilizer, Energy and Crops: A Marginal Analyses

As indicated earlier, the availability of low cost fertilizers has had dominant impacts on the productivity of American agriculture and made possible the fulfillment of the genetic revolution. Between 1955 and 1977, fertilizer use doubled in the United States. Even with a slight decrease in the total crop land base because of urbanization, and with the increased use of marginal and fragile lands, production of crops increased by more than 50 percent.

Corn yields in the midwest are highly dependent on the availability of sufficient nitrogen. An eight year Purdue agronomy farm average would suggest that typical corn yields using contemporary hybrids and 175 pounds of available nitrogen per acre would result in an average 144.4 bushels per acre yield. This is compared to only 46.6 bushels per acre with no nitrogen fertilizer. These data serve as a reminder that much of the productivity of grain production in the U.S. can be directly attributable to the availability of adequate nitrogen supplies at low cost.

Current production technology for ammonia, the primary source of fertilizer nitrogen, relies on natural gas as the primary ingredient. Some 37,600 cubic feet of natural gas is required to produce a ton of nitrogen fertilizer. The current price of this natural gas to the fertilizer industry ranges from 1.64-2.00 per 1000 cubic feet. By 1990, this natural gas is expected to increase to approximately $9.00 per 1000 cubic ft. (Chase Econometric Associates). Such increases might initially be expected to have substantive impactson fertilizer prices, fertilizer use, crop yields, crop prices, and supplies.

However, the true picture may not be as bleak as these initial data would suggest. Even though natural gas is the primary ingredient in the production of ammonia, the $1.64/1000 cubic foot price represents only 25.6 percent of the cost of the nitrogen to the farmer (Table 1).

Moreover, from a marginal product point of view, nitrogen fertilizer is extremely productive. Table 2 provides an estimate of the marginal physical and marginal value products of nitrogen in the production of corn at alternative corn prices and nitrogen application levels. Maximum profit is achieved by equating the marginal value product to the price per pound of available N. Even at corn prices of 3-4 dollars per bushel, nitrogen prices would have to increase several fold to have a significant impact on the profit maximizing level of nitrogen use and the resultant corn yields.

By how much fertilizer prices will increase in response to higher natural gas prices is unclear. However, we do know that an increase in natural gas prices per thousand cubic feet from $1.64 to $9.00 will increase the cost of natural gas of from 3.65 to 20.63 cents per pound of available N. Less clear are the magnitude of increases in other costs. Ammonia production is capital not labor intensive, typically requiring only one half hour of labor per ton. Transportation costs are important. A major production area for ammonia production is along the gulf, and transportation to the corn belt under current prices runs approximately 35 dollars per ton. Other costs should increase more in line with the general inflation rate in the economy, and it does seem unlikely that nitrogen prices would increase beyond a 70-80 cent per pound level even in the face of nine dollar natural gas prices.

Qualifications need to be made with respect to this analysis. Although the data used in estimating marginal products were experimental data, they are not unrepresentative of a typical yields at the farm level in productive regions of the corn belt on competently managed farms. However, yields as well as marginal products might be larger than could be generated in less productive regions, and, as a result, these findings may understate changes in nitrogen fertilizer use in response to higher prices for these regions. Moreover, most farmers face capital constraints and must ration capital such that nitrogen is not applied up to the point where the last dollar generates a dollar of additional revenue. As a result, farmers may again reduce nitrogen to higher prices to a greater extent than this analysis would indicate.

Agricultural crops and production technologies vary widely in the use of chemical nitrogen. Soybeans, the major alternative crop in much of the corn belt, is a legume, and little if any chemical nitrogen is normally applied. Wheat in general has lower requirements for nitrogen per acre then corn. In the upper great plains, production technology which requires that land lie idle in alternate years because of limited dryland moisture, also curtails the need for significant amounts of fertilizer nitrogen.

The impact of higher energy prices will probably be less for potash and phosphate than for nitrogen. This is because these fertilizers are mined rather than produced from natural gas. The primary energy requirements for potash and phosphate production are for processes such as mining, screening and washing, and for transportation. As a result, one might expect phosphate and potash price increases to not substantially outdistance the general rate of inflation. However, phosphate and potash sources represent nonrenewable resources, and as these resources become more scarce, prices will rise in real terms, through perhaps not at the rates we might expect for nitrogen. Marginal analysis can suggest the optimal level of fertilizer and energy use for the individual farmer. However, the marginal analysis can supply information on whether or not a farmer will continue to produce in the face of higher energy prices only if (1) the marginal products of all other inputs and their prices can be accurately measured (2) other constraints such as the availability of dollars for the purchase of inputs are known, and (3) the equating of ratios of value of marginal product to input prices between inputs takes place.

A Farm Budget Approach

Farm enterprise budgets reflect the short and long-run profitability of farm enterprise, and provide information with respect to whether or not an enterprise will be abandoned in the face of input price changes. A specific farm enterprise budget at the micro level applies only to a single crop or livestock activity for a farm, but is clearly not representative for all farms in all regions.

A farm enterprise budget is a simple way of determining for a set of possible input (energy and other) and output prices, if a farmer will continue to produce in the short or long-run, or abandon the enterprise.

Table 3 compares the costs of production for three major grain enterprises, corn and soybeans in the corn belt, and wheat production in the central great plains. If interest on capital investment is excluded, a minimum corn price of $1.60 per bushel is required to cover other production costs with current fuel and fertilizer prices. This increases to $3.34 per bushel if all costs are included. Comparable figures are 3.60 and 8.72 for soybeans and 3.13 and 5.38 for dryland wheat. A "worst case" assumption would entail a tripling of real nitrogen and fuel prices with resultant real increases in corn prices to $2.83 excluding capital investment or $4.57 if all costs are covered. Comparable figures for soybeans are $5.12 and $10.23 per bushel and $5.28 and $7.53 for wheat. Of course, the general level of inflation will affect prices of inputs other than fuel and fertilizer.

As a result, grain prices will need to increase at the same rate in money terms if production costs are to be covered.

Biomass, Gasohol, and Crop Surpluses

Biomass energy from agriculture can come from a number of sources. Alcohol might be distilled directly from grain crops. Crop residues, forestry products and agricultural wastes might also be used to produce alcohol or simple organic fuels such as methane.

The potential of agriculture as a producer of renewable energy has received considerable attention particularly in the past three years. Tyner calculates that we can produce approximately 2.5 percent of U.S. energy needs each year by transforming crop residues into alcohol, and that these residues could be removed without significantly reducing organic matter content nor impairing soil structure. However, cost estimates for alcohol production vary widely depending on the assumptions that are made. If current overcapacity existing in conventional distilleries were used to produce alcohol from grain, the cost of production would far exceed the cost of liquid fuels energy from petroleum distillates. New conversion technology now operating on an experimental basis suggests that the conversion of grain to alcohol could take place at a cost per gallon that would be competitive with the cost of liquid fuels produced from foreign oil, with grain at current market prices. However, the adoption of such technology will require massive fixed investment in plant and equipment (Meekhoff, Gill and Tyner).

Crop residues show considerable promise in that the cost of the residue is very low in comparison to the cost of grain. However, crop residues are bulky, and costly to transport. Optimal plans for alcohol producing plants from crop residue usually call for small plants located no more than a few miles from the residual production site. The production of significant amounts of alcohol will again require large fixed plant and equipment investments.

Moreover, market signals continue to be inadequate. Removal of crop residue on a large scale cannot be expected to ultimately have zero impact on soil productivity, and additional energy-based fertilizer might be necessary to restore productivity resource scarcity [and hence market prices] should summarize the direct and indirect sacrifices made to obtain the availability of a resource (Debertin and Pagoulatos, Smith and Krutilla).

Accordingly, we conclude that while energy from biomass production has the potential to remove large amounts of grain from the export market, and the technology now exists to convert grain to alcohol at prices competitive with fuel from petroleum. This is not going to take place on a large scale until market signals are clearly in favor of the alcohol production. This is necessary to support the massive fixed investment requirements. OPEC has chosen to put the real price of oil at levels below that necessary to support the capital investment, and it may be a decade or more before market signals are significantly reversed to sustain the investment. The same is true for the crop residue technology.

Concluding Comments

The productivity of American agriculture over the last several decades can largely be traced to the decline in real liquid fuels prices relative to labor, and the substitution of liquid fuels using capital for human and animal power. An aggregate supply approach, a marginal analysis, or an enterprise budget approach can be used to trace the impacts of increasing real energy prices on American agriculture.

Farm enterprise budgets, marginal analysis and aggregate supply models really provide insight into different aspects of the same problem. The farm budget provides the shutdown point for a farmer faced with a fixed array of output and input prices which include energy. Marginal analysis will lead to the same conclusions only if the productivity of all inputs can be accurately measured, and other constraints faced by the individual farmer such as limitations on the availability of dollars for the purchase of inputs are known.

An aggregate econometric approach cannot take into account these micro level constraints faced by each farmer individually, but does have the advantage in that output prices to the agricultural industry in total are treated as variable. This is consistent with the price theory of pure competition at the industry level. Aggregate price in the econometric approach is actually determined as a result of the summation of (1) decisions by individual farmers to produce or shut down, and (2) for farmers who choose to produce, with the application of marginal analysis by each farmer in the selection of the level of inputs to be used, given a set of input prices.

With increasing real liquid fuels price increases, we expect that:

1. The rate of productivity growth for U.S. agriculture will decrease markedly from the current average 1.7

percent per year to perhaps under 1 percent.

2. Increased costs for fuel and fertilizer will result in increased prices for grain and fed livestock products which perhaps outstrip the general rate of inflation.

   Nonrenewable energy inputs (natural gas and petroleum products) constitute a greater proportion of total costs for farm products than for many manufactured items.

3. Production technology for wheat and feed grains may not change as much as the pessimists like to believe. The marginal productivity of fertilizer and fuels are high enough such that no major shift in technology will take place without price increases for liquid fuels beyond "worst case" assumptions. For example, we do not see a return to labor intensive nor animal power agriculture for grain crops, nor more than slight decrease in nitrogen application rates.

4. The large scale conversion of grain to alcohol could remove large amounts of production from the market, and reduce or eliminate exports. However, the current price of oil is not sufficient to draw out the high capital investments needed for either grain nor crop residual based technology. It is in the best interest of oil exporting nations to price crude petroleum at a level somewhat below what is necessary to bring forth the next best alternative, whether that alternative is coal liquifaction, solar power or alcohol. We expect this pricing policy with respect to oil to continue. Barring unforseen political developments, it may be more than a decade before agriculture will be responsible for any significant amounts of liquid fuels.

Table 1. Costs of Ammonia Production, 1980.

	Cost/lb. of Available N	Percent of Retail Price
1. Natural gas used in Ammonia Production $1.64/1000 cu/ft	$.0365	(25.6)
2. Electricity @ 4¢/kwk	.0053	(3.7)
3. Labor @ 9.00/hr	.0021	(1.5)
4. Fixed and Other Costs Including Return on Investment	.0396	(27.8)
5. Spot Price on Gulf Coast	.0832	
6. Transportation from Gulf Coast Production Centers to Corn Belt	.0213	(14.9)
7. Retailing and Marketing	.0378	(26.5)
8. Cost to Farmer per Pound of Available N	.1426	(100.0)

Source: Compiled from Chase Econometric Associates, Paul and Kilmer, and Raikes and Heubrock.

Table 2. Marginal Physical and Marginal Value Products of N in the Production of Corn at Alternative Corn Price Levels.

Pounds of Available N applied	Yield[a]	MPP of N	MVP (corn at $3.00)	MVP (corn at $4.00)	MVP (corn at $5.00)	MVP (corn at $6.00)	MVP (corn at $7.00)
0	46.6	---	-----	-----	-----	-----	-----
25	83.6	.73	2.22	2.96	3.70	4.43	5.17
50	98.9	.52	1.57	2.09	2.61	3.14	3.65
75	110.6	.43	1.28	1.71	2.13	2.55	2.99
100	120.5	.37	1.11	1.48	1.85	2.22	2.59
125	129.2	.33	.99	1.32	1.65	1.98	2.31
150	137.1	.30	.91	1.21	1.51	1.81	2.11
175	144.4	.28	.84	1.12	1.40	1.68	1.95
200	151.1	.26	.78	1.05	1.31	1.57	1.83

[a]YIELD = $46.6 + 7.39N^{.5}$ fit from Purdue Agronomy farm data.

Table 3. Costs of Production for Three Major Crop Enterprises
(Corn Belt Corn & Soybean Enterprise, Central Great Plains Dryland Wheat)

	Corn @ 144 bu/acre	Soybeans @ 45 bu/acre	Wheat (dryland) 40 bu/
Variable Costs:			
Nitrogen @ 20¢/lb	$35.00	---	15.00
Phosphate @ 20¢/lb	12.00	12.00	12.00
Potash @ 20¢/lb	7.20	7.20	7.20
Lime @ $8.00/ton	4.00	4.00	---
Seed	16.00	18.00	8.00
Insurance @ $1.50/$100	9.00	6.75	4.50
Repairs @ $1.50/$100	9.00	6.75	4.50
Fuels & Lubricants for production @ $.95/gal of diesel (no tax)	25.00	25.00	20.00
Fuels & Lubricants for hauling @ $1.20/gal of gasoline	28.80	9.00	8.00
Labor @ $3.50/hr.	17.50	17.50	14.00
Subtotal	163.50	106.20	93.20
Fixed Costs:			
Machinery Depreciation @ 10%	30.00	25.00	20.00
Building Depreciation @ 5%	15.00	10.00	5.00
Interest on Machinery @ 10%	30.00	20.00	20.00
Interest on Buildings @ 10%	30.00	20.00	10.00
Interest on Land @ 10%	190.00	190.00	60.00

Table 3. (continued)

Taxes (1% of land & building value)	22.00	21.00	7.00
Subtotal	317.00	286.00	122.00
Crop price necessary to cover variable costs depreciation, and taxes (N at $.20/lb.)	$ 1.60	3.60	3.13
Crop price necessary to cover variable costs, taxes and depreciation (tripling of nitrogen and fuel prices in real terms)	2.83	5.12	5.28
Crop price necessary to cover all costs (N at $.20/lb.)	3.34	8.72	5.38
Crop price necessary to cover all costs (tripling of nitrogen and fuel prices in real terms)	4.57	10.23	7.53

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