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SOME PRODUCTION AND WELFARE EFFECTS OF ENERGY INPUT UNCERTAINTIES ON ANNUAL CROPS*

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I. Introduction

Agriculture continually adjusts to changing demand and supply conditions, but the events associated with the "energy crisis" of 1973-74 appeared as an abrupt shift in production conditions rather than a gradual trend in events of the past. An additional shock was adverse weather conditions in several important grain producing areas of the world, resulting in a heightened concern over world food supplies. In view of these developments, the prospect of energy related input shortages and rapidly rising agricultural energy costs is a matter of major concern for groups associated with agriculture. Changes in regional and national production patterns resulting from energy availability and cost adjustments or related policy decisions, could have important trade and welfare implications, both domestically and internationally. Further, producer and consumer groups within given regions may be affected differentially by specific policies. It is the overall purpose of this paper to estimate quantitatively the commodity price, quantity and welfare effects of various energy availability and cost assumptions and policy alternatives for a specific production region - California. Given California's significant national position in the production of many commodities, it is believed that certain empirical results, as well as the employed methodology, may prove of interest to economists, as well as suggesting areas for further inquiry.

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The study methodology features regional supply responses for 14 California production regions (homogeneous in climate and water cost characteristics further delineated in two soil quality classes) to reflect adjustments in production levels associated with varying commodity prices. The quantification of the model is achieved via quadratic programming techniques. The price endogenous nature of the model, coupled with the inclusion of yield variability or "risk" variables, provides a realistic framework with which to address the analysis of vegetable and field crop supply response under varying parameter adjustments. The study is a short run comparative static analysis, with the period 1969-72 serving as the base period. Production outside California is taken as given. The impacts of three commodity price levels, two energy input cost levels, and four energy availability levels on California agriculture are explored for 1977.[1/] The effect of these parameter adjustments are measured by changes in the levels of irrigated crop acreage and production, and in the resulting changes in consumer and producer welfare. (For additional impacts on regional cropping patterns, on-farm net revenues, and demand for land, water and energy inputs, see Adams, 1975).

II. The Model

The mathematical model used in this study bears close resemblance to several models presented or referenced in recent issues of AJAE, specifically those developed by Duloy and Norton (1973), Hazel and Scandizzo (1974), and Simmons and Pomerada (1975). In the two latter references, the Duloy-

1/ The three commodity price levels, designed to represent a low, medium and high set of commodity prices for 1977 are reflected in adjustments in the price-forecasting equation intercepts. The low and medium sets were achieved via a 25 and 50 percent increase in 1972 intercept values, respectively, while the high price set is represented by the highest actual prices observed in 1973-74. The two energy input cost structures examined are based on adjustments to the 1972 variable cost structure, with one cost level portraying an increase equal to the observed and anticipated rise in all farm non-energy inputs for the period 1972-77 (moderate energy cost projection). Energy availability levels within the study projection period are derived by reductions in projected 1977 energy quantities, with such reductions being of the magnitude of 20 and 40 percent, for both fuel (gasoline and diesel) and fertilizer inputs.

Norton model is expanded to incorporate risk into production decisions. Unlike the above models, however, the model presented here employs a quadratic solution procedure similar to those developed by Takayama and Judge (1964).

Perhaps the most notable feature of these models is the inclusion of product demand through the use of price-forecasting equations. This price endogenous characteristic, as well as the nature of the maximand, makes the model formulation particularly applicable to agricultural planning problems. Duloy and Norton (1975) provide a detailed discussion of the model characteristics and necessary conditions for the existence of an optimum, as well as a review of precursor developments.

The study model, given the quadratic objective function and the convex (linear) constraint set, is couched as a quadratic programming problem. Specifically, the objective function takes the following form:

$$\text{Max } \pi = q'(a + .5\, bq) - c'(q)$$

where q = a vector of aggregate activity levels in quantity units (e.g., 1000 cwt or 1000 tons);

a and b are elements of the linear demand structure ($P = a + bq$) where:

a = vector of intercept terms;

b = negative diagonal matrix of slope coefficients; and,

c = vector of activity variable cost levels

As discussed by Duloy and Norton, the maximization of the above objective function is analogous to maximizing the sum of consumers' and producers' surplus, a condition which ensures a perfectly competitive solution ($P = MC$). The disaggregation of the model objective function into its respective components (consumers' and producers' surpluses) may be used to provide a quantitative measure of welfare under varying policy parameter adjustments.

The model objective function is bounded by a convex constraint set of the following form:

$$Aq \leq b$$

where: A is an M x N matrix of input-output technical coefficients; and b is an M x 1 vector of resource availability levels.

The quadratic programming problem defined by the convex constraint set bounded quadratic objective function was solved via a non-linear programming algorithm developed at the University of California, Berkeley (Best, 1973). This algorithm, identified as FCD, when interfaced with the University of California, Berkeley ALPHAC simplex algorithm, provided a powerful mechanism for solving problems with non-linear objective functions constrained by a system of linear equations. This software system was adapted and used on a CDC 7600 computer located at the Lawrence Radiation Laboratory, Berkeley facility. The integration of this system of software with the speed of the CDC 7600 provided an expeditious means for solving the numerous parameter alternatives to which the large study problem was addressed.[2/]

III. Commodity Demand

Linear demand functions of the following form are specified at the farm level:

$$p = a + Dq$$

where p is an n x 1 vector of prices, a is an n x 1 vector of constants, D is a negative diagonal matrix of price-quantity slope coefficients, and q is an n x 1 vector of quantities. It should be noted that a diagonal D matrix implies zero cross-effects for competing commodities at the farm level.

[2/] The 14 production regions, with from 3 to 21 real commodity activities, on two soil types, and 156 resource and institutional constraints resulted in an A matrix of the dimensions 370 x 156. Individual execute times for all model solutions was less than 42 seconds per run.

Although less than rigorous from a theoretical viewpoint, major emphasis here is placed on farm-level price forecasting equations that attempt to caputre the effect of California production, production of other regions, and other variables on California commodity prices.

The general specification of a price forecasting model includes variables for California production (or the aggregate of the 14 sub-regions contained within the study) and "other" U.S. production.[3/]

$$Pc_i = f(Qc_i, Qo_i, S_i, Y)$$

where:

Pc_i = season average price received by farmers in California for commodity i,

Qc_o = production, California

Qc_i = production, "other" U.S. production

S_i = existing stocks, U.S.

Y = U.S. aggregate disposable personal income

On a seasonal and annual basis, price-forecasting estimates for 37 commodities were required, 33 of which were obtained via the above model.[4/] Price-quantity relationships for the remaining four commodities where simultaneity was suspected were derived from more detailed econometric studies.[5/]

3/ From an econometric viewpoint, it appears reasonable to treat some annual crop production as predetermined within the crop year. That is, current year production is not affected by current value of the other variables in the same equation structure, particularly price. Thus, quantity can be used as an independent variable in least squares price-forecasting equations to obtain unbiased statistical estimates.

4/ Independent variables other than "production, California," were evaluated at mean levels and added to the intercept terms in the objective function specification, resulting in general price forecasting equations of the form $Pc_i = a_i + d_i Qc_i$.

5/ The four commodities and the sources from which they were derived are: cotton (Blakley, 1962), processing tomatoes (King, et al., 1973), sugar beets (Bates and Schmitz, 1969), and safflower (Houck, 1964).

IV. Risk Treatment

Attempts to incorporate risk in quadratic programming models date back to Freund (1956). Recently, Hazell and Scandizzo (1974) have renewed interest in inclusion of risk variables in large programming problems. These authors propose a technique for handling risk that may improve the accruacy of supply projections from aggregate models, under the assumption of risk-averse behavior on the part of producers. Variations in observed income associated with a particular crop may be due to yield variability, price fluctuations, or the combined effects of both. Given the validity of the risk-averse behavioral hypothesis, as established by Lin et al., (1974) for California producers, crops with large variation in income may be viewed as "high risk" crops. If a particular crop is considered "high risk," risk-averse farmers will be less inclined to produce extensive acreages of that commodity. Hence, deterministic agricultural models, where all crops are treated as risk homogenous (or risk-free) tend to result in the over-estimation of "high risk" crop production at the expense of "low risk" activities.

The Hazell-Scandizzo approach to risk involves the attachment of a risk element to the cost structure of the model objective function. The risk term is essentially a marginal cost equal to the additional expected return demanded by producers as compensation for taking risk. Simmons and Pomerada (1975) employ this technique in an empirical study of Mexican vegetable exports. Varying levels of "risk compensation" are tested, ranging from the deterministic case (no risk) to a level equal to 1.5 times the cropping activity standard deviation of expected gross returns. The inclusion of such compensation for risk improved their programming results, based on comparison with actual activity levels.

The treatment of risk in this model follows the Hazell-Scandizzo technique by including an additional marginal cost to the cost structure of the objective function. The basic source of introduced risk is confined to yields, assuming that input costs and the market demand structure (as defined by the estimated price-forecasting equations) remains non-stochastic. As a measure of crop yield variability, the yield coefficient of variation, as estimated by the variate difference method, is used (Carter and Dean, 1960). While the use of such variability coefficients, based on county yield data, tends to underestimate subjective risk associated with specific crops, due to aggregation bias, such coefficients do recognize the stochastic nature of yields and relaxes the deterministic model assumption of homogenous yield variability across crops — a critical assumption in view of the seasonal yield variabilities observed in most vegetables. The model risk compensation cost for each crop is thus the product of the specific regional variable cost element in the cost vectors and the associated yield variability coefficient.

V. Policy Implications in the Study Methodology

The maximand of the mathematical model utilized in this study is the sum of the areas under the crop demand curves, less supply costs associated with the optimal quantities of each crop activity. Because of this characteristic, each model provides a quantitative measure of the total revenue, in dollars, to two distinct groups: (1) producers, who maximize returns to land and management (producers' surplus); and (2) consumers, whose benefits (consumers' surplus) may be equated to the residual between total value of the objective function and net revenue to producers. Thus, comparison of the values of these components among alternative model outcomes, serves as a relative indication of welfare gains and losses to the respective groups.[6/]

[6/] Within the maximand, the welfare of these two groups may be differentially "traded-off" in the optimization procedure. Thus, one, both, or neither groups may benefit under the parameter adjustments.

While the use of producers' and consumers' surplus as an empirical measure of welfare is the subject of continuing controversy within the economic discipline (Bergson, 1975), an effective case can be made for the use of such measures for policy analysis, under a set of rigorous assumptions (Willig, 1973; Dean and Collins, 1967).[7/] Even in the absence of any judgements concerning the merits of associated income redistributions, the empirical results obtained via this methodology may provide a quantitative measure of the aggregate net gain or loss, as well as identifying the gainers and losers, associated with alternative model outcomes.

It is recognized that the quadratic programming formulation and the associated analysis of consumers' and producers' surpluses may not provide a totally acceptable means of establishing societal gains and losses. However, the process of disaggregating gainers and losers from the maximand reveals clearly that under most economic adjustments, gains and losses are seldom neutral. This type of information should be useful to policy-makers.

VI. Empirical Results

To provide a framework of reference for the 1977 projection models, two 1972 base period models are presented in Table 1. Both base models represent 1972 observed values for the relevant model parameters and data base. Within the first model, energy inputs are treated as perfectly mobile within and across production regions (i.e., a statewide constraint for each energy input). This model formulation is consistent with the readily available energy supply situation of the late 1960's and early 1970's. However, as energy input supplies adjusted during the events of 1973-74, several allocation

[7/] Obviously, an ordinal measure of consumer utility, derived from individual consumers' indifference maps, is theoretically correct and desirable. However, the estimation of such a metric is infeasible for empirical research.

programs were advanced, including a mandatory regional allocation policy. Further, energy input suppliers were faced with curtailed supplies, as a result of manufacturer imposed quotas, with such quotas based on past sales. An implicit rationing scheme, in turn, was imposed on agricultural users, based on past purchases from respective suppliers. While not totally fixing input supplies within a specific region, this scheme did reduce input mobility. To examine the impacts of a rigid regional allocation policy, a second base model for 1972 was evaluated, with each region receiving levels of energy inputs comparable to actual recorded usage. A comparison of these base model results with actual, is provided in Table 1.

The 1977 projection model results, portraying varying adjustments to 1972 parameters, are presented in Table 2. As a basis for comparison, 1972 model results for the regionally constrained model are also provided. All 1977 projection results reflect energy levels allocated at the regional level. The projection models cover a range of commodity demand assumptions (3) integrated with the two energy cost levels. Each of these 6 models is further subjected to varying levels of energy availability with respect to nitrogen fertilizer and fuel (gasoline and diesel) inputs. Of these commodity demand-energy cost assumptions, perhaps the most likely to prevail in 1977, based on recent observations, is the medium commodity demand assumption and the higher energy cost assumption. The other demand-cost models serve as a basis for comparison with both the "most likely" model and 1972 base results.

Observations gleaned from the model results with respect to acreage levels and prices are not totally unexpected. Imposition of regional energy constraints generally reduced crop acreages, particularly in certain field crops, with an attendant rise in commodity price levels. Vegetables appear somewhat less sensitive to such an allocation scheme, with the exception of processing tomatoes, the state's most important vegetable commodity.

TABLE 1
COMPARISON OF STATEWIDE AND
REGIONAL ENERGY CONSTRAINT MODEL
ACREAGES AND PRICES[1] WITH ACTUAL, 1969-72

Crop	Statewide Energy Constraint Model		Regional Energy Constraint Model		1972 Actual	
	Acreage	Price	Acreage	Price	Acreage	Price
units	1000 acres	$/ton	1000 acres	$/ton	1000 acres	$/ton
Field Crops						
Beans, dry	224.0	135.20	156.6	196.80	176.3	285.00
Cotton	993.1	895.60	531.5	940.00	766.5	576.00
Feed Grains	801.8	62.50	489.2	72.50	1269.8	55.40
Rice	173.5	139.80	222.8	137.60	369.2	111.80
Safflower	331.9	129.90	145.2	131.60	200.7	113.00
Sugar Beets	198.9	16.66	191.7	16.67	302.0	15.57
Total Field Crops	2723.2	--	1736.9	--	3085.4	--
Vegetables						
Broccoli	49.3	215.80	36.5	232.40	37.3	209.70
Cantaloupes	58.3	124.30	56.0	127.85	58.1	141.30
Carrots	31.5	90.20	29.1	93.97	26.9	108.90
Cauliflower	14.8	222.90	13.2	245.6	19.5	197.70
Celery	20.2	94.85	18.7	99.05	17.2	106.60
Lettuce	157.4	101.95	141.0	107.90	139.0	101.40
Onions	56.4	38.70	33.5	46.35	24.9	76.80
Potatoes	76.9	62.88	68.4	70.16	81.9	58.96
Tomatoes Processed	314.0	22.23	187.0	30.6	181.9	33.20
Tomatoes Fresh	51.2	204.80	47.9	210.10	31.1	293.8
Total Vegetables	830.3		631.3		617.8	
Total, All Crops	3553.5		2368.2		3703.2	

[1] Actual price for vegetables represents weighted average of seasonal average prices.

TABLE 3
EFFECTS OF NITROGEN FERTILIZER, AND COMBINED
NITROGEN FERTILIZER AND FUEL REDUCTIONS, ON 1977
PROJECTED CROP GROUP ACREAGES

Model and Acreage Type	1977 Level	20% Reduction 1977 Nitrogen	40% Reduction 1977 Nitrogen	20% Reduction 1977 Nitrogen and Fuel	40% Reduction 197 Nitrogen and Fuel
	Energy Availability Assumption				
			1000 Acres		
Moderate Energy Cost Assumption					
Low Demand					
Field Crops	1588.9	1519.6	2041.4	1484.7	1611.2
Vegetables	715.8	710.8	722.9	708.0	615.0
Total	2304.7	2230.4	2764.3	2192.7	2226.2
Medium Demand					
Field Crops	1290.9	1922.7	1532.5	1755.4	1397.0
Vegetables	942.4	950.5	1040.2	858.8	758.4
Total	2233.3	2873.2	2572.6	2614.2	2155.4
High Demand					
Field Crops	1595.0	1707.6	1673.9	1518.5	1485.6
Vegetables	961.8	981.5	1009.4	925.6	789.8
Total	2556.8	2689.1	2683.3	2444.1	2275.4
Accelerated Energy Cost Assumption					
Low Demand					
Field Crops	1746.3	1542.1	2334.3	1512.4	1800.1
Vegetables	560.1	552.7	576.9	566.1	531.7
Total	2306.4	2094.8	2911.2	2078.5	2331.8
Medium Demand					
Field Crops	1459.9	2062.1	1890.2	1890.3	1613.7
Vegetables	794.0	806.2	846.2	771.7	677.3
Total	2253.9	2868.3	2737.1	2581.0	2291.0
High Demand					
Field Crops	1831.5	1952.9	1929	1833.5	1677.5
Vegetables	857.8	810.7	859.4	786.0	713.5
Total	2689.3	2763.6	2788.5	2619.5	2319.0

TABLE 2
IMPACTS OF 1977 COMMODITY DEMAND AND ENERGY
COST ADJUSTMENTS ON CROP ACREAGE

Model and Acreage Component	Energy Cost Assumption: Moderate	Accelerated
	1000 acres	
1972 Base		
Field Crops	1736.9	--
Vegetables	631.3	--
Total	2368.2	--
Low Demand		
Field Crops	1588.9	1746.3
Vegetables	715.8	560.1
Total	2304.7	2306.4
Medium Demand		
Field Crops	1283.5	1459.9
Vegetables	942.4	794.0
Total	2233.3	2253.9
High Demand		
Field Crops	1595.0	1831.5
Vegetables	961.8	857.8
Total	2556.8	2689.3

Acreages of major commodity groups for the projection period, as provided in Tables 2 and 3, indicate a rather strong negative response by vegetables to high energy input cost levels. Field crops, however, expand acreage at the expense of vegetables. However, even under a high energy cost assumption, vegetable acreage in two of the three models exceeds 1972 base acreage. The acreage pattern under reduced energy levels displays no pronounced directional movements, except that fertilizer reductions, in isolation, generally increase total cropped acreage.[8/] Combined effects of nitrogen fertilizer and fuel reduction dampen acreage levels from both nitrogen reduction models and 1977 energy level results. Again, vegetable acreages, with the exception of the low demand models, remain viable, registering actual increases in acreage over the 1972 regional energy model results. Such response would appear to indicate that California will remain a significant supplier of vegetables, in the aggregate.[9/]

VII. Gains and Losses from Alternative Energy Policies

The maximand of each model represents the integration of the producing and consuming sectors through the price-forecasting equations. Any model solution is "optimal" in the sense that it represents the maximization of the aggregate of these two surpluses under the normatively-imposed constraint set. Therefore, from the viewpoint of society, each model solution represents what is "best" with respect to production of the model commodities. However, within the maximand, the welfare of these two groups may be differentially

8/ This observation is consistent with lower yields associated with nitrogen reducation, and the specification of activity levels, in terms of quantity units, rather than acreage. Thus, given surplus irrigable land in most regions, the model solutions reflect the substitution of land for fertilizer in the solution procedure.

9/ Within vegetables, broccoli, cauliflower, cantaloupes and potatoes, display declining acreages. These acreage reductions are offset by substantial expansion of tomato, lettuce and onion acreages.

"traded-off" in the optimization procedure. Thus, one, both, or neither group may benefit under the parameter adjustments. The gains and losses associated with energy alternatives, and their accruement among consumers and producers, are presented in Table 4.

Of the model solutions obtained, the welfare effects of four general adjustments are perhaps most relevant. These include: (1) effects of regionally mandated energy allotments; (2) effects of rising energy costs; (3) effects of fertilizer reductions, and, (4) the effects of fuel reductions. The latter three effects, for the projection period, are depicted via use of selected models, specifically the medium demand assumption interfaced with the energy cost assumptions. Other projection models, in general, portend the same set of results.

From Table 4, total impacts of the above adjustments are as expected. That is, the imposition of economically constraining parameters, such as higher costs or reductions in fixed resources results in a reduction in the value of the objective function. What is perhaps more relevant is the means by which such reductions are accomplished. Reductions may be borne disproportionately by one sector. For example, under a regional allocation program, total value of the maximand is diminished by $182 million. Over $139 million of this reduction occurs in the economic surplus accruing to consumers. Similarly, in moving to a higher level of energy costs, the total loss approaches $233 million. While the absolute reduction in consumers' economic surplus is less than producers', the percentage reduction for consumers is greater.

Contrarily, the effects of fertilizer reductions on consumers are less severe on a percentage basis than on producers. Consumers' economic surplus remains relatively constant or even increases when fertilizer supplies are reduced. The reduction in the maximand is thus generally achieved via a

TABLE 4
WELFARE GAINS AND LOSSES ASSOCIATED WITH
ALTERNATIVE ENERGY ASSUMPTIONS

Model Identification	1972 Dollars 1/			Actual Dollars		
	Consumers	Producers	Total	Consumers	Producers	Total
			$ Million			
1972 Statewide Energy Constraint Base Model	383.298	662.331	1,045.629	--	--	--
1972 Regional Energy Constraint Base Model	244.172	537.849	782.021	--	--	--
Projection Models:						
Medium Demand Uniform Energy Cost Assumption	435.871	671.778	1,107.649	618.937	953.925	1,572.862
Medium Demand, Accelerated Energy Cost Assumption	332.053	542.480	874.533	471.515	707.322	1,241.837
With Nitrogen Reduction of:						
20%	320.940	494.886	815.826	455.735	702.738	1,158.473
40%	345.590	328.985	674.575	490.738	467.158	957.897
With Combined Nitrogen and Fuel Reduction of:						
20%	306.441	485.741	792.182	435.146	689.752	1,124.898
40%	264.851	353.213	617.360	376.088	501.563	876.651

1/ Deflator for projection model maximand values equal to actual and anticipated rise in C.P.I.

comparable reduction in producers' surplus. This observation is consistent with the "optimal" set of crop activities in the fertilizer alternative models. The "optimal" quantities of each crop remain similar to quantities in the primary models; however, acreages expand to adjust for lower yields. Thus, producers' gross revenues do not change significantly, while production costs rise in proportion to the expanded acreage, resulting in lower producer net revenues. Therefore, given the constancy of "optimal" quantities, the surplus to consumers remains relatively unchanged.

The impacts of reduced total energy (nitrogen, gasoline and diesel) diverge from the above observation on reduced fertilizer supplies in isolation, i.e., the effects on consumers are greater than on producers. While the imposition of reduced fuel results in decreases in consumers' surplus, the revenue of producers' increases over that realized in most reduced fertilizer models.

VIII. Summary and Conclusions

This paper has employed a quadratic programming model to provide quantitative estimates of possible price, quantity and welfare effects that could be expected as a result of alternative energy input assumptions. The welfare effects of these parameter changes are evaluated by using the concepts of economic surplus.

The empirical results suggest that vegetable production, in the aggregate, will continue to be a viable cropping alternative for California farmers, unless the overall level of commodity prices drops sharply. Within the vegetable group, some commodities such as processing tomatoes and lettuce, show strong gains. Such a response suggests that this region's contribution to national commodity markets will remain significant. However, vegetable acreages are sensitive to high energy cost levels, as well as to some availability levels. The welfare of producers and consumers, as measured by economic surplus, indicates that some parameter adjustments may have more severe impacts on one group. Producers' revenues, in general, are sensitive to energy availability levels, whereas consumers' losses are most severe under energy cost adjustments. There would appear to be an overall gain from a policy designed to provide abundant supplies of energy, at moderate prices, to the on-farm agricultural sector.

The partial equilibrium analysis of the study obviously places limits on the policy content of the models. Additionally, the price-endogenous nature of the model places importance on the estimated price-forecasting equations. Lack of alternative estimates makes the estimation process more difficult, as there are few sources of comparisons. The lack of such estimates is pronounced in vegetables, particularly on a seasonal basis. Additionally, the assumption of zero cross-price effects may be questionable for some commodity groups. The model solutions also display a high level of sensitivity to small adjustments in the price intercepts. However, given the range of variables and parameters examined, the directional aspects of the models appear sufficiently well established to deal with broad policy questions of the type discussed above.

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