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Tropospheric ozone is a pollutant which has detrimental effects on crop yields. The level of ambient ozone can be reduced by environmental policy changes and enforcement. The purpose of this study was to estimate the welfare effects of such changes in ambient ozone using recently available plant response data and an economically consistent approach. A 25 percent reduction in ambient ozone was estimated to increase total welfare by approximately $1.7 billion. About 40% of the benefits accrue to producers, 25 percent to domestic consumers and 35 percent to foreign consumers. These benefits estimates do not consider compliance costs. A variety of changes in ambient ozone are considered for ranges of crop sensitivity. The analysis was conducted using a mathematical programming sector model of the U.S. agriculture. The model is a long-run equilibrium model encompassing regional production of the major crops and livestock products, as well as processing and export activities. Proposals for improving the performance of sector models were examined. Alternative methods for incorporating aggregate response assumptions were found to have little effect on estimates of total welfare changes but had important consequences for the distributional effects between producers and consumers. An empirically based attempt to identify an appropriate producer response assumption was not successful due to problems inherent in validating sector models. The theoretically preferred response assumptions were incorporated in the sector model.

The Economic Effects of Ozone on U.S. Agriculture: A Sector Modeling Approach

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TABLE OF CONTENTS

LIST OF TABLES

THE ECONOMIC EFFECTS OF OZONE ON U.S. AGRICULTURE: A SECTOR MODELING APPROACH

Chapter 1

INTRODUCTION

INTRODUCTION

Ozone is an air pollutant that adversely affects vegetation. It can harm the plant directly through stomatal uptake of toxins resulting in premature senesence, as well as indirectly, by predisposing plants to insect and disease damage. The evaluation of the effects of such pollution is important when setting national air quality standards considering the importance of U.S. agriculture to the stability of the U.S. economy and world food and fiber consumption.

The purpose of this study is to estimate the welfare benefits of reducing ambient ozone using recently available data and a theoretically consistent assessment approach. Chapters 2 and 3 are concerned with the development of this approach which is based on a detailed mathematical programming sector model. Specifically, sector model proposals by McCarl (1982a) are compared with previous techniques in these chapters. Prior to his proposals, sector models often produced results which appeared satisfactory in the aggregate but lacked microeconomic realism. Microeconomic detail is important when distributional issues need to be addressed. Questions concerning who gains and who loses from policy changes are answered unreliably by sector models which lack microeconomic detail. Potential differences across sector model specifications, in terms of total welfare and distributional consequences, are examined in Chapter 2, to see if the differences between techniques are significant. A search for an appropriate alternative is undertaken in Chapter 3. Some difficult methodological issues are addressed in this chapter, and one method of overcoming them suggested. Following this discussion of the approaches to modeling, the full assessment model is constructed and applied to the benefits assessment which is undertaken in Chapter 4.

Five years of plant science information on crop response to ozone and other stresses had been collected and used to derive dose response functions for the major annual crops. These dose response assumptions are summarized by Heck et al. (1984a). Several scenarios differing by ozone level and crop sensitivity were incorporated into the sector model by modifying crop yields appropriately. The model then iterates until a market clearing solution is produced. Crop acreages, production levels, income, and producer and consumer surplus are altered in the process. On the basis of these changes, the economic impact of ozone on U.S. agriculture is calculated.

Chapter 2

THE EFFECT OF AGGREGATE RESPONSE ASSUMPTIONS ON ENVIRONMENTAL IMPACT ANALYSES

by

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Contribution of authors: Dr McCarl provided guidance with the model development and Dr Adams assisted with biological aspects and revisions to drafts. The remainder of the analysis was conducted by the primary author.

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THE EFFECT OF AGGREGATE RESPONSE ASSUMPTIONS ON ENVIRONMENTAL IMPACT ANALYSES

Numerous assessment techniques have been used to study the economic effects of potential environmental and policy changes on the agricultural sector. These range from very simple techniques which permit no change in producer and consumer response (e.g, without acreage or consumption pattern changes) to more complex simulation and sector analysis techniques that capture such responses. While theory suggests the need to include these responses, actual assessments tend to be evaluated in terms of the "reasonableness" of the generated estimates. Thus, a simple model that abstracts from some economic dimensions of a problem may have equal policy relevance if it predicts reasonably well. The importance of accurate assessments has been enhanced by the increased reliance on benefit-cost procedures in federal regulatory evaluations as required by President Reagan's Executive Order 12291. Incorporation of aggregate producer and consumer response becomes important if welfare consequences are to be used in benefit-cost analyses of environmental policy changes, such as those emanating from the Clean Air Act. As noted by Crocker, the type and structure of assumptions used in economic assessments may have as great an effect on the predicted welfare changes as the initial biological or physical change triggered by the environmental policy. This paper reports on an investigation of the implications of alternative response assumptions on the estimates of changes in welfare, prices and production due to environmental alterations. A variety of aggregate response assumptions are examined within a mathematical programming framework using a case example assessment involving the economic effects of air quality changes on agriculture. This type of empirical research is used by the U.S. Environmental Protection Agency (EPA) to evaluate the efficiency of alternative national ambient air quality standards, including acid deposition precursors. Benefits to agriculture are an important category in setting such standards (Heck et al. 1984a).

The Theoretical Refinement of Aggregate Response Assumptions

Programming-based sector models have evolved from the simple analytical technique of budgeting. In order to obtain more rigorous and perhaps more useful models, there have been attempts to increase the realism of producer and consumer responses. The following summary reviews the alternative response structures tested here.

(i) The simplest response assumption is that resource use and prices do not change as a result of a structural change. This naive assumption has sometimes been used to calculate a "revenue effect" by multiplying the anticipated yield change (due to environmental alteration) by current acreage and price (e.g., Shriner et al.). Although this approach provides monetary estimates of environmental changes, the procedure and results are largely discounted by economists as being an unrealistic abstraction that ignores well documented price effects and is incapable of addressing distributional consequences (Adams et al., 1982).

(ii) At the next stage, resource use is allowed to change, but market price remains constant. This is the assumption typically used when the welfare assessment is based solely on firm-level linear programming or budgeting analyses. Microeconomic detail of these models is high, but sectoral pricing of factors and products is neglected.

(iii) A common environmental assessment technique involves cost minimizing agricultural sector models as used by Heady and associates (see Heady and Srivastava) where a constant quantity is assumed to be produced. However, these models do not include consumer demand adjustments. In addition, these models typically do not contain much microeconomic detail.

(iv) Takayama and Judge's spatial equilibrium activity analysis model was a further development in the sector modeling approach. Here the objective function is welfare maximizing rather than cost minimizing. Prices and quantities are endogenously determined allowing restrictive assumptions of earlier models to be removed.

The first versions of the Heady cost minimizing and Takayama-Judge type models incorporated only single crop or livestock activities.

Such models often provide results that are plausible at the national level, but were overly specialized at the regional level, often with whole regions producing a single commodity. A tradeoff exists in model specification between the level of microeconomic detail and the size of the model. Consequently, rather aggregate representations are used. Thus, two extremes had been reached. Micro level detail could be achieved by excluding the sectoral level demand functions using fixed price analyses as in (ii), or the macro economic consequences could be incorporated if one was prepared to sacrifice microeconomic accuracy, as proposed in (iv). Various alternatives were proposed to provide greater realism at the regional level, including the incorporation of risk considerations, more detailed resource constraints, and crop rotation activities.

(v) One of the first modifications was the implementation of flexibility constraints that allowed activities to be restricted to some percentage deviation from an equilibrium level (Sahi and Craddock). However, the approach has been criticized for the inflexibility that is incorporated into the model.

Producing a tractable sector model with microeconomic accuracy presents somewhat of a dilemma. A formulation incorporating the individual farm level problem of each type of producer while still maintaining the macroeconomic linkages is conceptually appealing since both macro and microeconomic realism is included. However, this approach is infeasible because of data requirements as well as the sheer size of the subsequent matrix. Nevertheless, the approach is conceptually appealing and, coupled with the Dantzig-Wolfe decomposition algorithm, provided the basis for methodological suggestions given in McCarl.

McCarl's suggestions involve improvements in microeconomic accuracy by utilizing mixed crop budgets for model activities rather than individual crop budgets. Two ways were proposed for mixing the budgets.

(vi) The first utilized historical crop combinations to form activities. McCarl did not address the effects of acreage mix on yield. However, a recent attempt to implement the crop mixes suggested that yield effects arising from acreage mix changes should be included

(Adams, Hamilton and McCarl).

(vii) McCarl's second proposal involved generation of activities representing the optimal solutions of LP representative farm models.

Thus, a wide variety of alternatives are possible. Combinations are also possible, as exemplified by recent analyses combining alternatives (vi) and (vii) (Adams and McCarl; Hamilton, McCarl and Adams). A priori the responses portrayed by the crop mix alternatives are expected to most closely simulate reality. However, choice among the full spectrum of alternatives depends on the availability of funds and data and, perhaps most importantly, on how much variation there is likely to be between the results of the approaches. If the results do not differ dramatically, then the policy utility of each may be quite similar, suggesting that the simpler, less costly approaches may be adequate. Attention is turned to exploring this issue.

Methodology, Model and Problem Setting

The consequences of using a number of assumptions are examined within a mathematical programming framework, thus allowing a constant basis for comparison. Each of the approaches/assumptions is incorporated into a separate price endogenous sector model of the Cornbelt by modifying the parameters regarding corn, soybean and wheat production/consumption as needed (the estimates derived from the first approach (price times quantity) were simple enough to be calculated manually). For the sake of comparison, the results of a farm level LP study in the same region are also included (Brown and Pheasant). The modifications which distinguish each trial are summarized in Table 2.1.

The mathematical programming sector model used is similar to other sector models reviewed by Norton and Schiefer, and McCarl and Spreen. The particular model used was developed by Baumes, improved in data specification by Burton, and documented in Chattin, McCarl and Baumes. A version is also in use at USDA (House). The model is a long run equilibrium model encompassing production and processing of cotton, corn, soybeans, wheat, sorghum, oats, barley, rice, silage, hay, dairy

Table 2.1 Alternative Aggregate Response Assumptions

Scenario Number	Response Assumption	Distinguishing Features
i	No response	Prices held constant; crop acreage held constant.
ii/a	Constant price LP model	Sectoral implications of farm level LP results are derived (Brown and Pheasant).
ii/b	Constant price sector model	Prices held constant; export activities excluded; crop activities are LP budgets.
iii	Constant consumption	Crop consumption held constant; consumption of processed crop products held constant; export activities excluded; crop activities are LP budgets.
iv	No flexibility constraints - individual crops	Crop activities represent production of individual crops in individual states. No flexibility constraints imposed.
v/a	Limited flexibility	Crop activities represent production of individual crops in individual states. Upward and downward flexibility 20%.
v/b	Partial flexibility	Crop activities represent production of individual crops in individual states. Upward and downward flexibility 50%.
vi/a	Historical crop mix - no yield adjustment	Crop activities mixed to represent historical combinations - one activity for each state in each year: 1970-1980. Yields have not been adjusted to account for changes in acreage.
vi/b	Historical crop mix - with yield adjustment	Crop activities are mixed to represent historical combinations - one activity for each state in each year: 1970-1980. Yields have been adjusted to account for changes in acreage.
vii	LP crop mix[a]	Crop activities are optimal solutions of Brown and Pheasant's representative farms under different price ratios.

a This response assumption is expected to most closely portray producer adjustments and hence is a possible benchmark against which to judge the reasonableness of the other assumptions.

cattle, beef cattle, and hogs. The model contains a 10 region disaggregation of the U.S.

The problem setting is the evaluation of the economic effects of reduced ozone pollution levels on agriculture in the Cornbelt under alternative model assumptions. Ambient ozone adversely affects the yields of many crops, suggesting that reduced ozone levels will increase yields for sensitive crops. Using ozone dose-response functions reported in Heck et al., the changes in yields from a moderate (25 percent) ozone reduction in the Cornbelt are calculated for corn, soybeans, and wheat. These yield increases are approximately 1 percent, 6 percent and 3 percent, respectively, for these three crops. A previous analysis of the effect of air quality changes on agriculture in the Cornbelt using approach (vii) focused on the need for and importance of biological information on crop yield responses to ozone (Adams and McCarl). The analysis reported here can complement that analysis by providing a comparative analysis between the relative importance of biological versus economic assumptions.

Implementation of the Alternative Assumptions

The implementation of some models required special modifications to the sector model, while others could be implemented merely by changing the input files. The construction of the data files and the implementation of the response assumptions are discussed in this section.

The "no response" model was not implemented using the sector model. Rather, the 1980 level of crop production in the Cornbelt was multiplied by the appropriate yield response resulting from the ozone change, to determine the increased production of each crop in each region. The increased production was then multiplied by the average U.S. price for that crop to estimate the increase in revenue. For wheat, corn and soybeans respectively, the increased revenue was $30.146 mil., $85.637 mil. and $421.52 mil. The change in revenue is assumed to accrue only to producers since the demand curve is implicitly infinitely elastic, allowing no consumer response.

The "constant price" model by Brown and Pheasant was a farm level model. The effect of ozone on the income of representative farms in each subregion was assessed for different levels of ambient ozone, but not for percentage increases or decreases in ozone, which is the technique used in the current study. Brown and Pheasant reported their results by matching the yield change with income. The yield effects for a 25% decrease in ozone were calculated and compared to the yield effects of Brown and Pheasant. The income effects were then adjusted proportionally. Thus the yield effects that were obtained from the Brown and Pheasant study were consistent with the yield effects used in the analysis of the other response assumptions in the current study, with the exception of corn. (Since a corn effect was not studied by Brown and Pheasant, there was no subsequent income change to adjust.) The individual changes in farm income were aggregated to the regional level by multiplying the income effect by the quotient of the average farm size of the representative farm in each subregion and the number of acres in the subregion. Summing the income effects across subregions provided the regional income effect. Again, due to the horizontal demand curve, the full welfare effect was assumed to accrue to producers.

The "constant price" sector model (ii/b) was the first that required modification to the sector model. Model (vii) was used as a base from which the modifications occurred. The domestic demand curves for wheat, corn and soybeans were made perfectly elastic by providing a constant price on the input forms. The export demand curves for these crops and for soybean products were reduced to a near zero price to effectively eliminate them and ensure a constant domestic price. Note that some change in consumer surplus could still occur because the elasticities of the demand curves of the other products remained unchanged.

The "constant consumption" model also operated from a base model of (vii). Export consumption of each of the affected crops were added to domestic consumption and the quantity was fixed in the right-hand-side. The export demand curve was reduced to a price near zero. In this way, total consumption was held at the correct level.

The "flexibility constraint" models were simply instituted since the input forms for each crop activity allowed the specification of a flexibility constraint. The production activities were single crop activities: the production of one crop in a state. Hence, in the Cornbelt, there were 20 activities (four crops in each of five states). The flexibility constraints instituted were: unlimited (model iv), 20% (model v/a) and 50% (model v/b). The 20% and 50% levels were chosen for two reasons. First, these flexibility levels have been common choices in previous studies. Also, corn and soybeans tend to fluctuate in the 10-20% range in the Cornbelt from year to year, while wheat fluctuations can be in the 50% range.

The "historical cropmix" models had, as their production activities, combinations of crops that reflected actual crop mixes from the years 1970 to 1980. Thus, there were 55 crop activities in the Cornbelt, one for each of the 11 years in five states. Thus, if a cropmix in a state was say 50:40:10 for corn, soybeans and wheat then the production activity for that state suggested that each acre grew 50% corn, 40% soybeans and 10% wheat with a similar combination of per acre costs.

Two scenarios were considered under historical crop mix combinations. In the first, crop yields were assumed to be independent of the acreage planted. Thus, the yield of corn was assumed to be the same regardless of whether 30% or 70% of available crop land was planted to it.

In the second version (model vi/b) the cropping activities were the same except that the yield had been adjusted to reflect the effect on acreage.

The appropriate adjustment was difficult to achieve. First of all, the adjustment was attempted econometrically using time series data for each of the states. Yield per acre was the dependent variable, with independent variables being percentage of cropland planted to that crop, a trend variable, and weather variables, specifically, soil moisture (pasture conditions) and average temperature. Rainfall was considered instead of pasture conditions. Attempts were also made to capture rotation effects. Various functional forms were experimented with. All versions achieved minimal success. Coefficients varied widely between states with some coefficients being biologically unreasonable.

Attempts to capture the effects of weather per se were abandoned. Instead, dummy variables were used for each year and each state, following a technique used by Johnson (1960). This provided better results, but these were still regarded as inadequate. The conclusion was reached that the use of time series data to capture the acreage-yield effects was generally inadequate since the variaton in many of the important variables had been lost in aggregation.

Detailed cross sectional data on 26 farms growing soybeans and corn over five years in Illinois were obtained from Illinois Farm Business Farm Management Association Records. The results using these data were considered superior to any of the models based on time series data and so these models were used to adjust yield. The models are presented in equations (1) and (2) and the results in Tables 2.2 and 2.3.

(1) $$Y_c = b_0 + b_1A_c + b_2AC_s + b_tT_t + b_fF_f + u$$

(2) $$Y_s = b_0 + b_1A_s + b_tT_t + b_fF_f + u$$

where Y_i is the yield of crop i in bushels per acre,

A_i is the percentage of the farm planted to crop i,

AC_i is the change in the percentage acreage of the farm planted to crop i,

T_t is a dummy variable for year t,

F_f is a dummy variable for farm f,

c represents corn,

s represents soybeans,

b_i is an estimated coefficient, and

u is a disturbance term.

Equations (1) and (2) were estimated using ordinary least squares. Contemporaneous covariance between the disturbances of the models was a possibility but, on examination, the correlation between the disturbances was 0.046 and so more sophisticated estimation techniques were not sought.

Table 2.2 Corn and Soybean Agreage Response Models

Variables	Corn Coefficient	Corn t-ratio	Soybeans Coefficient	Soybeans t-ratio
Constant[a]	140.	4.90	41.4	10.59
Corn acreage	-0.319	-0.72		
Soybean acreage			-0.242	-2.57
Change in soybean acreage	-0.267	-1.08		
Dummy variables:				
1979			8.82	6.57
1980	-34.0	-8.71	4.04	3.17
1981	0.396	0.11	9.91	7.35
1982	9.17	2.07	5.23	3.46
Farm 2	-0.022	-0.00	-2.33	-0.87
Farm 3	14.2	1.58	8.32	3.12
Farm 4	24.1	2.29	10.43	3.63
Farm 5	2.78	0.29	2.45	0.90
Farm 6	19.8	2.31	6.31	2.35
Farm 7	28.4	2.71	8.63	3.02
Farm 8	24.0	2.38	8.44	3.01
Farm 9	22.9	2.68	12.1	4.79
Farm 10	24.8	2.82	2.92	1.13
Farm 11	29.7	3.30	5.84	2.23
Farm 12	30.2	3.67	7.21	2.89
Farm 13	18.7	2.11	8.48	3.28
Farm 14	12.4	1.18	2.67	0.93
Farm 15	23.6	2.40	13.5	4.96
Farm 16	15.8	1.70	6.72	2.52
Farm 17	25.5	3.00	2.66	1.00
Farm 18	6.16	0.78	2.57	1.04
Farm 19	5.52	0.68	2.66	1.03
R^2		0.83		0.66
$\overline{R}^2$		0.74		0.57
Standard error of the estimate		11.0		3.93
Number of observations		69		88

[a] For corn: farm 1, 1979; for soybeans: farm 1, 1978.

Table 2.3 Wheat Acreage Response Model.

Variables	Coefficient	t-ratio
Constant[a]	34.6	10.65
Wheat acreage index	-1.05	-0.60
Dummy variables:		
Indiana	0.895	1.05
Iowa	-8.60	-9.83
Missouri	-7.52	-7.21
Ohio	0.678	0.80
1962	-2.29	-1.31
1963	4.17	2.44
1964	0.902	0.53
1965	-5.86	-3.27
1966	5.77	2.92
1967	1.75	0.96
1968	2.87	1.45
1969	1.71	0.83
1970	3.07	1.38
1971	8.93	3.84
1972	8.69	3.94
1973	-1.98	-0.84
1974	1.23	0.64
1975	6.04	3.29
1976	3.80	2.16
1977	8.21	4.43
1978	0.763	0.33
1979	9.92	4.58
1980	12.8	6.42
R^2		0.88
$\overline{R}^2$		0.84
Standard error of the estimate		2.66
Number of observations		100

[a] In Illinois, 1961.

Unfortunately, the data did not extend to wheat yields and so the following equation was used to adjust these:

(3) $$Y_w = b_0 + b_1A_w + b_tT_t + b_jS_j + u$$

where Y_w is the yield of wheat in bushels per acre,
A_w is an index of the percentage acreage of wheat in a state with 1980 percenatge acreage equal to 100,
T_t is a dummy variable for year t,
S_j is a dummy variable for state j,
b_i is an estimated coefficient, and
u is the disturbance term.

Apart from the yield adjustment for acreage differences, models (vi/a) and (vi/b) were the same.

The final model, and the one with the most theoretical appeal was the "LP" model. Each crop production activity was the result of solving a farm level LP in each region. (The theory behind this approach was discussed in the previous section.) Consequently, the result of a farm level LP for a given price ratio may be 45% corn, 45% soybeans and 10% wheat. Consequently, the use of this production activity implies this crop mix. Costs of production were mixed in the same ratio. The farm level LP analyses were conducted by Brown and Pheasant. The five states of the Cornbelt were subdivided to make a total of 12 regions. The total number of cropping activities in the region was 366. This model was felt to be a better approximation of the real world because it reflected a wider variation of cropmix alternatives than did the historical crop mix models, while still maintaining the farm level constraints, which the flexibility models did not.

Results

Each of the alternative assumptions (Table 2.1) is incorporated into the agriculture sector model. The economic effects (benefits) of a 25 percent reduction in ambient ozone in the Cornbelt, as manifested in increased crop yields, are then evaluated. The consequences of the different assumptions are reported in Table 2.4.

The results are discussed in terms of the effects on the estimates of total welfare (sum of consumers' and producers' surplus), the division of benefits between producers and consumers, and the simulated producer response as reflected by estimates of changes in crop acreage. Comparison across the solutions arising from alternative assumptions can suggest the policy importance of response assumptions, i.e., whether they really matter in policy evaluation.

In comparing the total welfare measure, one notable feature of the various estimates is their general similarity. The range in benefit estimates generated from the sector model is approximately 25 percent, ranging from \$537 million for the no response approach to \$693 million for the no flexibility constraint model (iv). An extrapolation of the Brown and Pheasant LP farm model results to the Cornbelt results in an estimate of \$537 million. (The difference in estimates, although of similar magnitude, is influenced by the farm level model structure, as well as Brown and Pheasant's use of a different data base for ozone effects. Brown and Pheasant did not have data on the effect of ozone on corn, and so a lower estimate is expected.) The lower estimates of benefits elicited from the no response model are expected, given its inability to reflect optimizing producer and consumer responses to an altered environment. This suggests that the naive approach may understate benefits of environmental improvements. This result is consistent with those of Adams, Crocker and Thanavibulchai (1982) who demonstrated that the naive approach misstated the economic costs of environmental change. The more complex models (iv-vii) tend to show fairly similar total benefit estimates, implying that a model that captures certain economic dimensions, such as major market effects and some substitution possibilities, may provide an acceptable approximation to total benefits. It is also noteworthy that the range

Table 2.4 Ozone-Induced Changes in Cornbelt Economic Surplus and Crop Acreage

	Scenario	Estimated Changes[a] in: Welfare	Producer Surplus	Consumer Surplus	Percent Change from Regional Total in: Corn Acreage	Wheat Acreage	Soybean Acreage	Acreage[b] Std. Dev. Across States & Crops	Increase[c] in Acreage Planted
		---$1000 dollars---			---percent---				
i	No response	537,303	537,303	0	0.0	0.0	0.0	0.0	0.0
ii/a	Constant priced farm LP	536,871	536,871	0	-9.39	-0.08	9.52	2.186	0.0
ii/b	Constant price	603,935	452,283	151,991	-8.972	1.237	7.735	2.544	6.350
iii	Constant consumption	555,584	-872,063	1,427,647	1.662	-0.072	-1.590	0.918	-1.795
iv	No flexibility constraints	692,861	-244,349	937,216	-9.132	0.305	8.827	8.295	25.723
v/a	Limited flexibility (20%)	653,012	-96,475	749,487	0.607	1.082	-1.689	1.695	5.682
v/b	Partial flexibility (50%)	665,917	-101,974	767,759	2.439	0.093	-2.532	2.669	3.622
vi/a	Historical crop mix-no yield adjustment	653,597	-79,051	732,650	1.325	-.241	-1.085	.625	3.026
vi/b	Historical crop mix-with yield adjustment	646,182	105,768	540,414	-1.324	1.298	0.026	.521	2.663
vii	LP crop mix	604,003	45,958	558,043	.013	-1.011	.998	.403	1.231

[a] All dollar changes are measured in 1980 dollars.

[b] This gives the standard deviation of the change in percentage allocation of land to corn, soybeans, and wheat over the five Cornbelt states.

[c] This gives the percentage change of total land in the region devoted to corn, soybeans, and wheat.

[d] The results for this model were derived from Brown and Pheasant, who did not consider the effect of ozone on corn. Consequently, these results are not strictly comparable to the other results obtained from the model described in this paper.

of welfare effects due to economic asumptions approached the variability in estimates attributable to biological uncertainty in yield response data, suggesting the importance of both biological and economic concerns in such policy assessments (Adams, Hamilton, McCarl).

Considerably more variation was illustrated in the relative gains of producers and consumers. Distributional consequences varied not only in magnitude, but also in direction among the assumptions. At the extremes were the simplistic models: the constant price and no response models allocate all benefits of reduced pollution to producers. The constant consumption, at the other extreme, showed the greatest benefits to consumers. This implies that the models which do not fully accommodate producer or consumer response (models i, ii and iii) tend to understate total benefits and grossly misstate the distribution of those welfare effects.

The no flexibility constraint model showed the largest absolute changes in consumers' and producers' surplus, while the model with greatest micro detail (the LP crop mix model) showed the least. Only two of the models specifying price and acreage responses indicated that producers would achieve any welfare gains at all, thus stressing the importance of the aggregate response assumptions in determining the distributional consequences.

Acreage adjustment to changing crop yields is an important dimension of producer response and is important in evaluating potential regional impacts of policy changes. The more micro detail contained in the model, such as the crop yield adjustments, generally the less the crop substitution observed. The degree of specialization in state level crop mixes varied dramatically between the crop mix (vi and vii) and individual crop - flexibility models (iv and v). The standard deviation of acreage illustrates this. For example, the flexibility models show much more adjustment in acreage mix than the crop mix models. The less micro detailed sector models also showed considerable expansion in acreage planted to corn, soybeans, and wheat. This is as expected, as the more aggregate models ignore agronomic and economic constraints typically faced by producers. Usage of the crop mixes (derived historically or using an LP model) was found to be more restrictive than the use of flexibility constraints, although as the flexibility constraints are tightened the degree of crop substitution decreases. Examination of the state level data showed that the McCarl proposal is effective in restricting the model to realistic cropping mixes. As judged by the difference in the estimates, the inclusion of the crop mix-yield relationship when using historical crop mixes is important. Little indication is provided as to the more appropriate of these.

As less micro detail is included, the predictions of the distributional consequences became more diverse. From a micro theoretic perspective, the most acceptable model is the LP crop mix model since it should depict most accurately the producer's ability to adjust. This approach, however, is expensive both in data collection and computing requirements. The use of historical performances provide a quick and somewhat easier method of specifying the cropping activities.

The standard deviation of acreage can be used to obtain another important conclusion. Conceptually, for a given shift in supply, the maximum change in production is expected to occur when the demand curve is infinitely elastic. In this study, the most accurate representation of the supply curve occurs with the representative farm models (model ii) because these have the greatest level of microeconomic detail. The change incurred in model (ii/a) should thus be an upper bound on the production adjustment as this model is solved under infinitely elastic demand. The acreage standard deviation results show several interesting things. First, there is aggregation error between the farm and sector models as exhibited by the comparative results under infinitely elastic demand. The farm model exhibits a standard deviation of 2.186, while the sector model standard deviation equals 2.544. This indicates that the sector model apparently overstates the production adjustment relative to the farm models. However, this is not a large difference and one should also consider the differing data utilized (Brown and Pheasant use pre NCLAN data which did not include a corn yield response). Thus, this difference in response is not felt to be unacceptably large. Second, and more importantly, the production adjustment in the models with less than infinitely elastic demand (models iv and v/b) is larger than that of the farm models (ii/a) and is almost as large for model (v/a). On the other hand, the crop mix models all exhibit considerably smaller adjustments. These results indicate unacceptable performance on behalf of the single crop models unless relatively tight (less than 20 percent) flexibility constraints are imposed. The situation has been depicted in Figure 1 for the single product case. Suppose the initial equilibrium exists at quantity q_1 with supply s_1. If the demand curve is infinitely elastic, the new equilibrium following the supply shift to s_2 will be at q_3. This will be the upper bound on the production adjustment as long as the demand curve is downward sloping. A downward sloping demand curve was incorporated in the flexibility constraint models. Thus, the adjustment for these models should be somewhere between q_1 and q_3, say q_2. However, an adjustment level greater than q_3 resulted for models (iv) and (v/b). Thus, one is led to conclude that when the flexibility restrictions are not tight enough, the supply curve is being inadequately represented.

In summary, the changes in total welfare benefits displayed by most model specifications were not highly sensitive to response assumptions, while consumers'/producers' surplus and acreage distribution varied dramatically. In short, when addressing distributional and regional issues in policy analysis, the types of response assumptions used are important.

Conclusions

In this study, the importance of different assumed producer and consumer responses, as simulated with a series of modifications to an existing sector model, are examined across all model specifications. The estimate of aggregate social benefits from reduced ozone pollution in the Cornbelt is approximately $650 million in 1980 dollars, with lowest benefit estimates from the naive price times quantity model (i) and highest for the unconstrained- single-crop-activity model (iv). Greater diversity and hence greater uncertainty of policy implications occur within the estimates of the distributional (consumer versus

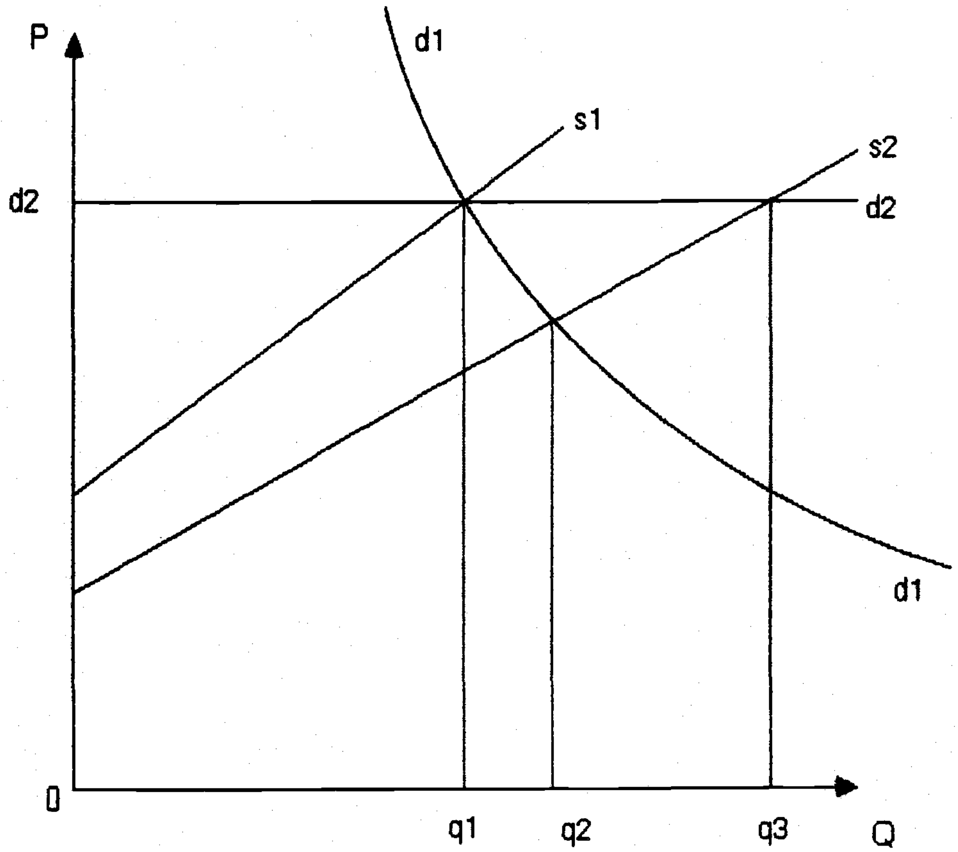

Figure 2.1 Supply adjustment under alternative supply scenarios.

producer) effects. At the extreme, the estimates varied not only in magnitude but also in direction and approached the variation in benefit estimates attributable to uncertainty in the biological assumptions. Thus, the choice of technique and associated response assumptions could provide dramatically different estimates of distributional consequences.

The various model results have differing implications for environmental policy. However, given the hypothetical nature of the policy problem, it is difficult to say which specification is most accurate. Theory and judgments based on reality allow elimination of the less restrictive single crop models (allowing 50 percent or more flexibility). Beyond this, despite guidance from economic theory, judgments concerning "best" model form must ultimately be tempered by consideration of the eventual use for those results as well as the policy consequences of misinformation in that setting. From the specific perspective of sectoral modeling, selection of the appropriate specification of a micro-sector model has many inherent difficulties, not the least of which is attempting to validate a long run equilibrium model against a short run disequilibrium world.

Chapter 3

ATTEMPTS TO IDENTIFY AN APPROPRIATE PRODUCER RESPONSE ASSUMPTION

ATTEMPTS TO IDENTIFY AN APPROPRIATE PRODUCER RESPONSE ASSUMPTION

Introduction

Sector models have been used for a variety of purposes for many years. The development of such models was reviewed briefly in Hamilton et al. 1985. Despite the extensive use of such models, few studies have been concerned with the appropriateness of the aggregate response assumption of the producers. Typically, flexibility constraints have been used to model producer's response. However, McCarl (1982a) has proposed two additional options: the use of single activities to represent the production of multiple crops mixed according to either historically observed combinations or predicted combinations resulting from representative farm linear programs. The former proposition has two versions: one in which the crop yield is not adjusted according to the regional crop mix, and one where it is.

Although the choice of response assumption has only a small effect on the estimated change in total welfare, the choice has important implications for the distributional consequences (Hamilton et al. 1985). Despite this importance, the response assumptions best suited to modelling policy impacts have not been identified. Typically, researchers choose a response assumption on the basis of availability and ease of use. While these are worthy considerations, the adequacy of the assumption is not known.

The purpose of the study presented in this paper is to examine the appropriateness of the various producer response assumptions. The approach used was to compare the acreage changes estimated by the sector models under the alternative assumptions with acreage changes in the real world. The similarity between the predictions and the real world could then be used to determine the suitability of the assumptions.

The terms verification and validation have a variety of meanings in the literature. The terms are defined here for clarity.

Verification is determining whether the computer program functions correctly. Validation is determining whether a simulation model is an accurate representation of the real-world system.

Problems Involved in Sector Model Validation

The particular sector model currently being examined is similar to the numerous agricultural sector models of Heady and associates (as reviewed in Heady and Srivastava, Norton and Schiefer, and McCarl and Spreen). The model was developed by Baumes, improved in data specification by Burton, documented in Chattin, McCarl and Baumes, and revised by Adams, Hamilton and McCarl. The model is a long-run equilibrium model encompassing production and processing of the major crop and livestock products in the U.S.

The method used here for identifying an appropriate producer response is essentially a validation technique and techniques useful in validating sector models have been discussed well in the literature. McCarl and Apland, for example, who emphasize the importance of validating a model for its intended use, have provided a broad range of validation tests.

Some of these tests have already been applied to the current model (Adams, Hamilton and McCarl). The test currently under consideration falls into the class of test McCarl and Apland call a change test. With this test the predicted change in a variable (or variables) is compared to the change in the real world. This test has not been used previously on the current sector model nor was evidence of its use found in the validation literature. However, the importance of this test arises not from its originality, but because it is this application for which this model has found most use (e.g. Burton; Adams, Hamilton and McCarl).

The implementation of many validations tests appear simple when explained. In practice, the implementation is often involved. The validation of the current model with the change test presents its own set of problems.

The model is a long run equilibrium model. The real world, against which the model is being compared, is in continual disequilibrium with numerous short run constraints in effect at any one time. Consequently, close resemblence between the results of the model with its necessary approximations and unique equilibrium point, and the real world, continually responding to a multiplicity of forces, would not necessarily be achieved, even by a perfect model. The current model was designed to abstract from reality in order to address the impacts of various potential policies, the influences of which do not occur in the real world in isolation. Since the real world does not respond to a single impact for a period long enough to achieve equilibrium, an ideal situation against which to validate the sector model does not exist.

The appropriateness of the response assumptions were explored using two different approaches. The first attempts to model the change in acreage planted resulting from changes in exchange rate and the second, the change in acreage planted resulting from changes in expected prices.

The sector model was designed to examine the impacts of structural changes in the U.S. agricultural sector. It is desirable to examine the response assumptions against an actual situation in order to insure that the model is suitable for its intended purpose. The first approach considered, therefore, was to use the model to examine the effect of exchange rate changes.

The Application of the Model to Exchange Rate Changes

The Reason for Selecting Exchange Rate Changes

When validating a sector model of this type, a structural change of a magnitude great enough to cause widespread changes in U.S. agriculture is needed. While there have been several impacts to agriculture in recent times, the one believed to be of most importance, and the one used in this approach, is the impact of exchange rate changes.

Among the factors influencing agriculture in the 1970s and '80s are: the emergence of the Soviet Union as a major factor in international commodity markets, the weather, cobweb type effects, trade restrictions, and changes in the structure of the international economy. It is this last aspect that Schuh concentrates on, citing two major developments: the emergence of a well integrated international capital market, and shift from a regime of fixed to flexible exchange rates. To quote Schuh (p. 8)

> "with a flexible exchange rate regime and a well integrated international capital market, agriculture and other trade sectors have to bear the burdon of adjustment to changes in monetary and fiscal policy. This problem has been exacerbated during the 1970s and early 1980s by extreme instability in monetary policy."

Thus, a situation now exists where the exchange rate can have an important influence on the international demand for U.S. exports.

Several features of the exchange rate changes make their use in the study suitable. A reasonably long lasting change is required so that producers and consumers perceive a new long run equilibrium. The length of the change is important because the models being assessed are long run equilibrium models. If long term expectations are not affected, there is little hope of capturing the effects of the change in the model. The exchange rate changes have been long lasting. For example, the cost of American wheat from an importer's viewpoint has increased at an average of 15 percent per year from 1978 to 1981 (see Table 3.2). The time period for use in the validation exercise needs to be chosen carefully. With models, it is easy to change just one impact to the model at a time. Rarely do impacts in the real world occur in isolation. Nevertheless, for the purposes of this study, it is helpful to select a time period with a small number of impacts. In this way, the effect of one main impact is more easily assessed. The period 1978 to 1981 was selected because it was during this change that significant changes in the exchange rate occurred, but interferences from various policy changes, particularly the PIK program have been excluded. The other reason for choosing this time period was that the model has been updated to 1980 base prices so that a relevant base exists for the period being studied. Consideration of periods distant from the base may require additional modification of the model to make it relevant and could introduce additional sources of error. Validation across a constant base is more desirable.

The choice of exchange rate changes in the 1978-1981 period is not without its problems. While the exchange rate changes have been long lasting, they have also been unstable since the U.S. dollar has progressively strengthened against the curriencies of its trading partners. Thus, it is not likely that any long term equilibrium in production has been approached.

Also, while exchange rate changes have been a major influence on agriculture in the period (according to Schuh) they have not been the only influence. This period has also seen a decrease in the inflation rate, a decrease in the interest rate, and, towards the end of the period, a recession. No attempt has been made to model these other influences because of the complexities inherent in such an attempt. Thus, it is not only the adequacy of the model that is under scrutiny. If the model is to validate the impact of exchange rates must be the dominant influence on agricultural prices. Consequently, one should be aware that the probability of incorrectly rejecting a valid model is high when using the case of exchange rate changes.

The Implementation of Exchange Rate Changes

The sector model previously described has export demand curves for wheat, corn, soybeans, cotton, rice, sorghum, barley, oats, soybean meal and soybean oil. The exports of these products in 1981 comprised about 70 percent of total agricultural exports. The exchange rate changes are assumed to influence the export demand curve in proportion to the size of the exchange rate change. That is, if the U.S. dollar strengthens by 10 percent, the quantity demanded is assumed to decrease 10 percent. The actual exchange rate change is calculated as the change in the weighted average of the exchange rate of individual countries.

The weights for the average are the proportions of the 1980 U.S. crop imports relative to total U.S. crop exports. (These proportions are presented in Table 3.1.) The export data were obtained from

Table 3.1 Major Importers of U.S. Crop Commodities

Country	Wheat	Corn	Soybeans	Cotton	Rice	Sorghum	Soybean Oil	Soybean Meal
	(Percentage of total US Exports)							
Algeria	1.05	0.0	0.0	0.0	0.0	0.0	0.0	.13
Australia	0.0	0.0	0.0	0.0	0.0	0.0	2.16	.08
Belgium	.46	3.48	3.40	0.0	3.36	.78	0.0	.80
Brazil	6.76	2.57	0.0	0.0	0.0	0.0	0.0	0.0
Canada	1.03	.93	1.75	4.51	3.06	0.0	1.08	5.38
Chile	2.51	.36	0.0	0.0	0.0	0.0	3.11	0.0
China	18.21	1.22	0.0	0.0	0.0	0.0	0.0	0.0
Colombia	1.00	0.0	0.0	0.0	0.0	0.0	8.11	0.0
Denmark	0.0	0.0	.79	0.0	0.0	0.0	0.0	0.0
Dominican Republic	0.0	0.0	0.0	0.0	1.48	0.0	0.0	0.0
East Germany	0.0	2.45	0.0	0.0	0.0	0.0	0.0	0.0
Ecuador	.74	0.0	0.0	0.0	0.0	0.0	5.27	0.0
Egypt	0.0	1.90	0.0	0.0	0.0	0.0	0.0	0.0
France	.30	0.0	2.50	.71	.33	0.0	0.0	0.0
Greece	0.0	1.21	.91	0.0	0.0	0.0	0.0	0.0
Haiti	0.0	0.0	0.0	0.0	0.0	0.0	2.97	.01
Hong Kong	0.0	0.0	0.0	3.46	0.0	0.0	0.0	0.0
India	1.40	.03	0.0	0.0	0.0	0.0	8.38	0.0
Indonesia	0.0	0.0	0.0	4.02	4.58	0.0	0.0	0.0
Iran	1.98	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Iraq	0.0	0.0	0.0	0.0	2.34	0.0	0.0	0.0
Israel	.97	.92	1.41	0.0	0.0	5.83	.68	0.0
Italy	1.90	3.13	4.22	.91	.40	0.0	0.0	11.11
Japan	8.08	21.20	19.36	19.22	0.0	35.39	0.0	2.50
Korea	4.88	3.88	2.58	21.99	34.82	0.0	0.0	.28
Lebanon	.57	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Liberia	0.0	0.0	0.0	0.0	2.80	0.0	0.0	0.0
Mexico	2.68	6.45	4.89	0.0	1.38	34.36	2.97	3.12
Morocco	1.66	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Netherlands	1.47	2.99	19.48	0.0	1.05	.14	0.0	0.0
Nigeria	0.0	.42	0.0	0.0	9.32	0.0	0.0	0.0
Norway	.42	.11	1.19	0.0	0.0	1.55	0.0	24.41
Pakistan	.43	0.0	0.0	0.0	0.0	0.0	17.04	0.0
Panama	0.0	0.0	0.0	0.0	0.0	0.0	2.03	.24
Peru	1.88	.71	0.0	0.0	0.0	0.0	5.54	.31
Philippines	1.97	0.0	0.0	1.43	0.0	0.0	0.0	0.0
Poland	0.0	4.33	.80	.61	0.0	0.0	2.03	5.07
Portugal	1.48	4.49	0.0	.56	0.0	0.0	0.0	0.0
Saudi Arabia	0.0	0.0	0.0	0.0	8.47	0.0	0.0	0.0
Senegal	0.0	0.0	0.0	0.0	.79	.17	0.0	0.0
South Africa	.69	0.0	0.0	0.0	3.69	0.0	0.0	0.0
Spain	0.0	4.46	7.02	1.01	0.0	0.0	0.0	.36
Sweden	0.0	0.0	0.0	.17	.36	0.0	0.0	0.0
Switzerland	0.0	0.0	0.0	.78	2.27	0.0	0.0	.60
Taiwan	1.43	2.53	5.39	5.92	0.0	0.0	0.0	0.0
Thailand	0.0	0.0	0.0	3.49	0.0	0.0	0.0	0.0
Tunisia	.37	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Turkey	.43	0.0	0.0	0.0	0.0	0.0	0.0	0.0
United Kingdom	0.0	2.27	1.99	.64	.63	0.0	0.0	.93
USSR	0.0	8.33	0.0	0.0	0.0	0.0	0.0	0.0
Venezuela	2.00	1.17	0.0	0.0	0.0	0.0	7.30	6.08
West Germany	0.0	2.13	9.09	1.89	.79	0.0	0.0	11.54
Yugoslavia	0.0	0.0	1.15	0.0	0.0	0.0	3.52	3.10
Total US Exports [a]	42246	59366	19712	5926	3036	7701	739.6	6154
Percentage of US Exports Included	68.74	83.68	87.90	71.31	81.92	78.21	72.20	76.04

Source: Agricultural Statistics, 1983

[a] Units are 1000s tons except cotton which is in 1000s bales.

Agricultural Statistics, 1983 but the country of destination data for barley and oats were sparse. For these crops, the weights used were those of corn since there were general similarities in the country of destination data. Also, oats and barley are of minor importance in U.S. exports comprising less than 0.1 percent of the total agricultural exports by value.

Using this method, an export demand curve shifter was obtained for each product exported in each of the four years 1978-1981, although the 1980 shifter is necessarily unity because this is the base year. (These shifters are presented in Table 3.2.)

It has already been noted that the assumptions relating to the sole importance of the exchange rate changes as the initiating force of changes in U.S. agriculture and the approaching of an equilibrium in U.S. agriculture are critical to the successful validation of the model. The confidence in the validity of these assumptions was not high. Consequently, due to the expense of running the model, a trial set of runs were tested using the theoretically preferred producer responses. These were the responses used in Adams, Hamilton and McCarl. For the Cornbelt, the cropping activities were crop mixes determined from the solutions to representative farm linear programming models. Outside the Cornbelt, the cropping activities were mixes of crops as determined by historical observations in the years 1970-1980 with yields being adjusted for acreage planted.

The success of the model, as for later assessments, was determined by a statistic which shall be called the relative aggregate absolute error statistic, or, more briefly, the error statistic. This is calculated as:

$$(1) \quad E = 100/T \times \sum_{i=1}^{c} a_{ij}/(n-1) \sum_{t=2}^{n} ABS[(a_{i,t}-a_{i,t-1})-(a^*_{i,t}-a^*_{i,t-1})]/ \left(\sum_{t=2}^{m} ABS(a^*_{i,t}-a^*_{i,t-1})/m\right)$$

where E is the relative aggregate absolute error statistic,

T is the total area of crop planted in year j,

c is the number of crops considered,

n is the number of years for which model results are available,

Table 3.2

Export Demand Shifters

Year	Wheat	Corn	Soybeans	Cotton	Rice	Sorghum	Soybean Oil	Soybean Meal
1978	1.337	1.164	1.132	1.135	1.206	1.253	1.140	1.074
1979	1.125	1.059	1.082	1.084	1.191	1.027	1.082	1.086
1980	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1981	.852	.882	.875	.934	.949	.872	.911	.889

$a_{i,t}$ is the area of crop i planted in year t as predicted by the model,

$a^*_{i,t}$ is the actual area of crop i planted in year t,

m is the number of years for which the average absolute change in crop acreage is calculated.

The name of this statistic was derived from its conceptual components. The basis of the statistic is the "absolute" difference between the predicted and actual change in acreage planted. The term "relative" is included because the error in prediction is related to the average absolute acreage change. This is important because the accurate prediction of a constant change is of little value while the accurate prediction of an acreage change that fluctuates widely is valuable. The term "aggregate" relates to the aggregate of errors across crops and years. A simple average of the years is calculated. A weighted average of crops by acreage planted in year j is used to sum over crops.

Note that a perfect predictor has an E statistic of zero. The error statistic for a naive model that assumes no acreage response can be calculated by setting the predicted acreage change component to zero. A good model should have an error statistic close to zero and less than that of the naive model.

Results of the Exchange Rate Change Analysis

Using the above procedures, the predicted acreage changes in the U.S. resulting from the exchange rate changes were calculated. These are presented in Table 3.3 together with the actual changes. The E statistic for this model was 93 and for the naive model was 83. This implies that the theortically prefered model is less than adequate. However, as stated previously, uncertainty exists as to whether the sector model itself is at fault, or whether the techniques and assumptions used to examine the effects of exchange rates are at fault, or whether the validation attempt is doomed from the start since a short run disequilibrium world is being used to validate a long run disequilibrium model. In the face of such uncertainty, a

Table 3.3 Actual and Predicted Crop Acreage Changes: 1978-1981

	Cotton	Corn	Soybeans	Wheat	Sorghum	Oats	Hay	Silage	Barley	Rice	Error Statistic
Actual acreage changes					(1000s acres)						
1978-1979	328	-1071	5696	4143	-1292	-2864	-1799	-830	-2140	-170	
1979-1980	217	-1131	-3337	7476	-5	-919	-3804	1052	32	420	
1980-1981	-597	-379	-4087	5852	-63	-96	-821	-1294	1142	342	
Av. abs. change (1970-1981)	1490	1923	5080	5203	1226	1661	1948	992	875	314	
Model acreage changes:											
1978-1979	-269	352	-493	-2391	-52	-104	-256	-4	-371	-5	
1979-1980	12	697	-1916	225	41	-81	85	4	34	-6	
1980-1981	-10	1344	-1920	-1780	-17	329	-48	0	-2	-1	
Average percentage absolute error	31	86	64	137	36	81	106	106	111	99	93
No response (naive) model:											
Average percentage absolute error	26	45	86	112	37	78	110	107	126	99	83

second approach was implemented. This approach is discussed in the next section.

Validation of Producer Response

With the apparent failure to validate the model for the exchange rate change another approach was needed which eliminated some of the problems involved. As noted previously, a main problem of the exchange rate change comparison is that a long run equilibrium model is being compared to a disequilibrium real world which is continually adjusting to new influences. Also, the success of the validation is dependent, in part, on the sole importance of exchange rate changes in determining changes in the producers perceptions of future prices.

A way of overcoming both these problems is achieved with a version of the "quantity test" (McCarl and Apland). With this test, price is held constant, and the quantity produced is compared against reality. The modification to this test involves the use of price expectations rather than real prices, and acreage sown rather than quantity produced. Then, the annual changes in the modeled acreages can be compared with those in the real world. This approach has three virtues. First, the model predicts a single stage adjustment by producers to a change in expected prices. Consequently, the results of the model are better able to be compared with what may happen in the real world. Second, all of the factors impacting demand, together with the producers interpretation of those factors, are summarized in the expected prices. Thus, the success of the verification is not dependent on one dominant force such as changing exchange rates. Third, since the object is to select the most appropriate producer response and expected price is exogenous to the model, there is no need to include domestic or foreign markets for the primary commodities. Thus, the model collapses to production of primary products and the use of necessary inputs. In addition, the model can be validated for a region rather than the nation since production from other regions no longer influences price. Consequently the amount of computing required is reduced considerably. The Cornbelt region was chosen because of its importance and because this was the only region for which the representative farm linear programmming solutions have been derived.

Unfortunately, the approach is not without its problems. The most serious of these is the determination of price expectations. Since there is no generally accepted method for determining these from aggregate data, three alternatives are considered:

(a) expectations are based on a distributed lag of previous prices - the form implemented here assumes the price in the previous year is twice as important and the year before, and that that year is twice as important as the year before it. Consequently, a weighting system of 4:2:1 is used for price lagged once, twice, and three times, respectively.

(b) perfect foresight - the actual price experienced in the year is the expected price on the assumption that producers have perfect foresight.

(c) futures price - this approach is included because the futures price should be determined on the basis of all the available information up to the time of trading. It is therefore similar to a rational expcectations approach. The expected price is the futures price for the close of trading in the first day of March for delivery in the month closest to harvest. This date was chosen because it allows adjustment of the planned planting acreages of corn and soybeans, the two major crops in the Cornbelt. Wheat has already been planted by this date, and so, to the extent that relative crop prices have changed between September and March, potential errors exist. The crop prices relative to those of corn for the years considered in the study are presented in Table 3.4. The prices relative to the corn price change by 10 to 19 percent depending on the crop. Another problem with this approach is that futures markets do not exist for all the crops being studied. For these crops, sorghum and hay, actual crops prices were used.

Two other problems exist with the utilization of the single stage response validation. First, short term constraints in the real world are not considered. For example, crop rotations pertinent to the real world are not considered in the model. Second, the model is no longer being used for its intended purpose, that is, as a long run

Table 3.4 Relative Changes in the Futures Prices of Traded Crops

	Real Futures Price					Price Relative to Corn				
	Corn	Soybeans	Wheat	Oats	Cotton	Corn	Soybeans	Wheat	Oats	Cotton
March	225.75	584.50	263.75	125.50	59.25	1.00	2.59	1.17	.56	.26
	256.50	729.00	326.00	146.00	65.80	1.00	2.84	1.27	.57	.26
	296.00	698.00	455.00	156.75	82.02	1.00	2.36	1.54	.53	.28
	374.50	805.00	461.75	219.50	85.75	1.00	2.15	1.23	.59	.23
	286.50	658.00	376.75	188.25	70.00	1.00	2.30	1.32	.66	.24
Sept.	211.75	542.50	250.75	130.00	57.65	1.00	2.56	1.18	.61	.27
	241.50	652.50	310.50	147.50	65.75	1.00	2.70	1.29	.61	.27
	307.50	756.00	444.75	179.00	68.70	1.00	2.46	1.45	.58	.22
	356.75	842.00	499.75	216.25	85.50	1.00	2.36	1.40	.61	.24
	345.00	745.50	449.50	194.50	75.80	1.00	2.16	1.30	.56	.22
Change in price relative to corn:						1.00	.99	1.01	1.10	1.04
						1.00	.95	1.01	1.07	1.06
						1.00	1.04	.94	1.10	.81
						1.00	1.10	1.14	1.03	1.05
						1.00	.94	.99	.86	.90

equilibrium model. These problems hinder the validation attempt.

Hamilton, McCarl and Adams considered seven types of aggregate response assumptions:

(i) no response - producers do not adjust acreage in response to a structural change;

(ii) constant prices - prices are held constant;

(iii) constant consumption - the consumption of products is constant;

(iv) no flexibility constraints - crop activities represent production of individual crops in individual states;

(v) restricted flexibility - crop activities represent production of individual crops in individual states with flexibility about the base of 20 percent or 50 percent;

(vi) historical crop mix - crop activities are mixed to represent historical combinations with one activity for each state in eah year. Two scenarios exist: one with yield being adjusted for acreage planted, and the other without a yield adjustment; and

(vii) LP crop mix - crop activities are optimal solutions of Brown and Pheasant's representative farm linear programs under different price ratios.

Of these alternatives, the constant consumption and constant price models are not relevant to the problem of selecting the appropriate producer response. Also, the model without flexibility constraints is not considered because the model is likely to dedicate the available cropland in one state to the production of a single crop. Since this is not realistic, this assumption is not considered. Each of the other alternatives are implemented in the sector model by incorporating the relevant crop production activities and by making the demand for each crop infinitely elastic at the expected price.

Inspection of acreage planted in the Cornbelt indicates an increasing trend from 1970 to 1980 (Table 3.5). Since the model was not designed to account for this trend component, the actual acreages were scaled to a 1980 base. The crop mix of the modified acreages is therefore the same as the actual acreages but the absolute acreage has been altered to remove the trend component.

Table 3.5 Actual and Modified Cornbelt Crop Acreages

	Year	Cotton	Corn	Soybeans	Wheat	Sorghum	Oats	Hay	Total
Actual					(1000s acres)				
	1970	224	30808	21837	3938	380	4950	9162	71299
	1971	401	33766	22405	3688	498	4831	9020	74609
	1972	440	30299	24510	4332	231	4589	8670	73071
	1973	180	31690	29530	3905	205	3449	9336	78295
	1974	230	33720	27410	6326	211	3395	9060	80352
	1975	196	34900	26570	6731	257	3217	9555	81426
	1976	165	37460	24570	7320	379	3145	9370	82409
	1977	235	36260	28060	6710	296	2920	9470	83951
	1978	188	35140	30430	4170	238	2820	9350	82336
	1979	157	36140	32500	5510	227	2245	9185	85964
	1980	177	37010	31500	6450	255	2130	8935	86457
	1981	168	36650	30980	8310	458	2060	9085	87711
Modified									
	1970	272	37358	26479	4775	461	6002	11110	86457
	1971	465	39128	25963	4274	577	5598	10452	86457
	1972	521	35850	29000	5126	273	5430	10258	86457
	1973	199	34994	32608	4312	226	3809	10309	86457
	1974	247	36282	29493	6807	227	3653	9748	86457
	1975	208	37056	28212	7147	273	3416	10145	86457
	1976	173	39300	25777	7680	398	3299	9830	86457
	1977	242	37342	28898	6910	305	3007	9753	86457
	1978	197	36899	31953	4379	250	2961	9818	86457
	1979	158	36347	32686	5542	228	2258	9238	86457
	1980	177	37010	31500	6450	255	2130	8935	86457
	1981	166	36126	30537	8191	451	2031	8955	86457
Annual average absolute change		80	1337	2096	1150	94	361	293	
3 year average absolute change		84	1778	3616	1963	142	1179	522	

Results of the Producer Response Validation

Error statistics for each response assumption under each price expectation model were calculated and the results of the analyses are reported in Tables 3.6 to 3.8. Two error statistics are reported: one for the annual change and one for the three year (triennial) change.

The three year change was considered to see if model performance differed for a longer term change. Under these circumstances, one would expect the naive model to do relatively worse than models based on economic considerations.

While the performance of the no response model did deteriorate when moving from the annual to the triennial change, it still outperformed nearly every other response assumption over all expectations assumptions. The distributed lag model was generally superior to the other expectations models with a noteable exception. The historical crop mix scenario with yield adjustment and the LP crop mix scenario both performed relatively well for the triennial change under the assumption of perfect foresight price expectations. Some doubt exists as to the true superiority of these reponse assumptions given the relative poor performance of the assumptions under other price expectations assumptions. Similarly, if the perfect foresight model was truely appropriate, one would expect better performance with this assumption for the other reponse assumptions and change analyses.

The validation attempt also appears to be hampered by unusual stability in planted acreage. For example, the average absolute change in acreage planted for corn was 700,000 acres, compared to the 10 year average of 1,337,000. For soybeans, the more recent average was 961,000 compared to 2,096,000 for the longer period.

Nevertheless, the supposed success of the "no response" model is not credible since theory and intuition both suggest some acreage change when price expectations change.

A more careful appraisal of the results, however, gives a better indication of the model response. Generally, the model provided acreage changes that were too sensitive to price changes. That is, for a given price change, the acreage changes predicted were very large. (Table 3.9 compares the annual average absolute change in cropland

Table 3.6 Results of the Distributed Lag Expectations Model

		Cotton	Corn	Soybeans	Wheat	Sorghum	Oats	Hay	Error Statistic
Modified acreage:	1978	197	36899	31953	4379	250	2961	9818	
	1979	158	36347	32686	5542	228	2258	9238	
	1980	177	37010	31500	6450	255	2130	8935	
	1981	166	36126	30537	8191	451	2031	8955	
Acreage change:	1978-1979	-40	-552	733	1163	-22	-703	-580	
	1979-1980	19	663	-1186	908	27	-128	-303	
	1980-1981	-11	-884	-963	1741	196	-99	20	
Annual av. abs. change		80	1337	2096	1150	94	361	293	
3yr av. abs. change		84	1778	3616	1963	142	1179	522	
No response:									
Ac. change	1978-1979	0	0	0	0	0	0	0	
	1979-1980	0	0	0	0	0	0	0	
	1980-1981	0	0	0	0	0	0	0	
Av abs error	(annual)	23	699	961	1271	82	310	301	
Av abs % error	(annual)	29	52	46	111	87	86	103	60
Av abs % error	(triennial)	24	85	15	211	155	64	51	65
Partial flexibility (50%):									
Ac. change	1978-1979	240	-4507	0	3312	0	0	-240	
	1979-1980	-240	0	0	2070	0	0	-2907	
	1980-1981	240	0	0	0	0	16	-525	
Av abs error	(annual)	263	1834	961	1684	82	305	1163	
Av abs % error	(annual)	330	137	46	146	87	84	397	130
Av abs % error	(triennial)	309	338	15	63	155	63	652	225
Limited flexibility (20%):									
Ac. change	1978-1979	0	-2895	0	1742	0	0	0	
	1979-1980	-96	0	0	702	0	-2	-1050	
	1980-1981	96	0	0	0	0	2	-226	
Av abs error	(annual)	87	1297	961	842	82	310	525	
Av abs % error	(annual)	109	97	46	73	87	86	179	85
Av abs % error	(triennial)	24	248	15	86	155	64	194	140
Historical - no yield adj:									
Ac. change	1978-1979	0	-1972	-1356	-7	0	-322	-431	
	1979-1980	-96	-3773	-3749	2449	1	-810	-1283	
	1980-1981	0	2090	1735	-143	0	141	252	
Av abs error	(annual)	55	2943	2450	1532	81	435	454	
Av abs % error	(annual)	69	220	117	133	87	120	155	166
Av abs % error	(triennial)	90	291	108	94	154	20	229	196
Historical - with yield adj:									
Ac. change	1978-1979	0	-1941	-1335	-7	0	-317	-425	
	1979-1980	0	-3312	-3171	285	0	-334	-714	
	1980-1981	0	1960	1348	7	0	320	429	
Av abs error	(annual)	23	2736	2121	1176	82	337	325	
Av abs % error	(annual)	29	205	101	102	87	93	111	146
Av abs % error	(triennial)	24	270	103	196	155	36	85	178
LP model									
Ac. change	1978-1979	0	-1227	-1229	0	0	525	-990	
	1979-1980	0	-7528	-6284	8952	383	-115	0	
	1980-1981	0	483	483	0	0	84	0	
Av abs error	(annual)	23	3411	2835	3649	191	475	244	
Av abs % error	(annual)	29	255	135	317	204	132	83	208
Av abs % error	(triennial)	24	550	210	245	115	106	139	373

Table 3.7 Results of the Perfect Foresight Expectations Model

	Cotton	Corn	Soybeans	Wheat	Sorghum	Oats	Hay	Error Statistic
Modified acreage: 1978	197	36899	31953	4379	250	2961	9818	
1979	158	36347	32686	5542	228	2258	9238	
1980	177	37010	31500	6450	255	2130	8935	
1981	166	36126	30537	8191	451	2031	8955	
Acreage change: 1978-1979	-40	-552	733	1163	-22	-703	-580	
1979-1980	19	663	-1186	908	27	-128	-303	
1980-1981	-11	-884	-963	1741	196	-99	20	
Annual av. abs. change	80	1337	2096	1150	94	361	293	
3yr av. abs. change	84	1778	3616	1963	142	1179	522	
No response:								
Ac. change 1978-1979	0	0	0	0	0	0	0	
1979-1980	0	0	0	0	0	0	0	
1980-1981	0	0	0	0	0	0	0	
Av abs error (annual)	23	699	961	1271	82	310	301	
Av abs % error (annual)	29	52	46	111	87	86	103	60
Av abs % error (triennial)	24	85	15	211	155	64	51	65
Partial flexibility (50%):								
Ac. change 1978-1979	0	0	-13400	6110	0	426	1082	
1979-1980	0	3219	13400	0	352	0	-2293	
1980-1981	0	-3219	-17773	0	31	-62	3448	
Av abs error (annual)	23	1814	15177	2532	171	432	2360	
Av abs % error (annual)	29	136	724	220	182	120	806	425
Av abs % error (triennial)	24	85	507	100	115	95	479	281
Limited flexibility (20%):								
Ac. change 1978-1979	0	0	-7819	2481	0	552	112	
1979-1980	96	2669	10233	0	113	50	-1420	
1980-1981	-96	-2669	-10984	0	0	-50	1882	
Av abs error (annual)	67	1448	9998	1323	101	494	1224	
Av abs % error (annual)	84	108	477	115	108	137	418	276
Av abs % error (triennial)	24	85	252	85	75	111	161	154
Historical - no yield adj:								
Ac. change 1978-1979	72	13143	9441	5667	184	1151	2962	
1979-1980	-71	10984	10178	-2282	-184	1232	2059	
1980-1981	165	6825	-4618	1542	-33	-115	351	
Av abs error (annual)	126	10575	7909	2631	215	1077	2078	
Av abs % error (annual)	158	791	377	229	230	298	710	575
Av abs % error (triennial)	221	1656	400	40	178	257	1079	976
Historical - with yield adj:								
Ac. change 1978-1979	0	0	0	0	0	0	0	
1979-1980	0	10992	6241	40	0	2425	2372	
1980-1981	0	-10415	-5913	-38	0	-2298	-2248	
Av abs error (annual)	23	6804	4370	1270	82	1818	1841	
Av abs % error (annual)	29	509	209	110	87	504	629	380
Av abs % error (triennial)	24	52	6	211	155	75	74	50
LP model								
Ac. change 1978-1979	0	1934	-1813	14446	-383	373	0	
1979-1980	0	22395	23130	-16652	383	1809	-165	
1980-1981	-240	-24450	-23091	6456	0	-1790	1155	
Av abs error (annual)	96	15928	16330	11853	305	1568	618	
Av abs % error (annual)	120	1191	779	1031	325	434	211	988
Av abs % error (triennial)	262	92	64	6	155	98	240	73

Table 3.8 Results of the Futures Prices Expectations Model

		Cotton	Corn	Soybeans	Wheat	Sorghum	Oats	Hay	Error Statistic
Modified acreage:	1978	197	36899	31953	4379	250	2961	9818	
	1979	158	36347	32686	5542	228	2258	9238	
	1980	177	37010	31500	6450	255	2130	8935	
	1981	166	36126	30537	8191	451	2031	8955	
Acreage change:	1978-1979	-40	-552	733	1163	-22	-703	-580	
	1979-1980	19	663	-1186	908	27	-128	-303	
	1980-1981	-11	-884	-963	1741	196	-99	20	
Annual av. abs. change		80	1337	2096	1150	94	361	293	
3yr av. abs. change		84	1778	3616	1963	142	1179	522	
No response:									
Ac. change	1978-1979	0	0	0	0	0	0	0	
	1979-1980	0	0	0	0	0	0	0	
	1980-1981	0	0	0	0	0	0	0	
Av abs error	(annual)	23	699	961	1271	82	310	301	
Av abs % error	(annual)	29	52	46	111	87	86	103	60
Av abs % error	(triennial)	24	85	15	211	155	64	51	65
Partial flexibility (50%):									
Ac. change	1978-1979	0	0	-17258	674	0	0	-1293	
	1979-1980	240	0	-3541	5436	383	0	1028	
	1980-1981	-240	36740	-22833	-989	-383	-320	-3450	
Av abs error	(annual)	163	12946	13583	2582	319	351	1838	
Av abs % error	(annual)	204	968	648	225	341	97	628	736
Av abs % error	(triennial)	24	1982	267	50	155	37	660	1019
Limited flexibility (20%):									
Ac. change	1978-1979	0	0	10264	0	0	0	-112	
	1979-1980	96	0	-816	2481	113	0	0	
	1980-1981	-96	14804	-5803	0	-113	0	-1308	
Av abs error	(annual)	67	5634	4914	1492	139	310	700	
Av abs % error	(annual)	84	421	234	130	148	86	239	303
Av abs % error	(triennial)	24	748	86	85	155	64	221	383
Historical - no yield adj:									
Ac. change	1978-1979	-96	16331	15861	3013	1	1346	3687	
	1979-1980	156	5113	-921	2787	-1	1108	792	
	1980-1981	10	8973	857	-125	-32	-748	541	
Av abs error	(annual)	72	10397	5738	1865	93	1311	1961	
Av abs % error	(annual)	90	777	274	162	99	363	670	523
Av abs % error	(triennial)	107	1626	422	78	178	209	1012	966
Historical - with yield adj:									
Ac. change	1978-1979	0	18514	14639	2973	0	1380	2715	
	1979-1980	0	4759	2263	18	0	1261	1017	
	1980-1981	167	8592	-319	709	-29	-644	638	
Av abs error	(annual)	79	10879	6000	1244	91	1339	1744	
Av abs % error	(annual)	99	813	286	108	97	371	596	532
Av abs % error	(triennial)	222	1708	443	22	175	234	887	993
LP model									
Ac. change	1978-1979	0	20169	19065	-1159	0	2795	-965	
	1979-1980	0	-3834	-6343	21515	0	-717	-280	
	1980-1981	-240	23823	4985	-20957	-383	539	0	
Av abs error	(annual)	96	16641	9812	15209	209	1575	142	
Av abs % error	(annual)	120	1244	468	1323	223	436	49	911
Av abs % error	(triennial)	262	2174	474	242	425	286	188	1266

Table 3.9 Average Absolute Changes in Estimated Total Crop Acreage

		Expectations		
		Distributed Lag Model	Perfect Foresight	Futures Price
			(1000s acres)	
Actual	1.80			
Limited Flexibility (50%)		.87	12.67	9.60
Partial Flexibility (20%)		1.00	6.30	6.50
Historical - no yield adjustment		4.90	19.53	19.53
Historical - with yield adjustment		5.13	10.97	19.53
LP crop mix		2.83	28.80	19.37

from each scenario with the actual change.) On average, actual annual change in acreage planted was about 1.8 million. (For the modified acreages, the average change in total acreges planted was necessarily zero.) The model predicted changes up to 16 times this figure. Two implications exist. First, price expectations are not modified quickly. Second, there may be some, as yet undetermined, rigidity in the real world system. The veracity of these implications is supported by the performance of the distributed lag model (a weighted average of past prices) which generally predicted more conservative changes than the other expectations models.

An inherent assumption in the model is that all producers have the same price expectation and instantaneous adjustment. In the real world, the modification of producers expectations to a single structural change may be spread over a considerable period of time. The longer the time period considered, the greater the number of producers who would alter their expectations.

Do these results imply that the model is invalid? To the contrary, it suggests that the method of validating the model is inadequate. The model was originally long-run equilibrium by nature. In the long term, then, the rate of modification of price expectations is not an issue since the time period is long enough for all producers to modify their expectations and for rigidities to be removed. That is, one of the problems invoking poor performance in the model in this analysis would not exist when the model is used for its intended purpose. Consequently, there is too little evidence to conclude that the model is not valid.

Areas for Future Research on the Validation of Sector Models

Once again it appears that the validation procedure is not straight forward but is strewn with hidden obstacles. The question remains: does a suitable method for validating sector models exist?

One possibility requires the greater utilization of price expectations. The problem with using price expectations is that the process by which price expectations are formed may not be rigid. The greater the annual price fluctuation, the greater the uncertainty in forming expectations, and the greater the importance of the expectations for profit. That is, analogies can be drawn between the way producers adopt new technology (at a rate dependent on the effect of the technology on profit) and the way producers modify their price expectations. Consequently, there is always the danger that a good model may be rejected because the price expectations formulation was not correct. However, if a suitable method for determining price expectations was developed, it seems as though it should be possible to implement a model similar to the one proposed above. However, the sector model and the price expectations formulation should not be developed coincidently since the correct answer may be obtained for the wrong reason. That is, the model may be constructed to validate by selecting a potentially infeasible set of relative prices. An econometric method for developing price expectations may be suitable as long as the method considers the speed with which producers modify their price expectations.

Conclusion

Two approaches for identifying an appropriate aggregate producer response have been proposed in this chapter. One dealt with the ability of the model to predict the effect of exchange rate changes. The other concentrated on the acreage adjustments of producers responding to changes in price expectations. Both techniques had inherent problems and were deemed inadequate. .

Despite the supposed reductions in problems from using price expectations, the error statistic for the exchange rate analysis was one of the closest to the error statistic of the no response model. However, the sample size is too small to draw conclusions as to the appropriate approach. Important practical considerations impede the implemenation of a potentially succesful validation approach.

The original problem, which involved the validation of a sector model for its intended purpose, remains: how to validate a long-run equilibrium model against a real world that is continually adjusting to a variety of impacts. The more the model is made to resemble the real world, the less the model is being used for its intended purpose.

The empirical support of a particular producer response assumption is not available from this study. Under these circumstances, theory is the sole guide for selection of response assumptions. As noted in Hamilton, McCarl and Adams, the model utilizing crop production activities derived from the representative farm LPs is the preferred method of incorporating producer response since it should incorporate the greatest microeconomic detail. Where insufficient data exist to incorporate this approach, the historical mix of crop activities (with yield adjustment for acreage) is preferred since this approach must necessarily provide feasible crop mixes. The yield adjustment version is selected because a reduction in the quality of available resources is expected as acreage increases.

Chapter 4

THE BENEFITS OF AIR POLLUTION CONTROL TO U.S. AGRICULTURE: METHODOLOGICAL AND POLICY ISSUES

by

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Contribution of authors: Dr Adams provided guidance with biological and welfare aspects of the analysis and Dr McCarl provided guidance with model implementation. The remainder of the analysis was conducted by the primary author.

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THE BENEFITS OF AIR POLLUTION CONTROL TO AGRICULTURE: METHODOLOGICAL AND POLICY ISSUES

Introduction

The adverse plant growth effects of air pollution are well documented (United States Environmental Protection Agency (USEPA), 1984; Heck et al., 1984a,b). The incidence of potentially damaging air pollution concentrations within major U.S. agricultural areas is also well established (USEPA, 1984). In view of the importance of U.S. agriculture within both the U.S. and the world, air pollution induced supply reductions could have a substantial societal welfare effect. This provides one of the motivations for the promulgation of National Ambient Air Quality Standards (NAAQS)[1] by USEPA. Indeed, current ozone (O_3) and sulfur dioxide (SO_2) secondary NAAQS are based largely on vegetative effects information (Heck et al., 1984c).

Estimates of the benefits of present or proposed standards are needed to formulate appropriate USEPA regulatory actions. Unfortunately, assessments of the agricultural benefits have not had adequate plant response information (e.g. Manuel et al. 1981, Adams et al. 1982, Leung et al. 1982). In addition, inappropriate or overly simplistic economic models of agriculture have been used as discussed in Adams, Lederboer and McCarl. To circumvent the need for plant science experimental data typically required in primal specifications some success has recently been achieved in dual cost procedures in agricultural assessment (e.g. see Mjelde et al. 1984). However, assessors in general have had little success in applying such techniques across large geographical areas, due to both data and statistical difficulties. As a result, there are highly divergent estimates of pollution control benefits (USEPA, 1984).

The National Crop Loss Assessment Network (NCLAN) was established to develop consistent data on crop response to air pollutants. This USEPA funded program involves field experiments on crop sensitivity to ozone, the major air pollutant in terms of plant effects. The output from these experiments are intended to form the basis for policy making by economic assessments of the national consequences of alternative ozone standards on agriculture. This study incorporates these recent data into a sector model of U.S. agriculture and uses the model to estimate the national economic consequences of ozone pollution.

This paper reports estimates of the societal benefits of alternative ambient ozone levels arising from the agricultural sector. The economic analysis is limited to those ozone effects directly associated with production and comsumption of a set of agricultural commodities. Effects on non-agricultural commodities and compliance costs of achieving the simulated changes in ozone are not evaluated here, hence these estimates are not necessarily net economic effects. The analysis, data and results represent the collective biological, meteorological and economic knowledge gained in USEPA's NCLAN program from 1980 through 1983. The results are derived from U.S. agricultural sector model (adapted from Baumes; and Chattin, McCarl and Baumes). The model is implemented using the cropping activity suggestions of McCarl (1982a).

The specific objectives of the research underlying this paper were:

1. to provide estimates of the benefits and costs arising from the agricultural sector under alterations in ambient ozone levels;
2. to test the sensitivity of the benefit and cost estimates to biological response data uncertainty;
3. to provide estimates of the returns to improved or augmented biological response information; and
4. to implement and discuss use of the cropping activity suggestions in McCarl (1982a).

The Problem Setting

Tropospheric ozone (O_3) has been identified as an air pollutant with harmful vegetative effects for more than 30 years (Middleton, Kendrick and Schiwalm 1950, Brisley and Jones 1950). Pollution may directly harm the plant through stomatal uptake of toxins that result in premature senesence, as well as indirect, such as predisposing plants to insect and disease damage. Ozone occurs naturally both in the stratosphere and troposphere but is also generated by man, primarily through industrial processes and automobile emissions (USEPA, 1984). Current estimates (Heck et al., 1984b) attribute approximately 40 percent of the tropospheric ozone to man-made sources. Tropospheric levels of ozone are regulated under existing Federal air quality standards.[2]

Attempts to assess agricultural costs soon followed recognition of ozone's implications. However, until recently, sparse or even contradictory biological information limited the usefulness of such assessments. Further, experimental procedures limited the usefulness of the data in economic analysis. For example, foliar injuries were often reported rather than yield. The NCLAN data constitutes superior yield effects estimates.

Most of the benefits assessments of pollution control focus on regional effects (e.g., Smith and Brown 1983; Benson et al. 1982, Mjelde et al. 1984, Howitt et al 1984). This regional emphasis is due to the availability of data on crop response and air quality for selected regions, as well as the national importance of some agricultural regions, such as the Cornbelt and California.

Most available national assessments assume perfectly elastic demand, multiplying an estimate of air pollution induced yield change by a constant crop price assuming away acreage or price changes as reviewed in Adams, Ledeboer and McCarl. Recent national assessments use more defensible economic models (Kopp, Vaughn and Hazilla; Adams, Crocker and Katz). While more defensible, these studies still exhibit limitations. For example, the yield response data do not reflect the most current NCLAN studies and possible producer adjustments in crop mix are limited. Further, economic linkages to processing, livestock production and export markets are ignored, again suggesting possible biases. If agricultural benefits assessments are to guide regulators towards efficient environmental policies, more comprehensive empirical analyses are warranted.

Methodological Considerations

Bioeconomic assessments need to incorporate direct physiological implications of ozone pollution to generate benefit and cost estimates. These benefits and costs will be determined by the marketplace interaction of producers and consumers.

In several regional studies (Benson et al. 1982, Adams et al. 1982) the results obtained from economic analyses that incorportaed market responses were compared with estimates obtained from the same data using methods where producer and consumer response were not considered (the naive approach). The differences were moderate to large with the naive approach overestimating the losses from air pollution when moving from "clean air" to ambient ozone condition (an environmental degradation). Also, the naive approach provides estimates which at best can only address producers' effects with no attention being paid to the fate of the consumer. Thus, conceptually and empirically, there is a fundamental difference between losses measured by the naive approach and those obtained from more comprehensive economic assessments. This suggests the need to consider broader implications in the evaluation of the induced change rather than simply isolating the farm level effects as economists have traditionally done (see reviews by Heady and Srivastava 1975, McCarl and Spreen 1980, Norton and Schiefer 1980).

Agricultural sector models have been used to simulate the marketplace under alternative agricultural policies or technological change. Mathematical programming sector models have been used frequently for this purpose. Such models enable the consumer and producer response to be estimated simultaneously, providing an estimate of the distribution of welfare gains and losses as reviewed in Heady and Srivistava; McCarl and Spreen; and Norton and Schiefer. The general methodology has been applied to numerous environmental assessments including regional air pollution studies (Adams, Crocker and Thanavibuchai; Howitt, Gossard and Adams; and Rowe et al.)

However, mathematical programming sector models often contain unrealistic regional results. For example, when doing appraisals of exogenous changes with aggregate models (i.e., models such as those used in Heady and Srivistava, Baumes, or Burton, 1982) one often finds extreme regional specialization in production. That is, one gets solutions where whole regions are devoted to a single crop. This situation usually leads to the imposition of inflexible "flexibility" constraints. McCarl (1982a) recently proposed an alterative formulation for embodied cropping activities so that they depict whole farm multiple crop mix rather than individual crop production. This suggestion is designed to avoid regional specialization and is motivated by a Dantzig-Wolfe decomposition scheme. McCarl suggested implementing this suggestion by "(a) running a representative farm model under a number of alternative prices," or "(b) utilizing historical crop mixes" (McCarl, 1982a, p. 770). Both methods have been used in this analysis. In addition, the implementation of these approaches was extended to include yield responses to changes in acreage mix (as explained below).

The Sector Model

The mathematical programming sector model used in this national assessment is similar to the numerous agricultural sector models of Heady and associates (as reviewed in Heady and Srivistava, Norton and Schiefer, and McCarl and Spreen). The particular model used here was developed by Baumes, improved in data specification by Burton, documented in Chattin, McCarl, and Baumes, and updated/revised for this study. A version of the model is also described in House.

The model is a long run equilibrium model encompassing production and processing of cotton, corn, soybeans, wheat, sorghum, oats, barley, rice, silage, hay, dairy cattle, beef cattle, and hogs. The model contains a ten region disaggregation of the U.S. containing 55 subregions. These subregions are 12 subregions in the Cornbelt (as developed by Brown and Pheasant) and the 43 non-Cornbelt states. The base cropping information is derived from the 1976 Crops Federal Enterprise Data System (FEDS) and associated FEDS Livestock budgets as reformatted by Burton. These were brought to a 1980 basis, using USDA state level yields, acreages, and prices. Miscellaneous production costs were altered following the procedures outlined in Fajardo, McCarl and Thompson (1981) and Baumes (1978)[3].

A complete description of the model is beyond the scope of this paper (the interested reader should refer to Chattin, McCarl and Baumes; House; Baumes; or Burton). In addition, related conceptual material is given in McCarl and Spreen; Norton and Schiefer; and Heady and Srivistava. Nevertheless, a description of how the microeconomic detail was incorporated in the sector model is necessary.

The Cornbelt and the rest of the U.S. were treated differently in terms of microeconomic detail. The Cornbelt model was developed following McCarl's representative farm model suggestions, one for each of 12 Cornbelt subregions as elaborated on in McCarl et al., 1984. These whole farm crop plans were derived using the work of Brown and Pheasant, who used 12 representative farm linear programs using the Purdue REPFARM package (McCarl, 1982b). Brown and Pheasant ran each farm model under a set of alternative crop prices developing a set of whole farm plans. Crocker argues that such detail is needed to adequately model potential producer mitigative behavior in the face of environmental changes.

Brown and Pheasant's results suggested an important consideration not covered in McCarl. Crop yields were found to be sensitive to crop mix. This is not surprising, as an increase in one crop's acreage would reasonably be expected to be accompanied by a change in average yield of other crops, as rotation effects, less favorable land and/or different planting/harvesting conditions are encountered. To reflect such influences, yield changes were incorporated in the cropping activities. The procedure involved mixing the FEDS budgets in the proportions specified within each crop mix generating one sector model activity for each mix in each region. Yields were also adjusted in the same proportion as given by the farm models.

The subregional REPFARM farm models were solved with five corn prices and twelve soybean to corn price ratios as well as five wheat prices. Thus each model was run under 300 different price ratios. The data were summarized to yield a series of unique crop mixes (i.e., land use patterns) and accompanying yields for each of the representative farms. Specifically, when the REPFARM model was solved under a particular price ratio it yielded a particular combination of crops; for example, 45 percent corn, 35 percent soybeans, and 20 percent wheat with associated yields. These were used to generate the activities in the sector model. The relevant FEDS budgets were multiplied by the crop mix percentages and summed with the individual crop yields adjusted to account for the percentage yield change from a selected base crop plan. Thus, each LP activity represents a whole farm plan, rather than a single crop.

For areas outside the Cornbelt, the historical data procedures suggested by McCarl (1982a) were utilized to develop whole farm plans. Yield adjustments reflecting crop mix changes were also included. Crop records by state for 1970-1981 were used both to develop representative state level crop mixes and to econometrically derive estimates of crop yield response to crop mix changes. Specifically, yield response estimates were derived using historical data on relative crop acreages as the principal independent variables; i.e., the yield of a crop was estimated as a function of its planted acreage, and the planted acreage of other crops, as discussed in Hamilton, Adams and McCarl.

The Cornbelt and the rest of the country cropping activities are included in the model along with livestock and processing activities, and supply and demand activities to form the full sector model. Such a model has the advantages that:

a) the sector model solution will refect sensible crop mixes in the microeconomic context,
b) the model may validate more easily without the need for flexibility constraints, and
c) the microeconomic context of the model will be more adequately reflected allowing the aggregate model to be less detailed.

Model Validation

The adequacy of this or any model rests partially on the plausibility of the model results. This was examined by comparing base model price, quantity and acreage results with 1980 actual values (Tables 4.1 and 4.2), using the 1980 technical data.

The model predicts equilibrium prices within five percent or less of the actual 1980 prices (Table 4.1). For 11 of the 12 crops the model price levels are equal or slightly higher than actual. The model quantity results presented are generally within 10 percent of actual (the exceptions are sorghum, 17 percent, and silage, 20 percent). For 7 of the 12 commodities, model production exceeds actual. The model prices and quantity results display strong similarities with actual livestock results. Specifically, model prices fall within 3 percent of actual, while quantities are again within 10 percent of actual 1980 levels. Overall the model prices and quantities for both crop and livestock commodities appear to capture the relative magnitudes of equilibrium prices and quantities observed in recent years.

The changes in producer welfare at the regional level are another dimension of the regulatory policy issue. A comparison of model cropped acreage results with actual acreages for the ten major USDA production regions is given in Table 4.2. There is a close correspondence between model regional acreages and actual. The model results are slightly below actual national acreage for all crops, due to the exclusion of some minor specialty crops from the model specification. Subregional crop acreage also exhibits close correspondence. The accuracy with which the 1980 base model solution simulated the observed 1980 results was considered acceptable and so the model was deemed suitable for use in the subsequent analysis.

Data on Air Pollution and Its Effects

A major goal of the NCLAN program is to develop a base of plant science information on the response of crops to ozone and other stresses. Heck et al. (1984b) summarizes the cumulative response information for the four years of the program in dose response form.

Table 4.1 Actual and Model 1980 Prices and Quantities for Crops and Livestock Commodities

Commodity/Product		1980 Prices		1980 Quantities	
		Model	Actual	Model	Actual
Crops	Units	$/unit		million units	
Cotton	(500 lb. bales)	366.72	358.00	17.45	15.65
Corn	(bushels)	3.25	3.11	7,339.85	6,645.84
Soybeans	(bushels)	7.74	7.57	1,778.07	1,792.06
Wheat	(bushels)	3.71	3.91	2,633.94	2,374.31
Sorghum	(bushels)	3.00	2.94	700.88	579.20
Rice	(cwt)	12.79	12.80	164.78	146.15
Barley	(bushels)	2.91	2.85	335.50	360.96
Oats	(bushels)	1.93	1.79	472.91	458.26
Silage	(tons)	19.46	NA	91.24	110.97
Hay	(tons)	70.90	71.00	141.58	131.03
Soybean Meal	(pounds)	0.11	0.11	46,180.80	50,624.00
Soybean Oil	(pounds)	0.24	0.23	10,755.81	11,270.00
Livestock					
Milk	(cwt)	12.95	13.00	1,282.24	1,286.20
Pork	(cwt)	139.00	139.50	141.68	165.77
Fed Beef	(cwt)	237.50	237.60	138.20	159.36
Veal	(cwt)	310.30	309.50	3.66	4.11
Non-Fed Beef	(cwt)	150.20	149.76	64.40	73.22

Source: USDA, Statistical Reporting Service, Statistical Bulletin 552.

Table 4.2 Model and Actual 1980 Regional and Total U.S. Cropped Acreages[a]

Region	Model	Actual
	1,000 Acres	
Northeast	13,157	12,949
Lake States	39,637	37,770
Cornbelt	84,740	90,064
Northern Plains	75,533	77,956
Appalachian	20,439	20,797
Southeast	15,234	14,944
Delta	20,938	22,078
Southern Plains	35,779	37,805
Mountain	22,709	27,393
Pacific	11,938	14,728
Total	340,104	356,484

Source: USDA, Agricultural Statistics, 1981.

[a] Cropped acreage refers to land planted to crops. It excludes pasture and grazing land.

The relationship between yield and ozone levels is charatcterized by a Weibull density model (Rawlings and Cure 1984). The data used to estimate the response are drawn from experiment on multiple cultivars (varities) of corn, soybeans, wheat and cotton, as well as single cultivars of grain sorghum and barley. Together these crops account for about 70 percent of the U.S. cropped acreage. These data are the source of the individual crop response functions used to project yield adjustments for each ozone alternative in the economic analysis.

Measures of the ambient ozone concerntrations in rural production areas of the U.S. are needed to effectively utilize the NCLAN response functions. Unfortunately, such complete data do not exist, as available data from USEPA's Storage and Retrieval of Aerometric Data (SAROAD) system are taken from predominately urban monitors. However, a surrogate data set is available through the NCLAN program. Specifically, surrogate county-level ambient ozone concerntrations are derived by spatial interpolation of the USEPA SAROAD monitoring data based on "Kriging" procedures discussd in Heck et al. (1983). Certain meteorological aspects of ozone make this pollutant amenable to interpollation procedures; e.g. its pervasive nature and the existence of smooth gradients of concerntrations rather than abrupt spikes or plumes. Further, the nature of the dose measure (seasonal seven-hour average) is also assumed to "smooth" out some of the variability in the ozone events. A comparison of the interploated (Kriged) ozone levels reported in Heck et al (1983) with some actual values recorded at NCLAN sites (and reported in the same publication) reveal a fairly close correspondence.

These data are incorporated in the model assuming that ozone imposes a neutral technological change but a proportional reduction in yield. Thus, each yield in each production activity is adjusted by the proportional change in yield generated using the response function when the ozone concerntration is altered.

The Ozone Assessment Procedure

Several separate analyses of the agricultural effects of ozone were performed. The analyses were intended to investigate the benefits and costs of ozone concentration changes as well as the sensitivity of these results to alternative ozone response assumptions. Each analysis considers four ambient ozone concentration scenarios: 10 percent, 25 percent and 40 percent reductions and a 25 percent increase. These changes are measured as departures from the 1980 actual ambient ozone levels (Heck et al. 1983), and are assumed to occur solely within the U.S.[4]

The 10 and 25 percent adjustments are considered plausible. Changes of this magnitude are encompassed in the temporal variability displayed by ambient ozone levels in recent years (from 1978-1982). The 10 and 25 percent improvements in ozone levels are of policy importance in that these adjustments parallel changes in ambient ozone likely to be associated with proposed alternative Federal SNAAQS of 0.10 and 0.08 ppm (not to be exceeded more than once per year). Assuming the imposition of a Federal standard more strict than the present standard of 0.12 ppm, ambient rural concentrations should decline. Heck et al. (1982) state that a hypothetical Federal hourly standard of 0.08 would translate into a seasonal seven-hour average of about 0.04 ppm. Such an ambient ozone level is consistent with those achieved with the 25 percent ozone reduction scenario. Further, the 25 percent ozone increase results in ozone levels somewhat similar to what would be realized if a Federal SNAAQS of 0.14 ppm were achieved.

The 40 percent ozone reduction is an extreme analysis in that such a reduction in ozone would bring actual ambient concentrations down to or below what is generally thought to be background or natural ozone levels (Heck et al., 1984a). Thus, the economic benefits measured in the 40 percent analysis may not be particularly relevant from a policy standpoint. However, these results can suggest the maximum benefits of ozone control, assuming control of all man-made sources of ozone.

The four years of NCLAN data contains results on several corn, soybean, wheat and cotton cultivars (varieties). Initial screening indicates that differences in cultivar response (proportionate response or slope) are not a significant factor for most of the soybean, wheat, and corn data (Rawlings and Cure, 1984). Thus, the yield adjustments for corn, soybean, and wheat are derived from response functions estimated with data pooled across each crop's set of cultivars. For cotton, individual reponse functions for irrigated (western U.S.) and nonirrigated (southeast) cotton cultivars are used. Only single cultivar response functions are available for grain sorghum and barley. Using this mix of response functions, the four ozone alternatives are then translated into corresponding yield changes for use in the benefit evaluations.[5] Economic effects estimates are generated using the resultant four model solutions. Compared to the base, changes in economic surplus are an estimate of the welfare consequences of each ozone level. This constitutes the base benefit analysis which is called Analysis A.

One important commodity for which NCLAN data are not available is hay. Alfalfa or grass-legume hay is an important crop in several regions. It is also important in the feed-livestock balance and the resulting spatial characteristics of livestock feeding. While sufficient data are not currently available to gauge the effects of ozone on hay yields, a study of alfalfa hay response indicates moderate sensitivity of hay yield to ozone (Oshima et al.). Thus, Analysis A contains runs both with and without hay response. When present the hay response is assumed to be approximated by the average NCLAN yield response of the other crops.

A few varieties of corn, soybean, and wheat display atypical responses. For example, the response of the Davis cultivar of soybean was approximately twice as sensitive to ambient ozone. However plausible it may be to view these as atypical responses, it is nonetheless possible that their response may characterize some regional responses. An analysis based on these more extreme responses can be used to bound the benefits and costs. Thus an analysis is done using the most sensitive varieties along with the surrogate hay response. These analyses constitute the first part of Analysis B.

Preliminary evidence suggest that moisture-stress and other environmental covariates alters the effect of ozone on crop yield (Tingy et al.). This type of interaction has important implications given that the production of most nonirrigated crops typically occurs under less than optimal moisture conditions. Further, ozone concentrations tend to increase during hot, clear weather. Consequently it is expected that high ozone effects are accompanied by periods of low water availability to the plant moisture-stress. Unfortunately, such interactions have only recently been introduced into the NCLAN experiments, i.e., most NCLAN data are generated under adequate moisture conditions. However, limited data are available on ozone moisture-stress interactions from three NCLAN experiments, one on cotton and two on soybeans that suggest that moisture-stress reduces ozone yield effects. In addition, simulation results on moisture-stress ozone interactions based on these three NCLAN experiments are available (King and Snow, 1984). King and Snow's results provide the basis for a preliminary analysis of ozone effects in the presence of moisture-stress. These analyses constitute the remainder of Analysis B.

Results and Implications

The U.S. agricultural effects of changes in ambient ozone pollution based on the pooled response data assumption (Analysis A) are portrayed in Table 4.3. Annual benefit estimates of reduced pollution increase as pollution is reduced. Specifically, the benefit estimates of 10, 25 and 40 percent reductions in ambient ozone are approximately $0.7, $1.7, and $2.5 billion, respectively.[6] The cost of a 25% increase in ozone is $2.1 billion. These economic estimates amount to percentage changes of the objective function of approximately 0.5, 1.4, 2.0 and -1.7 percent, respectively. These changes are triggered by ozone induced average crop yield changes of 1.1, 2.5, 3.8, and -3.0 percent. Marketplace substitutions permit a partial mitigation of the yield reductions.

The hay response analysis is intended to account for the effects of ozone pollution arising through livestock hay consumption. With the inclusion of a hay yield adjustment, the benefit values are now $0.75, $1.9, $2.9, and -$2.4 billion, approximately a 13 percent increase in benefit estimates. This points out the importance of the feed livestock linkage in the model and demonstrates the need for data on the ozone-sensitivity of hay, pasture and range.

The distributional consequences of regulatory policies are also relevant in setting air pollution standards. In this analysis, both

Table 4.3 Benefits of Alternative Ozone Levels - Analysis A

	Economic Surplus			Changes in Economic Surplus		
Ozone Assumption	Producers' Surplus	Consumers' Surplus	Total Surplus	Producers' Surplus	Consumers' Surplus	Total Surplus
	$ billion					
Without Hay Adjustment						
Base	26.015	114.957	140.971	—	—	—
10% Reduction	26.250	115.390	141.640	0.235	0.433	0.669
25% Reduction	26.567	116.116	142.683	0.552	1.159	1.712
40% Reduction	26.788	116.701	143.489	0.773	1.744	2.518
25% Increase	25.413	113.462	138.875	-0.607	-1.495	-2.096
With Hay Adjustment						
Base	26.015	114.957	140.971	—	—	—
10% Reduction	26.337	115.389	141.727	0.322	0.432	0.756
25% Reduction	26.807	116.101	142.908	0.792	1.144	1.937
40% Reduction	27.271	116.559	143.830	1.256	1.602	2.859
25% Increase	25.122	113.486	138.608	-0.893	-1.471	-2.363

producers and consumers shared in the gains from increased supply. In absolute terms, consumers benefit substantially more than producers. The benefit to domestic consumers from falling prices is expected. However, the observation that there are aggregate gains to producers is initially surprising.

The change (increase) in producer's surplus resulting from an increase in supply is due to the complex interaction of the demand and supply relationships within the model. Domestic and foreign demand is characterized by varying elasticities (including elastic assumptions for some exports). Further, it is the change in intercept and slope of the supply curve that partially determines net changes in producer surplus (i.e., the shifts in supply within the model are not always characterized by parallel shifts). In addition, primary (e.g., feed grains) and intermediate (e.g., livestock) commodities are included in the model, with corresponding derived demand implications vis a vis producers effects. Under these conditions, increases in producer's surplus with increased supply are realized. Given the open nature of the economy in the model, it should also be noted that the analysis and results are based on the assumption that changes in ozone standards within the U.S. will not affect supplies in other exporting or importing countries. While some "spillover" of ozone changes may occur in southern Canadian wheat-producing regions, the meteorology of ozone formation and transport suggests that transboundary effects should be minimal, particularly with respect to transcontinental effects.

Another result within the model involves the distribution of consumers' surplus between domestic and foreign consumers (Table 4.4). The bulk of the consumers' surplus arises from domestic consumption. However, when the changes in consumers' surplus are calculated, the foreign consumers' share is greater. This implies that the benefits of increases in air quality manifest in increased supplies will accrue to both domestic and foreign consumers with the foreign consumers benefitting relatively more. This is not surprising given the relative elasticities of the demand curves.

A final distributional aspect concerns regional effects. Regions display different ambient ozone levels and hence different yield

Table 4.4 Annual Effect of Ozone on Distribution of Consumer Surplus Between Domestic and Export Markets - Analysis A

	Consumer Surplus			Change in Consumer Surplus		
Ozone Assumption	Domestic	Export	Total	Domestic	Export	Total
Base Case (1980)	100.940	14.016	114.956	—	—	—
10% Reduction	101.059	14.330	115.389	0.119	0.314	0.433
25% Reduction	101.383	14.717	116.101	0.443	0.701	1.145
40% Reduction	101.516	15.043	116.559	0.576	1.027	1.603
25% Increase	100.296	13.189	113.486	0.644	0.827	-1.470

responses. Table 4.5 contains a regional breakdown of producers' surplus by ozone alternative. Almost all regions benefit from reduced ozone and suffer losses from increased ozone. The greatest absolute benefits generally accrue to regions with the greatest value of included crops, i.e., the Cornbelt. However, in relative terms, the distribution of gains and losses is somewhat different. The regions exhibiting the most sensitivity in percentage terms from reduced ozone have fairly high ambient levels and a crop mix dominated by sensitive crops; i.e., soybeans and cotton. These regions are the Pacific (including California), Delta, Northeast, and Southeast. Regions, like the Northern plains, received almost no benefits (or losses) from adjustments in ozone due to relatively low ambient ozone levels and a crop mix that does not feature ozone-sensitive crops.

Comparison with Previous Benefits Estimates

The 25 percent ozone reductions can serve as a useful comparison with some recent economic estimates derived by other researchers, given that it closely simulates the ozone standards or levels used in these recent national assessments. Specifically, recent national analyses by Kopp et al. (1983) and Adams et al. (1984) use less complete sets of NCLAN data to derive yield adjustments. In the Kopp et al. analysis, improvement in air quality from the present ozone secondary standard of 0.12 ppm hourly maximum (not to be exceeded more than once per year) to a 0.08 standard are estimated to result in benefits to society of approximately $1.1 billion. Such an assumed improvement in ambient levels is close to the 25 percent ozone reduction alternative in this study, assuming a log-normal distribution of ozone events. The Kopp et al. analysis does not include hay, sorghum, barley or livestock. Empirically, it is perhaps closest to the "without hay" analysis. The difference in benefits recorded ($1.71 vs $1.1 billion) is due to more complete crop coverage, inclusion of an endogenous livestock sector and use of more recent biological data (through 1983) in the present study. Also, the assessment methodologies differ, particularly with respect to the aggregation of regional supply and the regional adjustment process to

Table 4.5. Annual Effect of Ozone on Regional Producer Surplus With Hay Included - Analysis A

Region	Base	Ozone Assumption							
		10% Reduction		25% Reduction		40% Reduction		25% Increase	
		Surplus	% Change	Surplus	% Change	Surplus	% Change	Surplus	% Change
		---- $ billion ----							
Northeast	0.551	0.569	3.27	0.575	4.36	0.601	9.07	0.516	-6.35
Lakes	3.743	3.788	1.20	3.782	1.04	3.828	2.27	3.681	-1.66
Corn Belt	7.261	7.404	1.97	7.492	3.18	7.633	5.12	7.106	-2.13
North. Plains	3.576	3.570	—	3.578	—	3.599	0.60	3.559	-0.50
Appalachia	2.298	2.331	1.44	2.364	2.87	2.402	4.53	2.224	-3.22
Southeast	1.377	1.409	2.32	1.440	4.58	1.475	7.12	1.274	-7.48
Delta	1.348	1.395	3.49	1.448	7.42	12.495	10.91	1.224	-9.20
South. Plains	2.540	2.549	0.35	2.573	1.30	2.603	2.48	2.485	-2.17
Mountain	2.508	2.506	—	2.570	2.47	2.576	2.71	2.439	-2.75
Pacific	0.813	0.820	0.86	0.984	21.03	1.059	30.26	0.614	-24.48
Total	26.015	26.337	1.23	26.807	3.04	27.271	4.83	25.122	-3.43

ozone-induced supply shifts.

The Adams et al. (1984) study uses a comparable 25 percent ozone reduction and estimates the benefits from increased yields of corn, cotton, soybeans and wheat to be approximately $2.4 billion. The higher value in that study is due to use of higher ambient levels (uses the upper bound of regional ozone levels for 1980), the use of national supply functions for each crop (no micro detail) and a different benefits calculation procedure. The present study thus overcomes some conceptual and empirical shortcomings of these previous national assessments. The relative positioning of the estimates (higher than Kopp et al. 1983, lower than Adams et al. 1984) seems consistent with the respective model structures and empirical focus.

Overall, the results indicate that the benefits of moderate ozone reductions are substantial in absolute terms but a relatively small percentage of total agricultural value (approximately 3 percent of gross crop value). The benefits of ozone reductions accrue to both producers and consumers, with about 60 percent of the consumer benefits accruing to foreign consumers. Domestic consumers benefit from slightly lower prices of livestock products, due to increased supplies of feedgrains and oil seed. Regionally, the major beneficiaries are those areas with high relative levels of ozone and ozone-sensitive crops.

Sensitivity of Benefits Estimates to Response Assumptions

Alternative analyses using different sets of crop-ozone response assumptions can suggest the sensitivity of these benefits estimates to the nature of the response data as well as provide guidance on the efficiency of obtaining more response information. The benefits estimates arising from these alternative analyses are reported in Table 4.6 for the 25 percent ozone adjustments. The first alternative analyses focuses on the magnitude of benefits of ozone reductions if average crop response in the U.S. parallels that of extreme cultivars in the NCLAN data. These estimates are approximately 50 percent higher over the range of ozone levels than those observed in the pooled cultivar response assumption used above. Specifically, the 25 percent ozone reduction now translates into benefits of $2.9 billion, rather than $1.9 billion as in the earlier analysis. This benefit estimate amounts to nearly 5 percent of the farm value of primary crops. The greater economic estimates arise from much greater yield adjustments associated with the extreme cultivar response.

The distribution of the effects across producers and consumers is similar to those observed in the previous analyses, that is, the consumers benefit the most from ozone reductions in absolute terms, but producers have a larger relative gain. Compared with the initial analysis, however, the gain to consumers is slightly larger across all ozone levels, due in part to the larger shift in supply.

Ozone effects, like any environmental stress, do not occur in isolation. The second alternative analysis represents an attempt to account for the likely interaction between water stress and ozone by using drought estimates for 1980, water-stress yield regressions and the soil moisture plant growth simulation model to arrive at adjustment factors for fully watered response functions reported in NCLAN literature. Although simplistic, this water stress analysis can serve to reinforce the need for more information on a broad range of interactive processes.

The adjustment factors used to modify the full-watered response data range from about 0.65 to 1.00 (no drought). These adjustment factors are derived by measuring July drought (departures from normal rainfall) for 1980 and then introducing these drought levels into the plant simulation model that describes the relationship between ozone and levels of moisture stress. The departures from normal July rainfall are calculated for each of the 55 production subregions using National Oceanographic and Atmospheric Administration (NOAA) data (1980). Thus, the yield changes for each ozone level will be lower than in the first analysis.

As the numbers in Table 4.6 indicate, the use of moisture stress adjustments in the analysis lowers the benefits estimates. For example, the 25 percent ozone reduction now results in benefits of approximately $1.56 billion as opposed to $1.94 billion in the earlier analysis, based on the non-stressed ozone-response estimates, a 26 percent difference. Similar divergences are found in the three other

Table 4.6 Sensitivity of Benefits Estimates to Response Assumptions - Analysis B

	Economic Surplus			Changes in Economic Surplus		
Ozone/Response Assumption[a]	Producers' Surplus	Consumers' Surplus	Total Surplus	Producers' Surplus	Consumers' Surplus	Total Surplus
	$ billion					
Base	26.015	114.957	140.971	—	—	—
<u>25% Ozone Reduction</u>						
Pooled Cultivar Analysis	26.807	116.101	142.908	0.792	1.144	1.937
Extreme Cultivars	26.972	116.920	143.892	0.958	1.963	2.921
Moisture Stress	26.659	115.874	142.532	0.644	0.917	1.561
<u>25% Ozone Increase</u>						
Pooled Cultivar Analysis	25.122	113.486	138.608	-0.893	-1.471	-2.363
Extreme Cultivars	24.212	112.867	137.711	-1.171	-2.090	-3.261
Moisture Stress	25.460	113.664	139.124	-0.555	-1.293	-1.847

a. All analyses include the surrogate hay response.

ozone levels. This implies that the inclusion of moisture stress is an important consideration in accurately assessing the broad-scale effects of ozone. Further, its inclusion has a perceptible effect on the economic estimates. If the basic hypothesis of an antagonistic effect between moisture stress and air pollution is correct (whether or not these adjustments are correct), then it seems likely that any future analysis of moisture stress-ozone interactions will lead to a reduction in the economic estimates generated from ozone yield data.

This moisture stress adjustment analysis also points to the need to address other interactions. It is possible that other interactions may have equally important but opposite effect on the estimates. For example, some evidence suggets that increasing the ambient ozone levels may predispose plants to insect or disease damage, with increases in yield variability.

Limitations of the Analysis

The assumption and abstractions inherent in the analysis can be viewed as caveats on the assessment results. For example, several limitations of the experimental design and procedure underlying the generation of the biological data are apparent. First is the failure to account for a range of environmental interactions in the experiments, such as moisture stress. This issue is partially addressed in one of the analyses, but only preliminary data are available. Second, the response data are also generated at relatively few sites, requiring extrapolation to broad regional scales. Third, while data are generated under field conditions, the plants are in semi-controlled chamber environments, which may introduce biases. Fourth, the exposure dynamics to date are confined to a seven-hour per day exposure over the growing season. Longer daily exposures (e.g. 12 hour) may have shown to result in substantially higher yield losses. Since plants under natural conditions would be exposed for this longer period, the seven-hour exposure may not be the most appropriate exposure regime. Fifth, the amount of anthropogenic versus "background" ozone is not known on a region to region basis. This study introduces biases if policy can potentially influence ozone concerntrations in some regions more than in others.

In addition to experimental design and procedure questions, the cropmix and cultivars tested to date are limited to major annual field crops and a relatively few cultivars of each crop. The effects of ozone on crops such as rice, sugar beets and perennials have not been examined. Also, with the exception of corn, soybeans and wheat, only one or two cultivars of each crop have been tested. Others cultivars may respond differently (though the soybean data suggest a rather common response accross cultivars). Thus, while the current assessment covers a large percentage of annual field crops, the area of perennials and specialty crops is ignored.

The ambient ozone data used in the assessment are also open to question due to the interpolation procedure and the limited number of monitoring sites on which the interpolations are based. However, a comparison of the Kriged ozone levels with actual values for a few NCLAN sites revealed an error of less than 5 percent.

Finally, the economic model and its many assumptions/abstractions is a possible source of error in the economic estimates. As with most models of this type, a conceptual limitation is the absence of cross price effects between commodities. Thus, there is assumed independency of the factor supply and product demand schedules. Also, the influence of income as a demand shifter has been ommitted. The model does not include some mitigative adjustments, such as changes in fertilizer, that may accompany yield changes due to ozone. Finally, measurement errors in the economic data, statistical errors in the paramter estimates and algorithmic errors in the model solution procedure may also introduce biases. To the extent that these conceptual and empirical limitations will be constant accross all model analyses, potential biases should be minimised as the economic estimates are measured as deviations from the base solution, not as the total value of an objective function.

Concluding Comments

This study leads to three types of general conclusions. First, conclusions may be drawn on the U.S. agricultural effects of ozone and of alternative air pollution regulations. Second, conclusions may be drawn regarding future NCLAN response research. Third, methodological implications can be drawn concerning the use of large scale sector models in environmental assessments.

The results of the various analyses indicate substantial benefits to society from ozone reductions. The 10, 25 and 40 percent reductions in ozone result in annual benefits of $.756, $1.937, and $2.859 billion. A 25 percent increase in ozone results in an annual social cost of $2.363 billion. The regions that tend to be most sensitive to changes in ozone are those areas with fairly high ambient levels and a crop mix dominated by sensitive crops; i.e., soybeans and cotton.

More extreme biological response information assumptions derived from the NCLAN data sets increases the range of the benefits estimates. Conversely, the inclusion of interactions between ozone pollution effects and moisture-stress reduced the expected annual economic benefits by approximately 25 percent. Sufficient prior biological and statistical information is available to indicate that the extreme responses used in the first part of Analysis B are indeed extreme responses. However, there is also sufficient evidence concerning environmental interactions to suggest that the latter effects are plausible and indeed likely. Thus, future assessments of environmental stress on agriculture need to include such interactive effects, given their likely influence on benefits calculations.

Overall, the results indicate that there are substantial absolute but small relative (3%) agricultural benefits of moderate ozone reductions. These benefits are not spread uniformly among participants in the agricultural sector. About 60 percent of the annual consumer benefits accrue to foreign consumers. Domestic consumers benefit from slightly lower prices of processed grain and livestock products, due to increased supplies of feedgrains and oil seed. Producer benefits accrue due to export and factor market adjustments. Regionally, the major beneficiaries are those areas with high relative levels of ozone and ozone-sensitive crops.

In addition to measuring the benefits of alternative pollution levels on agriculture, this study also attempts to improve the methodological basis of such assessments. The implementation of the McCarl (1982a) proposal within the sector model yielded satisfactory results. Specifically, the sector model generated plausible regional acreages and crop mixes for the various ozone analyses. McCarl's linear programming representative farm model proposal was used to generate the Cornbelt crop activities while historical data were used elsewhere. The linear programming procedure provided a more satisfactory range of potential crop activities than did the use of historical cropping patterns (used for the remaining U.S.)

However, data and computational costs were correspondingly higher for the linear programming procedure. The McCarl proposal does need to be modified so that yield changes associated with crop mix changes are incorporated. The unification of the microeconomic and sector model results is important. Based on experience with this and other sector models, the cropping activity proposals have merit for inclusion in most mathematical programming sector models.

Finally, a caveat. The benefits assessment above not only accounts for biological responses but also captures the economic responses as portrayed by micro-level producer behavior and the market structure in the sector model. The resultant benefits estimates of alternative ozone pollution levels obtained from this bioeconomic analysis provide one measure of the efficiency of Federal air pollution control strategies. It should be noted, however, that the compliance costs of achieving such ozone changes are not available and hence are not included in these benefit estimates. Thus, the net benefits to society from ozone changes are not evaluated.

Endnotes

1. Both primary and secondary National Ambient Air Quality Standards are promulgated by USEPA. Primary standards are based on human health considerations, whereas secondary standards refer to vegetative, and other non-health effects.

2. The current Federal standard is 0.12 ppm ozone measured as an hourly maximum not to be exceeded more than once per year. In 1978, about one-fourth of the U.S. counties exceeded this standard.

3. An assumption of perfect competition is that producers receive a return just sufficient to keep them in the industry. In addition, transportation costs are not explicitly included in the model. To account for these factors, the Fajardo et al. procedures are implemented. These procedures involve calculating and including miscellaneous costs in the activity budgets so that the production costs and the value of production are equal. The base level prices are used in determining this equality. A more detailed description of the process is provided in Baumes.

4. Ozone concentrations are assumed constant in the rest of the world. Such an assumption is generally consistent with the meteorology of ozoneded program involves field experiments on crop sensitivity to ozone, the major air pollutant in terms of plant formation and transport.

5. The range of ozone-crop sensitivities captured in the NCLAN data vary from cotton and soybean (most sensitive) to barley (least sensitive). For the 25 percent ozone reduction alternative, the respective average yield adjustments (increases) are: cotton, 9.0 percent; soybean, 6.5 percent; wheat (winter), 3.4 percent; wheat (spring), 1.5 percent; corn, 1.2 percent; grain sorghum, 1.0 percent; and barley, .2 percent.

6. The 25% ozone reduction analyses are most comparable with previous

national assessments. Kop, Vaughn, and Hazilla provide a benefit estimate of $1.1 billion for a reduction in rural ambient ozone to values comparable to the 25% reductions used here. The difference in benefit estimates is due to coverage of fewer crops, omission of livestock, use of older data and used a different analytical framework. Adams, Crocker and Katz's estimate of $2.4 billion reflects a greater reduction in assumed ambient ozone levels, national supply coverage only, and a different methodology.

Chapter 5

CONCLUSION

CONCLUSION

The purpose of the study presented in this thesis was to estimate the economic impact of changes in ambient ozone on U.S. agriculture. Ozone is an air pollutant occurring naturally in the atmosphere but which can also be transformed in the atmosphere from man-made pollutants. It is the major pollutant in terms of adverse plant effects. Information on the economic effects of this pollutant is important for determining National Ambient Air Quality Standards. A sector model of U.S. agriculture was used to estimate the welfare benefits of changes in such ozone levels. The model contained regionally disaggregated activities for the production of the main crops and livestock products in the U.S., as well as processing and export activities.

Recent suggestions for improving the performance of sector models were considered. The effect of these proposals were compared to more traditional methods of incorporating producer and consumer response. All methods provided approximately similar estimates of total welfare. Greater diversity occurred in the distribution of welfare between producers and consumers. While some response assumptions could be rejected as being unrealistic, several feasible alternatives remain. Despite guideance from economic theory, selection of the most appropriate model form must be tempered by consideration of the eventual use for those results and the costs of misinformation. Nevertheless, the estimated distributional consequences of a policy change will be influenced by the choice of response assumption.

A search for the most appropriate of the available producer response assumptions proved fruitless. The problem of finding the best response assumption is closely associated with the validation of a sector model in terms of its intended purpose. The operation of the sector model is fundamentally different from the real world against which the performance of the model could be assessed. The question remains unanswered of how to validate a long-run equilibrium model against a real world that is responding continually to a variety of impacts, and yet, still insure that model is useful for its intended purpose.

With little empirical evidence to support the choice of any particular response assumption, the approaches which are most sound theoretically yet feasible emperically, are implemented. These involve the implementation of crop production activities which represent the production of multiple crops. In one region the crop mixes are provided from the solution to linear programs for representative farms. In the other regions where such representative farm models were not available, historical observations were used to provide realistic crop mixes. In the latter case, yields were adjusted in response to the percentage of given state planted to that crop to account for resource availability and the quality of crop land at the margin.

The results of the analyses suggest substantial benefits to society from reduced ambient ozone. A 25 percent reduction in ozone would result in annual benefits of approximately $1.7 billion. This represents about 3 percent of gross farm income in 1980. Near elimination of man-made sources of ozone generated benefits estimates of approximately $2.5 billion while a less ambitious reduction in ambient ozone of 10 percent would generate benefits of about $0.7 billion. These benefits estimates do no consider the compliance costs of achieving such ozone changes. About 40 percent of the benefits accrue to producers, and 60 percent to consumers. Of the consumers, only 40% of the benefits are realized by domestic producers.

The benefits assessment above not only accounts for biological responses, but also captures the economic responses as portrayed by micro-level producer behavior and market structure in the sector model. The resultant benefits estimates of alternative ozone pollution levels obtained from this biological analysis provide one measure of the potential efficiency of air pollution control strategies.

The implementation of the McCarl (1982a) proposal in the sector model yielded satisfactory results. The model generated plausible regional acreages and crop mixes for the various ozone analyses. The linear programming procedure provided a greater and more realistic range of potential crop activities than did the use of historical cropping patterns, lending support to the theoretical suppositions that the former is superior.

Overall, both the methodological and emperical components of this work were completed successfully. Techniques involving the theoretically most appealing response assumptions have been implemented to estimate the welfare effects of reducing ambient ozone. Various reductions have been considered for ranges of crop responsiveness. Distributional consequences between producer and consumer, as well as regional impacts have been detailed.

In terms of further environmental regulatory applications, the economic effects of other pollutants such as acid rain is worthy of attention. On a more general level, streamlined methods for updating both the technological and economic data on which sector models are built would be advantageous. The development of a reliable and thorough method for validating sector models for their intended purpose is a difficult but necessary task if sector models are to gain credibility. Such a task is left for further research.

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