Appendix F: Effects of Criteria Pollutants on Agriculture

Introduction

One potential impact of air pollutants on economic welfare is their effect on agricultural crops, including annual and perennial species. Pollutants may affect processes within individual plants that affect growth and reproduction, thereby affecting yields of agricultural crops. Possible physiological effects of pollutants include the following: decreased photosynthesis; changes in carbohydrate allocation; increased foliar leaching; decreased nutrient uptake; increased sensitivity to climatic stress, pests, and pathogens; decreased competitive ability; and decreased reproductive efficiency. These physiological effects, in conjunction with environmental factors and intraspecies differences in susceptibility, may affect crop yields.

Primary air pollutants that might damage plants include SO_2, NO_x, and volatile organic compounds (VOCs). These pollutants may have direct effects on crops, or they may damage crops indirectly by contributing to tropospheric (ground-level) ozone, peroxyacetyl nitrate (PAN), and/or acid deposition, all of which damage plants. Tropospheric ozone is formed by photochemical reactions involving VOCs and NO_x, while SO_2 and NO_x cause acidic deposition.

While all of these air pollutants may inflict incremental stresses on crop plants, in most cases air pollutants other than ozone are not a significant danger to crops. Based primarily on EPA's National Acid Precipitation Assessment Program (NAPAP) conclusions,[1] this analysis considers ozone to be the primary pollutant affecting agricultural production.

This analysis estimates the economic value of the difference in agricultural production that has resulted due to the existence of the CAA since 1970. The analysis is restricted to a subset of agricultural commodities, and excludes those commodity crops for which ozone response data are not available. Fruits, vegetables, ornamentals, and specialty crops are also excluded from this analysis. To estimate the economic value of ozone reductions under the CAA, agricultural production levels expected from control scenario ozone conditions are first compared with those expected to be associated with ozone levels predicted under the no-control scenario. Estimated changes in economic welfare are then calculated based on a comparison of estimated economic benefits associated with each level of production.

Ozone Concentration Data

To estimate the nationwide crop damages as a result of ozone exposure, the first step is to estimate the nationwide ozone concentrations under the control and no-control scenarios. This section describes the methodology used to estimate ozone concentrations for each county in each of these two scenarios.

First, historical ozone concentration data at the monitor level were compiled from EPA's AIRS system. Differences between the modeled control and no-control scenario ozone concentrations were then used to scale historical data to derive no-control scenario ozone air quality profiles.[2] Next, the ozone index used in the exposure response evaluation was calculated and applied at the monitor level. For this analysis, the W126 index, a peak-weighted average of cumulative ozone concentrations, was selected to conform with the index currently being used by EPA in ozone NAAQS benefits analysis. The W126 index is one of several cumulative statistics, and may correlate more closely to crop damage than do unweighted indices.[3] EPA has not yet made a final determination of the appropriate index to use in agricultural benefits analy-

[1] Shriner et al., 1990; NAPAP, 1991.

[2] Derivation of these ozone air quality profiles for the control and no-control scenario is summarized in the following section and described in detail in Appendix C.

[3] Lefohn et al., 1988.

sis; thus this analysis should be viewed only as an indicator of the magnitude of potential benefits.

The third step in ozone concentration estimation involved the use of triangulation and planar interpolation to arrive at a W126 statistic at the county, rather than at the monitor, level. For each county centroid, the closest surrounding triangle of monitors is located and the W126 is calculated for that county using a distance-weighted average of the ozone concentration at each of these monitors.

Control and No-control Scenario Ozone Concentration Data

The initial estimation of ozone concentrations in the control and no-control scenarios was performed by Systems Applications International (SAI). To create the control scenario, SAI compiled ozone data from the EPA's Aerometric Information and Retrieval System (AIRS).[4] SAI summarized these data by fitting gamma distributions to them and providing the alpha and the beta parameters to these distributions. Each of these distributions describes a set of ozone concentration levels, and the distributions are categorized by year, season, and averaging time. SAI defines six distinct "seasons," each composed of a two month period in the year. This analysis uses those distributions which describe 1-hour average ozone concentrations taken from 7 AM to 7 PM and separated into seasons. The analysis utilizes only those monitor records that were modeled in both the control and no-control scenarios.

To determine the ozone concentrations for the no-control scenario, SAI utilized the Ozone Isopleth Plotting with Optional Mechanisms-IV (OZIPM4) model. The input data required for OZIPM4 includes air quality data, surface and upper-air meteorological data, and estimates of anthropogenic and biogenic emissions of volatile organic compounds, NO_x and CO.[5] To create these inputs, SAI used (among other sources) outputs from the Regional Acid Deposition Model (RADM) and the SJVAQS/AUSPEX Regional Modeling Adaptation project (SARMAP). Additional detail concerning the development of ozone concentration data is available in Appendix C and in the SAI report to EPA.[6]

Calculation of the W126 Statistic

Using the SAI ozone concentration distributions, we calculated a sigmoidally weighted ozone index for each monitor. The generalized sigmoidal weighting function used in calculating such indices is presented in Lefohn and Runeckles (1987) as:

where:

$$w_i = 1 / [1 + M \cdot \exp(-A \cdot i)] \qquad (1)$$

w_i = weighting factor for concentration$_i$ (unitless)
c_i = concentration$_i$ (ppm)
M= an arbitrary constant
A = an arbitrary constant

The constants M and A are chosen to give different weights to higher or lower concentrations. The index used in this analysis is the W126 statistic, which is calculated as follows:[7]

$$w_i = 1 / [1 + 4403 \cdot \exp(-126 \cdot c_i)] \qquad (2)$$

and

$$W126 = \sum w_i \qquad (3)$$

Missing values are accounted for by multiplying the resulting W126 statistic by the ratio of the number of potential observations to the number of actual observations (i.e., total hours in period/hours of data in period).

To calculate W126 indices from the monitor level gamma distributions, we used an inverse cumulative density function to calculate a separate representative air concentration for each hour in the two month season. These values are then used in the above equation to obtain a monitor-level W126 statistic.

To ensure that the interpretation of the gamma distributions in this manner does not generate errors, we tested our gamma-derived control-scenario W126s

[4] SAI, ICF Kaiser, 1995.

[5] SAI, ICF Kaiser, 1995.

[6] SAI, ICF Kaiser, 1995.

[7] Lefohn et al., 1988.

against W126s calculated directly from the AIRS database. We found that insignificant error resulted from the utilization of the gamma distributions to create W126 statistics.

Aggregating Ozone Data to the County Level

Because crop production data are available at the county level, the lowest level of aggregation that could be used for ozone indices is also the county level. Therefore, monitor level data needed to be aggregated to a county level. For each county, we first located the monitors from which we would be interpolating data. To identify these monitors, we searched for the three monitors which formed the closest triangle around the centroid of the county.[8] The closest triangle was defined as that triangle in which the sum of the distances from the three monitors to the county centroid was the least. The algorithm stopped searching for closest triangles of monitors when it had searched all monitors within 500 km of a given county centroid (an arbitrary distance, selected to reduce computational requirements).

For coastal counties and some rural counties in some years, monitor triangles around the county centroid do not exist. We assigned the W126 value from the monitor closest to the centroid to these counties. Approximately 15 percent of all county-years (36,973 of 248,880 records) were assigned W126s in this manner.

For the remaining 85 percent, after the closest triangle of monitors was found, a "planar interpolation" was used to calculate the W126 at that county for that year. One way to picture this process is to plot each of the three monitors as a point in space. For each monitor, the x axis represents longitude, the y axis represents latitude and the z axis represents the W126 statistic. A plane can then be drawn through these three points in space. Furthermore, using the equation for the plane, and given the x and y values (latitude and longitude) for the county centroid, the county centroid's z value (W126 statistic) can be calculated. In essence, this procedure calculates a distance-weighted average of three monitors' W126 index values and assigns this value to the county centroid.

The result of this data manipulation is a monthly W126 statistic for each county in the continental United States for the years 1971-1990. From these data, yield change estimates were generated, and economic impacts were estimated.

Yield Change Estimates

There are several steps involved in generating yield change estimates. The first is the selection of relevant ozone exposure-response functions (minimum and maximum) for each crop in the analysis. Ozone data, triangulated to the county level, are transformed into an index suitable for use in the selected function(s) to estimate county level predicted yield losses for both the control and no-control scenarios. In the next step, the proportion of each county to the national production of each crop is calculated to permit national aggregation of estimated yield losses. Finally, the control scenario percentage relative yield loss (PRYL) is compared to the minimum and maximum PRYL for the no-control scenario. Each step is discussed in more detail below.

Exposure-Response Functions

To estimate yield impacts from ozone, exposure-response functions are required for each crop to be analyzed. This analysis was restricted to estimating changes in yields for those commodity crops for which consistent exposure-response functions are available and that are included in national agricultural sector models. To maintain consistency with the current ozone NAAQS benefits analysis being conducted by OAQPS, NCLAN-based exposure-response functions using a Weibull functional form and a 12-hour W126 ozone index were used.

Several crops included in the NCLAN research program were not evaluated in this analysis. Non-commodity crops that are not modeled in national agricultural sector models were not included in this analysis: lettuce, tomatoes, potatoes, alfalfa, tobacco, turnips, and kidney beans. In addition, one commodity crop, spring wheat, was excluded because the NCLAN exposure-response function was only developed for winter wheat.

[8] The vast majority of monitors had latitude and longitude data available through AIRS. 1,528 of 1,536 monitors were located in this manner. For the remaining 8 monitors, if in a given year of monitor data another monitor exists in the county of the unfound monitor, we discarded the unlocated monitor's data. Otherwise, we located that monitor at the county's centroid. We located 5 of the remaining 8 monitors in this fashion.

Minimum/Maximum Exposure-Response Functions

Estimated responsiveness of a given crop to ozone varies within the NCLAN data. This range of response is partially explained by the program's evaluation of several cultivars for some crops; ozone sensitivity varies across cultivars. In addition, the conditions for different experiments varied due to variations in location, year, and additional treatments included in some experiments. No one exposure-response function can be assumed to be representative of all cultivars in use, or of all environmental conditions for crop production. To develop a range of benefits estimates that reflects this variation in responsiveness, a minimum responsiveness and a maximum responsiveness function were selected for each crop. In actuality, a number of different cultivars are planted by producers, and so ozone response will be a weighted average of the responsiveness of each cultivar to its ozone condition and its proportion of total acreage. It is important to note that these values do not necessarily bound the analysis, since the number of cultivars evaluated by NCLAN is small relative to the number grown for many crops.

For the crops used in this study, CERL conducted an analysis to identify the ozone concentration required to reduce yields by 10 percent for each crop cultivar using its 12-hour W126 exposure-response function. For each crop, the function demonstrating the lowest ozone concentration at a 10 percent yield loss represents the maximum response, and the function with the highest concentration at 10 percent yield loss represents the minimum response. Table F-1 reports the minimum and maximum exposure-response functions for each crop. Two crops, peanuts and sorghum, did not have multiple NCLAN experiments on which to base a comparison of the responsiveness of different cultivars or the variation in response with different experimental conditions.

Table F-1. Agriculture Exposure-Response Functions.

Crop	Cultivar	Equation Type	Yield Function (PRYL, ppm)	Duration (days)
Barley	CM-72	Both	1-exp(-(W126/6998.5)$^{1.388}$	95
Corn-Field	PAG 397	Min	1-exp(-(W126/94.2)$^{4.176}$	83
Corn-Field	Pioneer 3780	Max	1-exp(-(W126/92.7)$^{2.585}$	83
Cotton	McNair 235	Min	1-exp(-(W126/113.3)$^{1.397}$	125
Cotton	Acala SJ2	Max	1-exp(-(W126/74.6)$^{1.066}$	98
Grain Sorghum	DeKalb A28+	Both	1-exp(-(W126/205.3)$^{1.957}$	85
Peanuts	NC-6	Both	1-exp(-(W126/96.8)$^{1.890}$	112
Soybeans	Corsoy-79	Min	1-exp(-(W126/476.7)$^{1.113}$	93
Soybeans	Davis	Max	1-exp(-(W126/130.1)$^{1.000}$	93
Wheat	ART	Min	1-exp(-(W126/76.8)$^{2.031}$	54
Wheat	VONA	Max	1-exp(-(W126/24.7)$^{1.00)}$	61

Source: EPA/CERL (unpublished) for all functions.

Calculation of Ozone Indices

Each NCLAN ozone exposure-response experiment exposed each studied crop over a portion of the crop's growing season. The duration of the NCLAN experiments was provided by CERL and was rounded to the nearest month. The W126 index is cumulative, and so is sensitive both to the duration over which it is calculated and to the specific month(s) within a growing season that are included in it. Because cropping seasons vary across the U.S., the ozone index used to calculate county-level changes in yield due to ozone must reflect the local season for each crop. To determine which portion of the growing season a particular exposure period pertains to (in order to calculate an exposure index), we developed state-specific growing seasons based on planting and harvesting data developed by USDA.[9] The W126 index was calcu-

[9] USDA, 1984. Some states did not have explicit growing seasons reported for certain crops due to the low production in these states. In these cases a proxy state growing season was used. In most of these cases the proxy growing season was taken from a state with an adjoining boundary within the same geographic region.

lated using the county level ozone data developed in the prior section, summed for the number of months of NCLAN experimental duration, with the exposure period anchored on the usual harvest month for each crop.[10]

Calculations of County Weights

Because the benefits analysis did not require a regional level of disaggregation and to minimize computational burdens the economic analysis was conducted at a national level. Ozone data and estimated yield responses, however, were developed at a county level. To conduct a national analysis, the county level yield change estimates were weighted to develop a single national percent relative yield loss for each crop relative to the control scenario, for both the minimum and the maximum yield responses. As a part of calculating a percent change in yield at the national level, weights for each county and crop were created for 1975, 1980, 1985, and 1990. The weights for these four years were used to represent the year itself and the four years immediately following it (e.g., 1975 weights were also used for 1976, 1977, 1978, and 1979). Although weather and other conditions may change the proportion of counties' production to the total national production in each year, five year weights should reflect stable periods of agricultural policy between each Farm Bill, and are sufficient for the level of precision needed for this analysis. The weights were calculated by dividing the production level of a crop in a county[11] by the sum of all states' reported production for that crop.[12] These county weights were applied to the percent relative yield loss results for each county, as discussed below.

Calculation of Percent Change in Yield

Ozone exposure-response functions are expressed in terms of percent relative yield loss (PRYL); the ozone level being analyzed is compared with "clean" (charcoal filtered/zero ozone) air. To calculate a percent change in yield between the control and no-control scenarios, we first calculate a PRYL based on the county-level control scenario W126 ozone index, and a PRYL based on the no-control scenario W126 index. Next, the county weights are applied to the PRYLs. The change in yield, measured relative to the hypothetical zero-ozone crop production, is then:

$$(PRYL_C - PRYL_{NC}) \tag{4}$$

To obtain the change in terms of our (non-zero) baseline yield, we divide by that yield, and get:

$$(PRYL_C - PRYL_{NC}) \,/\, (100 - PRYL_C) \tag{5}$$

To create the national percent change in yield for each crop, the results of this equation are summed for each scenario (maximum and minimum) and for each year. Tables F-2 and F-3 present the resulting percent yield changes that were used as inputs to the economic model.

Economic Impact Estimates

To estimate the economic benefits of controls on ozone precursor pollutants under the Clean Air Act, changes in yields due to those controls need to be evaluated in terms of their effect on agricultural markets. To do this, yield changes can be incorporated into an economic model capable of estimating the associated changes in economic surpluses within the agricultural economy, preferably one that reflects changes in producers' production decisions and demand substitution between crops. This type of dynamic analysis is needed because even small changes in yield or price expectations can cause large shifts in the acreage allocated to specific crops, and the degree to which alternative crops will be substituted (particularly for feed uses).

Agricultural Simulation Model (AGSIM)

The modeling approach used in this analysis is an econometric model of the agricultural sector, which estimates demand and supply under different production technologies and policy conditions. The AGricultural SImulation Model (AGSIM) has been

[10] This analysis required "rounding" some months: if a harvest date was specified to be from the 15th to the end of a month, the W126 index was calculated using that month's data; if the harvest date was specified to be from the first to the 14th of a month, the W126 index was calculated using the prior month's data as the final month in the exposure period.

[11] USDA, 1995.

[12] The national total does not include USDA areas designated "other counties". These areas are groups of counties that for one reason or another (disclosure rules, low amount of production, etc.) are not individually listed. Because we did not have ozone values for these groups, we did not use their production levels in the calculation of the total national production.

Table F-2. Relative No-control to Control Percent Yield Change (harvested acres) for the Minimum Scenario.

	Crop						
Year	**Barley**	**Corn**	**Cotton**	**Peanuts**	**Soybeans**	**Sorghum**	**Winter Wheat**
1975	-0.000020	-0.000171	-0.011936	-0.006635	-0.001166	-0.000717	-0.005631
1976	-0.000013	-0.000329	-0.017505	-0.024048	-0.002171	-0.001841	-0.004841
1977	-0.000013	-0.000169	-0.013114	-0.015150	-0.001562	-0.001118	-0.005464
1978	-0.000019	-0.000291	-0.018692	-0.017606	-0.002480	-0.001844	-0.005894
1979	-0.000027	-0.000100	-0.017217	-0.013067	-0.001898	-0.001389	-0.004998
1980	-0.000019	-0.000200	-0.021315	-0.022761	-0.002397	-0.002222	-0.005385
1981	-0.000016	-0.000071	-0.018552	-0.014269	-0.001951	-0.000802	-0.003964
1982	-0.000020	-0.000070	-0.017295	-0.014200	-0.002107	-0.001050	-0.004773
1983	-0.000023	-0.000617	-0.020842	-0.028601	-0.003901	-0.002366	-0.005904
1984	-0.000027	-0.000111	-0.023552	-0.019225	-0.002919	-0.002881	-0.006121
1985	-0.000025	-0.000132	-0.020947	-0.017965	-0.002645	-0.001726	-0.007316
1986	-0.000029	-0.000158	-0.027968	-0.031605	-0.002899	-0.001564	-0.007597
1987	-0.000033	-0.000358	-0.034584	-0.043854	-0.003776	-0.001812	-0.009669
1988	-0.000027	-0.000662	-0.035069	-0.038085	-0.004563	-0.002922	-0.019873
1989	-0.000024	-0.000150	-0.031245	-0.022094	-0.003769	-0.001359	-0.007605
1990	-0.000024	-0.000210	-0.037988	-0.047395	-0.003819	-0.001567	-0.006449

Note: There is only one scenario for barley, peanuts, and sorghum, because there was only one exposure-response function..

Table F-3. Relative No-control to Control Percent Yield Change (harvested acres) for the Maximum Scenario.

	Crop						
Year	**Barley**	**Corn**	**Cotton**	**Peanuts**	**Soybeans**	**Sorghum**	**Winter Wheat**
1975	-0.000020	-0.001139	-0.021059	-0.006635	-0.005808	-0.000717	-0.034803
1976	-0.000013	-0.002281	-0.032063	-0.024048	-0.010298	-0.001841	-0.040303
1977	-0.000013	-0.001232	-0.025773	-0.015150	-0.007764	-0.001118	-0.049636
1978	-0.000019	-0.002015	-0.033075	-0.017606	-0.011803	-0.001844	-0.050308
1979	-0.000027	-0.001052	-0.031433	-0.013067	-0.009592	-0.001389	-0.052211
1980	-0.000019	-0.001537	-0.037278	-0.022761	-0.011845	-0.002222	-0.054128
1981	-0.000016	-0.000923	-0.035058	-0.014269	-0.009902	-0.000802	-0.053470
1982	-0.000020	-0.000974	-0.034101	-0.014200	-0.010815	-0.001050	-0.058409
1983	-0.000023	-0.003888	-0.040405	-0.028601	-0.018597	-0.002366	-0.063556
1984	-0.000027	-0.001443	-0.043890	-0.019225	-0.014502	-0.002881	-0.067612
1985	-0.000025	-0.001377	-0.040845	-0.017965	-0.013384	-0.001726	-0.072177
1986	-0.000029	-0.001451	-0.052426	-0.031605	-0.014754	-0.001564	-0.081225
1987	-0.000033	-0.002565	-0.061295	-0.043854	-0.018578	-0.001812	-0.089042
1988	-0.000027	-0.004318	-0.061660	-0.038085	-0.021767	-0.002922	-0.120703
1989	-0.000024	-0.001987	-0.059573	-0.022094	-0.018739	-0.001359	-0.086958
1990	-0.000024	-0.002056	-0.071659	-0.047395	-0.018670	-0.001567	-0.082309

Note: There is only one scenario for barley, peanuts, and sorghum, because there was only one exposure-response function.

used extensively to evaluate air pollution impacts, as well as a number of other environmental policy analyses. AGSIM is an econometric-simulation model that is based on a large set of statistically estimated demand and supply equations for agricultural commodities produced in the United States. The model is capable of estimating how farmers will adjust their crop acreages between commodities when relative profitability changes as a result of crop yield and production cost changes. Acreage and yield changes from various scenarios will affect total production of crops, which then affects commodity prices and consumption. The commodity price changes, in turn, affect profitability and cropping patterns in subsequent years. Federal farm program and conservation reserve effects are also incorporated into the model.

The initial version of AGSIM (which went through various acronym revisions) was developed in 1977.[13] The model was developed to permit estimation of aggregate impacts associated with relatively small changes in crop yields or production costs, which might result from various policy conditions such as changes in pesticide input availability, or in this case, changes in crop exposure to ozone. Subsequent revisions to the model as well as the current specification are described in Taylor (1993a).[14] Several policy applications of AGSIM were tested and reported in Taylor (1993b)[15] to provide a comparison to the results of several alternative agricultural sector models. These tests included an expansion of Conservation Reserve acreage, reduced target prices, elimination of agricultural programs in the U.S. other than the Conservation Reserve Program (CRP), and a tax on nitrogenous fertilizer use in the U.S. The model has been used to evaluate the effects of changes to the CRP,[16] changes in agricultural price support programs,[17] and evaluations of policies concerning pesticide availability.[18]

AGSIM is designed to estimate changes in the agricultural sector resulting from policies that affect either the yields or the costs of crop production. Changes in economic variables are computed by comparing a policy simulation of the model with a baseline simulation of the model. For this retrospective evaluation, the baseline reflects actual farm programs, prices, and other parameters since 1970. The model's author, Dr. C. Robert Taylor, modified AGSIM for this analysis to reflect production conditions and policies as they changed through the 20-year span of the Clean Air Act, from 1970 to 1990. During this period, U.S. farm policy parameters changed every five years with the enactment of each Farm Bill, and producer participation varied significantly over the period. Over this time, due to policy, weather, technological development, and other variations, production levels and prices have varied, as have production technologies, costs of production, and relevant cultivars. To reflect these changes, Dr. Taylor re-estimated demand relationships for three periods (1975-79; 1980-84; and 1985-89) based on the farm policies in effect in each period, and structured the model to run on a national level rather than a regional level. The period from 1970-1975 was not modeled because of data limitations and because there was limited impact from the CAA on ozone levels during that period.

The AGSIM baseline production and price data serve as the control scenario baseline. Percent relative yield losses (PRYLs) between the control and no-control scenarios are the relevant input parameter for this analysis, from which AGSIM calculates new yield per planted acre values. Based on these values (as well as on lagged price data, ending stocks from the previ-

[13] Taylor, C.R., R.D. Lacewell, and H. Talpaz. 1979. Use of Extraneous Information with the Econometric Model to Evaluate Impacts of Pesticide Withdrawals. Western J. of Ag. Econ. 4:1-8.

[14] Taylor, C.R. 1993a. AGSIM: An Econometric-Simulation Model of Regional Crop and National Livestock Production in the United States. In: C.R. Taylor, K.H. Reichelderfer, and S.R. Johnson (Eds) Agricultural Sector Models for the United States: Descriptions and Selected Policy Applications. Ames Iowa: Iowa State University Press.

[15] Taylor, C.R. 1993b. Policy Evaluation Exercises with AGSIM. In: C.R. Taylor, K.H. Reichelderfer, and S.R. Johnson (Eds) Agricultural Sector Models for the United States: Descriptions and Selected Policy Applications. Ames Iowa: Iowa State University Press.

[16] Taylor, C.R. 1990. Supply Control Aspects of the Conservation Reserve. In: T.L. Napier (Ed) Implementing the Conservation Title of the Food Security Act of 1985. Ankeny, Iowa: Soil and Water Conservation Society; Taylor, C.R., H.A. Smith, J.B. Johnson, and T.R. Clark. 1994. Aggregate Economic Effects of CRP Land Returning to Production. J. of Soil and Water Conservation 49:325-328.

[17] Talyor, C.R. 1994. Deterministic vs. Stochastic Evaluation of the Aggregate Effects of Price Support Programs. Agricultural Systems 44:461-474.

[18] Taylor, C.R., G.A. Carlson, F.T. Cooke, K.H. Reichelderfer, and I.R. Starbird. Aggregate Economic Effects of Alternative Boll Weevil Management Strategies. Agricultural Econ. Res. 35:19-19;Taylor, C.R., J.B. Penson Jr., E.G. Smith, and R.D. Knutson. 1991. Impacts of Chemical Use Reduction in the South. S. J. Of Ag. Econ. 23:15-23.

ous year, and other variables), AGSIM predicts acreage, production, supply, and price parameters for each crop for each year, as well as calculating yield per harvested acre. From these results and the demand relationships embedded in the model, AGSIM calculates the utilization of each crop (i.e., exports, feed use, other domestic use, etc.), as well as the change in consumer surplus, net crop income, deficiency payments and other government support payments. Net surplus is calculated as net crop income plus consumer surplus, less government payments. The first year of results is 1976 because AGSIM must have one year (1975) of lagged data.

Table F-4 presents the net *changes* in economic surpluses (in 1990 dollars) annually and as a cumulative present value (discounted at 5 percent) over the period 1976-1990 due to the Clean Air Act. The positive surpluses exhibited in almost all years are a result of the increase in yields associated with lower ozone levels than those predicted to occur under the no-control scenario. The present value of the estimated agricultural benefits of the CAA ranges between $7.8 billion in the minimum response case to approximately $37 billion in the maximum response case. This range represents the impacts that would occur if all of the acreage planted to a given crop had an ozone response function similar to either the minimum *available* response function or the maximum *available* response function. The available response functions do not necessarily bracket the true range of potential crop responses, and it is unrealistic to anticipate that all acreage will be planted in cultivars with a uniform response to ozone exposure. These considerations notwithstanding, these values do indicate the likely magnitude of agricultural benefits associated with control of ozone precursors under the CAA, but not the precise value of those benefits. In addition to estimating the present value of net surplus at a discount rate of five percent, two alternative discount rates were used. At a three percent discount rate, the range of net surplus is between $6.7 billion and $32 billion; at seven percent discount rate, the range is between $9 billion and $43 billion. For more detail on AGSIM intermediate model outputs, see Abt Associates (1996).

Table F-4. Change in Farm Program Payments, Net Crop Income, Consumer Surplus, and Net Surplus Due to the CAA (millions 1990 $).

	Change in Farm Program Payments		Change in Net Crop Income		Change in Consumer Surplus		Change in Net Surplus	
Year	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
1976/77	0	0	243	486	236	993	477	1,479
1977/78	0	0	-97	-259	349	1,557	253	1,297
1978/79	43	345	30	298	392	1,646	379	1,597
1979/80	0	0	-140	-406	449	2,000	309	1,594
1980/81	0	0	8	-178	392	2,049	400	1,870
1981/82	112	518	-99	-406	440	2,594	231	1,670
1982/83	168	981	64	107	377	2,730	273	1,856
1983/84	153	1,009	231	958	316	1,969	395	1,917
1984/85	-182	808	82	560	-279	1,686	-14	1,437
1985/86	289	1,291	181	879	616	2,054	509	1,644
1986/87	270	1,356	230	966	462	2,265	422	1,875
1987/88	469	2,033	320	1,405	708	2,990	558	2,361
1988/89	557	2,023	316	1,508	796	2,943	556	2,428
1989/90	329	1,401	161	614	527	2,572	358	1,785
1990/91	414	1,927	180	473	618	3,047	384	1,593
Cumulative Present Value of Net Surplus at 5 percent ($ 1990)							7,763	37,225

Conclusions

Agricultural benefits associated with control of ozone precursors under the Clean Air Act are likely to be fairly large. Because it is possible that over time producers have adopted more ozone-resistant cultivars, it may be appropriate to consider the lower end of the range of predicted benefits to be more indicative of the likely total benefits. The estimates developed in this analysis, however, do not represent all of the likely benefits accruing to agriculture, in that many high-value and/or ozone sensitive crops could not be included in the analysis due to either exposure-response data limitations or agricultural sector modeling limitations. The second consideration implies that benefits will likely be larger than estimated. The minimum case may be the most appropriate starting point, however, due to the first consideration: the current crop mix is probably biased toward lower ozone responsiveness. Therefore, we anticipate that cumulative total agricultural benefits from the Clean Air Act are on the order of ten billion dollars (real terms).

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