The Impacts of Carbon Permit Prices on the U.S. Agricultural Sector

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Executive Summary

Recent analyses of U.S. greenhouse gas options indicate that reductions could be accomplished through a carbon cap and trade system, under which carbon permit prices would emerge and eventually be internalized into higher energy prices (Edmonds 1998, EIA 1998, CEA 1998). This study explores potential impacts on the U.S. agricultural sector from higher energy and other input prices stimulated by imposition of various carbon permit prices. Specifically, it examines economic welfare, commodity price, and environmental impacts associated with introducing four levels of carbon permit prices ($10, $25, $50, or $100 per ton carbon) in 2000, 2005, 2010, 2015, or 2020. A national agriculture model (ASMSOIL) is used to assess these impacts. The findings of this study suggest relatively small agricultural sector losses may occur from the imposition of these carbon permit prices, while positive local environmental benefits result in terms of lower soil erosion and water use.

The major observations are that when carbon permit prices are imposed:

1. the U.S. agricultural sector is not very sensitive to these prices because the resulting higher energy prices make up a relatively low part of the total cost of production for the U.S. farm sector;

2. soil erosion, pesticide nitrogen fertilizer and irrigation water use declines, but cropland usage expands slightly initially;

3. achieving U.S. soil erosion goals may become cheaper;

4. carbon permit values are large and almost offset the welfare losses;

5. carbon permit price implications are largely stable over the 2000-2020 time period and do not imply that, within agriculture, any one time period of implementation is better than any other for introducing a carbon trading system; and,

6. carbon permit price induced farm welfare losses are partially offset by environmental gains to the country in terms of increased soil erosion control and greater greenhouse gas emissions reduction.

The results of this analysis demonstrate that important environmental co-benefits – soil erosion control and reduced chemical usage – could be created under carbon permit pricing, which encourage greenhouse gas emissions reductions. In addition, this study indicates that carbon permit pricing creates far less detrimental agricultural welfare impacts – less than one percent - than most of the recent changes in U.S. farm support policies.

Background

Climate change policies are being considered by the U.S. government to reduce anthropogenic greenhouse gas emissions towards 1990 levels and fulfill international obligations under the United Nations Framework Convention on Climate Change (UNFCCC). The climate change policies could impact many sectors of the U.S. economy. One market-oriented option is the introduction of carbon permit prices to create the economic incentives to reduce U.S. greenhouse gas emissions. This study examines potential impacts on the U.S. farm sector of the introduction of carbon permit prices, which in turn may raise farm energy and other input prices. The key impacts from the imposition of carbon permit prices that are assessed in this report are changes in farmers' (producers') and consumers' welfare, commodity prices, and land management practices at the national and regional level. In addition, the study looks at the potential magnitude of permit-induced revenues, which the U.S. Government might decide to recycle back into the farm sector.

The introduction of carbon permit prices will result in higher energy, fertilizer and pesticide costs for U.S. farmers. If U.S. farmers face increased production costs, they in turn will respond by adjusting a combination of farm practices that result in tillage intensity reduction, lower fertilizer consumption, crop mix realignment, and changes in the mix of other factors of production (e.g., land, labor, and capital). The types of changes, effects of such changes on the welfare of farming communities and consumers, and environmental impacts from these changes are important considerations to the U.S. government.

This report presents the findings and implications of this impact assessment, assuming four levels of potential carbon permit prices ($10, $25, $50 and $100 per ton of carbon) and the imposition of the permit prices in the years 2000, 2005, 2010, 2015, or 2020. The first section covers the methodology and assumptions for conducting the impact assessment based on the use of the U.S. agricultural sector model (ASMSOIL), along with a brief description of the model. The results follow in the second section, which discusses the potential impacts of carbon permit prices on total (societal), farmer, and consumer welfare, farm commodity prices, and natural resource use (e.g., land and water). The final section summarizes the key impacts and their implications for the U.S. farm sector and national climate change policy.

Analysis Approach and Assumptions

This study relies on assessing the impacts of introducing various carbon permit prices into the current and future technological, farm supply and consumer demand relationships that are represented in the national Agricultural Sector Model (ASMSOIL). The only major changes to the model are the introduction of different energy price assumptions due to the internalization of carbon permit prices at various time periods. The five years at which these permit prices might be imposed are considered in the study -- the years 2000, 2005, 2010, 2015, or 2020.

The U.S. Agricultural Sector Model: ASMSOIL

The findings of this study are derived from running the national Agricultural Sector Model (ASMSOIL), which simulates potential shifts in U.S. tillage systems, cropping patterns and many other farm sector items in response to the introduction of carbon permit prices. The model, developed and maintained by Texas A & M University in conjunction with the U.S. Department of Agriculture Natural Resource Conservation Service (USDA/NRCS), is an equilibrium nonlinear programming model with thousands of variables (e.g., farm input provision, crop mix choice, tillage choice, domestic consumption, processing, exports). The model operates subject to a 63 region depiction of resource availability (cropland in 4 classes, pasture land, water, labor, aum grazing). It has been used extensively for agricultural sector policy analysis to project sector impacts under policy and environmental scenarios. The model allows an analyst to assess farm sector as well as natural resource (e.g., soil use, erosion and water demand) impacts by region and nationally. This methodology was chosen to provide consistency and comparability with other national agricultural sector assessments.

A few characteristics of the ASMSOIL model and the nature of their ramifications on the results are useful for accurate interpretation of the output from the analysis. These include:

1. We assume supply has sufficient time to adjust to demand and production costs. Thus, the solution is not short-run, but rather intermediate-run, in which, for example, livestock herds have sufficient time to adjust to potential changes in feedstock prices due to the internalization of higher energy costs.

2. The carbon permit price implications are simulated as if they are fully in place during the time period. No path of adjustment is assumed or simulated.

3. We allow a choice of crop mix, tillage method, irrigation method, and rotation as well as consumption, processing export and import. Thus higher input costs would stimulate the model to substitute in terms of less energy intensive tillage method, crops, water use or other related inputs as well as in consumption.

4. ASMSOIL embodies crop production budgets, which vary across tillage types and rotations. The items in these budgets reflect the extent that USDA Natural Resource Service personnel have been able to identify changes in yields, cost, energy use and pesticides based on U.S. farm surveys and extension service budgets. Generally pesticide use varies across tillage and rotations only in a small number of the cases. Fertilizer use across tillage and rotation alternatives is unchanged. Yields, costs and energy inputs do vary systematically.

5. ASMSOIL is a price endogenous model that reflects demand curves for exported and domestically consumed products. In such a system, changes in production costs are matched by altered crop sale prices. Farm prices have historically varied due to yield enhancements and cost savings. Real prices have fallen by more than 33% during the last 25 years. A cost increase caused by higher energy prices is likely to translate into higher prices, much as have prices adjusted upwards under the recent El Nino and La Nina events.

Farm Energy Prices Under Various Carbon Permit Prices

The carbon permit prices examined in the analysis are zero, \$10, \$25, \$50, and \$100 per ton carbon, with a zero price implying no change. The zero price scenario provides a baseline in terms of future farm sector prices, welfare and natural resource use at each time period.

The introduction of carbon permit prices is expected to result in higher prices for several agricultural inputs, in particular energy (i.e., diesel, electricity, natural gas), farm chemicals (i.e. pesticides) and fertilizer. ASMSOIL model does not endogenously determine the prices of these items, thus an estimate of the percentage change in these inputs due to carbon content and carbon permit prices was computed exogenously as explained later, and entered into each run of the model for the respective year. Described below are: (1) the procedures for developing estimates of the percentage change in input prices paid by farmers if the carbon permit prices were introduced; and (2) the process for applying these prices to the ASM production data.

The study used two different procedures to develop data on the implications of carbon permit prices for farm input prices, depending on the data available. These approaches include:

1. ***Farm energy prices:*** The first and simplest approach involved using the results from an EPA study of the potential carbon permit prices on U.S. household energy costs, which gave the projected effects on the prices of gasoline, natural gas, and electricity given various carbon permit prices (Hohenstein 1997, 1999). The same procedures were used to provide a diesel cost estimate.

2. ***Fertilizer and agricultural chemical costs:*** The second set of procedures involved the use of U.S. input-output data to derive the effects on fertilizer and agricultural chemical costs from higher energy prices.

Procedure for Determining Farm Energy Prices:

This study used a spreadsheet that was created during an earlier EPA analysis (Hohenstein 1997, 1999) to adapt a procedure for determining potential farm energy price rises which accounted for carbon content of fuels and applied the tax. The procedure for using the U.S. EPA spreadsheet data for obtaining farm energy prices for ASMSOIL was as follows:

Step 1 Diesel price sensitivity was included in the spreadsheet by multiplying the projected gasoline price sensitivity times by the ratio of the carbon content per gallon of diesel to carbon content per gallon of gasoline (1.17) to derive an estimated effect on the diesel price.

Step 2 Base prices for farm energy were developed. These were developed with the aid of (a) the recent DOE energy outlook; (b) calls to input suppliers and farmers regarding current prices and sales tax exemptions and (c) consultation with energy experts. It was found that farmers paid commercial prices for natural gas and gasoline but paid a discounted price for off-road diesel use where they received tax exemptions. The prices were $2.57 per thousand cubic feet for natural gas, $0.80 per gallon for diesel, $0.065 per kilowatt-hour for electricity and $1.25 per gallon for gasoline.

Step 3 Percentage changes in prices paid by farmers were calculated by dividing the carbon permit price level dependent forecasts of energy price sensitivity from the EPA spreadsheet by the base prices. The resultant percentage changes in energy prices appear in Table 1 below.

Procedure for Determining Fertilizer and Other Chemical Costs

Fertilizer and pesticide manufacturing involves use of fossil fuels, hence, a carbon permit price will result in higher fertilizer prices. The cost sensitivity of these costs to permit prices was derived based on factor-usage data derived from the national input-output (I/O) tables used by the USDOC and other government agencies. The procedure is summarized below.

Step 1 We obtained the technical coefficients which tell how much of each dollar in industry sales is spent on industries including those that provide energy. This matrix was drawn from the latest version of IMPLAN (Olson and Lindall 1996).

Step 2 We derived an estimate of the total direct and indirect expenditures by using the IMPLAN generated matrix $[(I-A)^{-1}]$ where A is the matrix from Step 1. This gives the sum of all energy expenditures involved in selling nitrogen fertilization including the manufacturing and distribution process. These estimates give the total energy expenditures involved with production of "a dollars worth" of fertilizers and pesticides.[1]

Step 3 We assumed that any price increases in the energy inputs to fertilizer and pesticide manufacturers were passed on to farmers and that there was no energy cost induced substitution in fertilizer or pesticide production.

Step 4 We derived the percentage change in fertilizer and pesticide prices, by adding up the proportional change in energy costs by energy source as presented in Table 1 times the energy expenditure from step 2. This then gave us a cost increase in dollars and we assumed that was the percentage increase in the fertilizer and pesticide costs as given in Table 1.[2]

A composite table of the farm energy price adjustments entered in the model due to the imposition of a variety of potential carbon permit prices appears in Table 1. Notably, because of the nature of agricultural input usage patterns, the incremental price changes for diesel and

[1] The procedure used in this step differed from that used in an earlier draft (McCarl et. al. 1997) due to the variation in our results from calculations done by Lewandrowski (1999) at USDA. In particular a more than an order of magnitude difference in fertilizer cost existed between the studies. Originally, our earlier paper had used just the direct effects but in an attempt to narrow the gap between the estimates we used the direct and indirect effects in this later analysis. The effect of this change narrowed the discrepancy to a factor of around three.

[2] Lewandrowski predicts changes in fertilizer prices using a procedure based on Helsel's estimates of energy requirements for fertilizer and pesticide production (Helsel 1987, 1992). Helsel's 1992 estimates provide diesel-equivalents for producing fertilizer and pesticides. Applying the carbon content of diesel, Lewandrowski computed price increases for nitrogen fertilizer in the neighborhood of 16% at a $100 permit price. However a conversation with Dr. Helsel indicated that the diesel equivalent approach while appropriate for energy content would overestimate carbon content due to the non equivalent nature of diesel and other fossil fuels on a carbon basis. Consequently we stayed with the Input Output based approach.

fertilizer costs are the most significant when carbon permit prices are internalized. The results of these energy-related farm price adjustments show that diesel prices go up by almost one-third under the imposition of a $100 carbon permit price, while nitrogen prices rise by about seven percent.

Table 1.
Assumed Percentage Increase in ASMSOIL Input Values for Key Farm Goods under Alternative Carbon Permit Prices

Farm Input	Alternative Carbon Permit Price			
	$10 per ton (%)	$25 per ton (%)	$50 per ton (%)	$100 per ton (%)
Nitrogen Fertilizer	0.69	1.74	3.47	6.95
Potassium Fertilizer	0.11	0.27	0.55	1.1
Phosphorous Fertilizer	0.69	1.74	3.47	6.95
Pesticides and Other Chem.	0.11	0.27	0.55	1.1
Diesel Fuel	3.46	8.65	17.29	34.59
Gasoline	2.3	5.76	11.52	23.05
Natural Gas	5.25	13.13	26.26	52.53
Electricity	2.62	6.54	13.08	26.15
LP Gas	4.25	10.64	21.27	42.54
Coal	18.72	46.81	93.61	187.22

Projected Energy Price Changes Relative to Other Farm Prices and Programs

The relative impacts of these projected percentage changes in agricultural sector energy costs due to the internalization of carbon permit prices can best be put in perspective by examining U.S. crop production budget data and sector impacts of recent changes in other farm support programs. Box 1 provides the perspective on how much corn production costs might increase if $100 per ton C permit prices were to be introduced into the U.S. farm sector.

Box 1.
An Illustrative Example: Internalizing Carbon Permit Prices into Iowa Corn Production Costs

Suppose we examine the relative impact on farm production costs due to carbon permit price induced input cost changes. We will do this in terms of the largest U.S. crop in one of its major production areas -- corn in Iowa. In Iowa, farmers use about $50 dollars worth of fertilizer per acre, $15 per acre for drying and about $11 per acre for diesel fuel. This combination of inputs produces a state average yield of 150 bushels per acre, which brings a gross revenue of $375 per acre at $2.50 per bushel. If one uses the production cost increases associated with the $100 permit price, this adds about $3.30 per acre to diesel costs, $7.50 to natural gas-based drying, and about $3.50 to fertilizer cost. In relative terms, this internalization of carbon permit prices into Iowa's corn production results in about a four percent increase in total costs relative to gross revenue.

When reviewing the model results presented below, it also is important to keep in perspective the impacts of such carbon permit price adjustments relative to other impacts from recent U.S. farm support program changes. In Box 2 the effects on the farming community due to U.S. policy changes from the 1996 farm bill are reviewed. The bill phased out direct commodity-based U.S. farm support program payments, and it has been estimated to cost the farm sector in this country an annual loss of anywhere from $7-10 billion per year over time, i.e., possibly equal to a 20 percent loss in net farm income.

Box 2.
U.S. Agricultural Sector Income and Other Economic Characteristics

General Information

Total Farm Income (1996)	$ 49 billion
Farm Sector Subsidy Phase-Out Program Losses (1996)	$ 7-10 billion
National Cropped Acreage (1996)	330 million acres
1997 Conservation Reserve Program Target	16 million acres

Potential Farm Price Increases with $100 Carbon Permit Price

Energy Costs as Percentage of Corn Production Costs	3%

Further, as a preview of the kinds of farm sector adjustments that may result from the introduction of carbon permit prices as seen in the model results, let us also examine the energy intensity of tillage systems. A switch from the current mix of tillage in the U.S. to predominantly zero-till systems allows one to reduce the diesel energy used for Iowa corn by around 20 percent, possibly with short-term increases in pesticide costs. As the results show, farmers might move to less intense tillage if carbon permit prices are imposed, which may mitigate the effect of the increasing diesel price.

Implementing Energy Price Rises into the U.S. Farm Budgets

The U.S. agricultural sector impacts from the introduction of carbon permit prices were investigated by altering the budgetary costs of energy inputs in ASMSOIL. The estimated increase in U.S. farm production costs, as seen below, was due to shifts in the cost of input use for tillage, fertilization, pesticides, irrigation pumping, drying and other energy using practices under the different permit prices. The sum of these input costs was added to the cost of production for all the crops and tillage systems in ASMSOIL (in excess of 10,000 budgets) and the model was solved. This process was repeated for years 2000, 2005, 2010, 2015, and 2020. During these time periods, dynamic updating was done to reflect technological progress in yields and increases in consumption and exports stimulated by changes in population and other economic conditions.

Measuring National, Farmer/Producer, and Consumer Welfare

This study assesses four measures of social welfare changes in the U.S. agricultural sector due to the introduction of carbon permit prices. These measures include:

- **Producers' Surplus (PS):** a concept analogous to net farm income for the sector. Mathematically, it equals the area under the equilibrium market price line (market clearing price) but above the farm product long-run supply curve for all farm goods. It is the income gain above the supply curve costs that are distributed across all U.S. farmers.

- **Consumers' Surplus (CS):** generally equivalent to a change in consumers' income due to farm commodity price increases or decreases. Mathematically, it is the area above the equilibrium market price and below the demand curve. Changes in consumers' surplus may also be used to reflect the satisfaction or dissatisfaction that consumers realize when having to pay a different price (lower or higher, respectively) for farm commodities that they consume. In this study, consumers' surplus will represent the welfare gain or loss to the domestic *U.S*. farm product buyer (as distinguished from the Foreign Surplus, defined below)

- **Foreign Surplus (FS):** the gains or losses to foreign farm product consumers and producers in the form of their PS and CS.

- **Total Social Welfare (TS):** the sum of producers' (PS), consumers' (CS), and foreign (FS) surplus.

In this report, Total Social Welfare ***does not include*** *the addition of any potential positive or negative* ***environmental externalities****, such as reduced soil erosion and/or lower global warming benefits, which may be associated with the imposition of a carbon cap and trading system.*

Determining Soil Erosion and Water Impacts of Carbon Permits

Raising farm sector input prices due to the internalization of carbon permit prices could have important impacts on the U.S. farm sector's land management practices and soil erosion control policy. As part of the analysis, land management impacts due to the imposition of potential carbon permit prices were assessed. This environmental assessment indicates the extent to which permit-induced impacts might make attainment of other environmental agricultural goals easier or more difficult.

Analysis Results: Potential Impacts of Carbon Permits on the U.S. Agricultural Sector

The results of the carbon permit price impact analysis on the U.S. farm sector are presented in the following sections. The fundamental question is the general economic impact of permit prices on the agricultural sector.

Interpretation of ASMSOIL Analysis Results

The analysis involved twenty-five model runs for the various combinations of farm sector impact scenarios. The factors varied were:

- ***Permit Price Levels:*** five carbon permit price levels (**zero, $10, $25, $50, or $100**);
- ***Permit Price Time Lines:*** five time periods for the imposition of a carbon trading and cap system in the U.S. (at years **2000, 2005, 2010, 2015, 2020**);

The file of ASM results requires in excess of 21 megabytes of storage. We chose to only focus on key sector impacts, which we summarize in two ways:

1. ***Results Overview:*** a summary of how carbon prices affect total welfare provides a broad view of potential welfare and temporal differences in the imposition of any U.S. carbon permit prices.
2. ***Comparison of Carbon Permit Impacts by Year:*** an in-depth analysis of the results for the year 2000, and to a lesser extent 2010, is provided since it typifies the results obtained from the other later years (these closer also have the least extrapolative error.) The results cover the farm sector effects.

All analyses only consider climate change policy impacts as they affect the U.S. agricultural sector, including consumers of U.S. agriculture products. Additional EPA studies assess the impacts on the non-agricultural sectors of the economy from the imposition of carbon permit prices. The gains due to reduced emissions are not treated in this study.

Study Results Overview: Welfare Impacts

Some general observations emerge from the results about the potential impacts of carbon permits:

1. ***Increasing Welfare Losses Occur with Higher Carbon Permit Prices (Table 3)***
   - A $10 permit price will cost agriculture somewhere around $220 million annually, or *less than one half percent of 1996 total farm income*, across any of the years by which the carbon permit system would be imposed (e.g., 2000 up to 2020)

- A $25 permit price will cost agriculture somewhere around $550 million annually, or *less than one percent of 1996 total farm income*, across any of the years by which the carbon permit system would be imposed (e.g., 2000 up to 2020)

- A $50 dollar permit price somewhere around $1.1 billion annually again across any of the years by which the carbon permit system would be imposed (e.g., 2000 up to 2020), and

- A $100 permit price will cost the farm sector somewhere around $2.1 billion U.S. dollars annually, similarly across all years.

2. ***Producers' Surplus Impacts Larger than Consumers' Surplus Impacts (Table 6)***

- The results show that farmers lose more than consumers from the imposition of a carbon permit system, and that at some low permit prices consumers are largely unaffected.

- These projected impacts on producers' surplus, however, still are quite small relative to total farm gross income, which, for example, in 1996 was $49 billion. For example, the results at a $100 tax amounted to less than a 3% reduction in net farm income (Table 7).

3. ***Welfare Costs To Sector Not Dependent on Year of Carbon Permit System (Table 4)***

- As noted above, the year at which one begins a carbon permit trading system into the U.S. farm economy does not appear to have much effect on surplus results, which show quite minimal variability in quantitative or relative terms across the years.

4. ***Farm Sector Welfare Losses from Carbon Permit System Small (Table 7)***

- These changes in TS, CS, PS and FS are relatively small if one puts them in context of the totality of U.S. agriculture. For example, we computed a percentage change in farm sector welfare by dividing the change in consumers' surplus by consumers' expenditures on food and producers' surplus by the base producers'. When doing this, we found that the farm welfare losses for $100 million dollar permit price amount to around 6/10 of 1% of the welfare in the base situation for the year 2000.

- For perspective on the farm sector welfare impacts from a carbon permit system, one should note the estimated $7-10 billion annual losses generated from changes in the U.S. farm program recently enacted in the 1996 farm bill. Similarly, annual fluctuations in net farm income as reported by USDA have varied during the decade from $20-50 billion per year and that does not include the changes in consumers' surplus.

These observations are substantiated by the following tables, which report the outcomes of the model runs. Table 2 gives the results (in millions of dollars) for potential changes in the total societal welfare in million dollars under the four carbon permit prices at the selected time periods. The net changes in TS are given in Table 3, and represent the net change between having no carbon permit system (zero price) to the price under consideration (e.g., difference from zero to $10/ton C, zero to $25/ton C, zero to $50/ton C, or zero to $100/ton C).

Table 2.
Potential Total U.S. Agricultural Social Welfare Impacts under Alternative Carbon Permit Prices by Year ($U.S. Millions[1])

Initial Year	Alternative Carbon Permit Price				
	Zero	**$10 per ton**	**$25 per ton**	**$50 per ton**	**$100 per ton**
2000	1,405,350	1,405,133	1,404,801	1,404,287	1,403,303
2005	1,451,024	1,450,804	1,450,463	1,449,939	1,448,940
2010	1,499,634	1,499,414	1,499,064	1,498,532	1,497,516
2015	1,551,590	1,551,370	1,551,017	1,550,482	1,549,462
2020	1,606,113	1,605,891	1,605,518	1,604,963	1,603,905

[1] Dollars are in constant terms based on 1997 values.
Note: Environmental externalities are not included in the welfare estimate.

Table 3.
Potential Changes in Total U.S. Agricultural Social Welfare from Introduction of Carbon Permit Prices ($U.S. Millions[1])

Initial Year	Alternative Carbon Permit Price			
	$10 per ton	**$25 per ton[2]**	**$50 per ton**	**$100 per ton**
2000	-218	-549	-1,063	-2,047
2005	-219	-561	-1,084	-2,084
2010	-220	-570	-1,102	-2,118
2015	-220	-573	-1,108	-2,128
2020	-222	-595	-1,150	-2,208

[1] Dollars are in constant terms based on 1997 values.
[2] Values represent the change in welfare difference between the zero carbon permit price to the price under consideration.
Note: Environmental externalities are not included in the total social welfare.

Table 4 gives the estimates of the amount of revenue raised for the government or other agencies under the permit price levels. Notice that under a $25 permit price we have around

$510 million being raised, with about $1 billion raised under the $50 permit price and $1.9 billion under the $100 permit price, respectively. The results give permit price revenue if the permit price was in place at the specified level during the identified time period. These results also show a net social loss as the amount of welfare foregone in the agricultural sector exceeds the revenue raised from application of the permit price. However, this policy would also lead to a reduction in carbon emissions and erosion, as shown below. As noted earlier, there net societal impacts do not account for the value of the environmental benefits from the introduction of carbon permit prices and, as seen later, improvements in soil erosion.

Table 4.
Potential Revenue Raised from the U.S. Agricultural Sector under Alternative Carbon Permit Prices by Year ($U.S. Millions[1])

Initial Year	Alternative Carbon Permit Price			
	$10 per ton	**$25 per ton**	**$50 per ton**	**$100 per ton**
2000	216	504	967	1,856
2005	218	510	976	1,882
2010	218	519	999	1,897
2015	218	525	999	1,905
2020	220	538	1,008	1,918

[1] Dollars are in constant terms based on 1997 values.

Potential Agricultural Sector Impacts for 2000 and 2010

The above results estimate the potential impacts that a carbon permit system would have on overall welfare in the U.S. agricultural sector. In this section, we take a more detailed look at the results for the year 2000, and to a lesser extent for 2010. We made In-depth analysis of the 2000 model runs for two reasons. First, the farm sector impacts are basically the same across each of the time periods. Second, the time extrapolation error in the results is compounded when moving further and further out into the future. Under year 2000 conditions, the model gives the best representation of the economy. The detailed results can be looked at in many different ways. In this section, we will look at the potential impacts for year 2000 on:

- producer' and consumers' welfare;
- foreign interests;
- farm price and quantity indices;
- regional farm welfare;
- use of major farm inputs both nationally and regionally;
- farm commodity prices; and,
- changes in tillage methods and erosion control.

Welfare Impacts: Producer, Consumer, and Society

Tables 5 through 7 give results on the distribution of welfare for the year 2000. They show that most of the welfare lost due to the permits is borne by producers. In addition, a substantial amount of the burden at high prices is borne by consumers, through higher prices and decreased levels of exports from the US. In terms of percentage changes, Table 7 shows that these are relatively small percentage changes across the parties. If carbon permit prices are in place in 2010, similar magnitudes of welfare tradeoffs and small farm sector impacts occur as shown by Tables 8 and 9.

Table 5.
Potential Year 2000 Welfare Levels for Agricultural Sector Related Groups Under Alternative Carbon Permit Prices
($U.S. Millions[1])

Welfare Group	Alternative Carbon Permit Price				
	Zero	$10 per ton	$25 per ton	$50 per ton	$100 per ton
CS	1,212,179	1,212,172	1,212,175	1,212,178	1,211,803
PS	58,044	57,818	57,480	56,931	56,415
FS	135,127	135,143	135,146	135,179	135,085
TS	1,405,350	1,405,133	1,404,801	1,404,287	1,403,303

[1] Dollars are in constant terms based on 1997 values.
Note:
- CS is consumers' surplus -- a measure of consumers' welfare
- PS is producers' surplus -- a measure of producer net income or farm welfare
- FS is foreign surplus -- a measure of welfare for trading partners
- TS is a measure of total social welfare

Table 6.
Potential Changes in Year 2000 Welfare Levels for Agricultural Sector Related Groups Under Alternative Carbon Permit Prices
($U.S. Millions[1])

Welfare Group	Alternative Carbon Permit Price			
	$10 per ton	$25 per ton	$50 per ton	$100 per ton
CS	-7	-4	-1	-376
PS	-227	-564	-1,113	-1,629
FS	16	19	52	-42
TS	-218	-549	-1,063	-2,047

[1] Dollars are in constant terms based on 1997 values.

Table 7.
Potential Changes in Year 2000 Welfare Levels for Agricultural Sector Related Groups Under Alternative Carbon Permit Prices
(Percentage)

Welfare Group	Alternative Carbon Permit Price			
	$10 per ton (%)	$25 per ton (%)	$50 per ton (%)	$100 per ton (%)
CS	0	0	0	-0.13
PS	-0.39	-0.98	-1.96	-2.89
FS	0.01	0.01	0.04	-0.03
TS	-0.06	-0.16	-0.31	-0.59

Note: The results for consumers give change in consumers' surplus divided by the consumption expenditures in the base (zero permit price) and the results for producers give change in producers' surplus divided by the base (zero permit price) producers' surplus.

Table 8.
Potential Year 2010 Welfare Levels for Agricultural Sector Related Groups Under Alternative Carbon Permit Prices
($U.S. Millions[1])

Welfare Group	Alternative Carbon Permit Price				
	Zero	$10 per ton	$25 per ton	$50 per ton	$100 per ton
CS	1,265,202	1,265,201	1,265,231	1,265,060	1,265,065
PS	89,493	89,264	88,875	88,556	87,453
FS	144,939	144,948	144,958	144,916	144,998
TS	1,499,634	1,499,414	1,499,064	1,498,532	1,497,516

[1] Dollars are in constant terms based on 1997 values.
Note:

- CS is consumers' surplus -- a measure of consumers welfare
- PS is producers' surplus -- a measure of producer net income or welfare
- FS is foreign surplus -- a measure of welfare for trading partners
- TS is a measure of total social welfare

Table 9.
Potential Changes in Year 2010 Welfare Levels for Agricultural Sector Related Groups Under Alternative Carbon Permit Prices
(Percentage)

Welfare Group	Alternative Carbon Permit Price			
	$10 per ton (%)	$25 per ton (%)	$50 per ton (%)	$100 per ton (%)
CS	0	0.01	-0.04	-0.04
PS	-0.26	-0.7	-1.06	-2.33
FS	0.01	0.01	-0.02	0.04
TS	-0.05	-0.14	-0.27	-0.51

Note: The results for consumers give change in consumers' surplus divided by the consumption expenditures in the base (zero permit price) and the results for producers give change in producers' surplus divided by the base (zero permit price) producers' surplus.

Farm Commodity Prices and Production Impacts

As a result of the introduction of carbon permits into the U.S. economy, the U.S. farming sector adjusts its farm commodity production and partially passes on the higher production costs on to the consumer. An analysis of estimated farm commodity price changes and consumer purchasing power impacts puts these potential price increases in perspective. Tables 10 and 11 give more detailed looks at commodity price implications in the years 2000 and 2010, respectively In each year, the projected base prices are represented by the values under "zero" carbon permit price. Again, even with a $100 carbon permit price these model results suggest that the projected U.S. farm product price effects are relatively small across the whole portfolio of farm goods. Tables 12 and 13 give the farm production consequences, which are again small.

Regional Welfare Impacts

An assessment of potential regional impacts on the farm sector from the introduction of a carbon trading system in the U.S. also was conducted. Again, the results of this analysis show a relatively small change across regions of the country (Tables 14 and 15). The regional incidence of these impacts is the largest in the U.S. Corn Belt, but is still relatively small when one considers the magnitude of income and the number of people living in that region.

Impacts on the Use of Land, Water, Chemicals and Labor in the Farm Sector

Some of the most interesting results on the U.S. farm sector from the introduction of carbon permit prices appear to occur in the use of natural resources. A sensitivity analysis of farm input use due to a carbon permit system, as shown in Tables 15 and 16, presents these findings. There are decreases in grazing, farm labor, the use of nitrogen, and pesticides. The results on potassium, phosphorous, are mixed. Regional effects are relatively small here and are reported in Table 17.

Table 10.
Projected U.S. National Farm Commodity Prices
under Alternative Carbon Permit Prices for 2000 and 2010
($U.S. per unit[1])

Commodity	Alternative Carbon Permit Price Year 2000					Alternative Carbon Permit Price Year 2010				
	Zero	**$10**	**$25**	**$50**	**$100**	**Zero**	**$10**	**$25**	**$50**	**$100**
Cotton	302.01	302.01	302.01	302.01	303.77	368.21	368.18	367.24	366.75	363.36
Corn	2.69	2.69	2.69	2.69	2.72	3.7	3.7	3.7	3.71	3.72
Soybeans	6.9	6.88	6.87	6.84	6.86	8.44	8.42	8.39	8.4	8.29
Wheat	4.99	4.97	4.96	4.94	4.96	7.43	7.43	7.43	7.43	7.43
Sorghum	2.34	2.34	2.37	2.37	2.33	2.82	2.82	2.85	2.91	2.91
Rice	7.74	7.82	7.94	8.07	8.14	11.59	11.61	11.73	12.01	12.11
Barley	3.55	3.55	3.55	3.55	3.55	5.41	5.41	5.41	5.41	5.41
Oats	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71	1.71
Silage	11.74	11.8	11.91	12.08	12.37	12.12	12.17	12.24	12.37	12.6
Hay	105.81	105.85	106.47	107.22	107.22	142.85	143.04	143.45	143.43	144.96
Sugarcane	216.02	214.98	213.34	212.2	214.95	317.96	317.96	317.96	317.96	317.96
Sugarbeets	216.02	214.98	213.34	212.2	214.95	317.96	317.96	317.96	317.96	317.96
Potatoes	11.99	12.1	12.1	12.1	12.1	17.86	17.86	17.86	17.86	17.86
Tomato=frsh	11.66	11.66	11.66	11.66	11.66	16.19	16.13	15.91	16.33	16.23
Tomato-proc	55.16	55.23	55.07	55.69	56.3	60.51	60.66	61.34	60.54	60.59
Orange-frsh	6.5	6.5	6.49	6.46	6.72	10.23	10.23	10.23	10.23	10.23
Orange-proc	7.03	7.03	7.03	7.03	7.03	7.03	7.03	7.03	7.03	7.03
Grpfrt-frsh	3.15	3.15	3.15	3.15	3.15	3.39	3.39	3.39	3.56	3.6
Grpfrt-proc	3.87	3.87	3.86	3.88	4.11	0	0	0	0	0
Nonfed beef	41.47	41.47	41.47	41.47	41.47	50.67	50.66	50.63	50.57	50.5
Fed beef	73.7	73.7	73.72	73.73	73.83	85.67	85.67	85.67	85.67	85.67
Beef yearling	73	73	73	73	73	83.74	83.72	83.69	83.62	83.54
Calf slaughter	62.71	62.71	62.67	62.64	62.64	62.55	62.53	62.5	62.49	62.47
Cull beef cow	41.47	41.47	41.47	41.47	41.47	50.67	50.66	50.63	50.57	50.5
Milk	14.56	14.57	14.58	14.6	14.63	16	16.01	16.02	16.03	16.05
Cull dairy	41.47	41.47	41.47	41.47	41.47	50.67	50.66	50.63	50.57	50.5
Feeder pig	104.47	104.46	104.41	104.35	104.53	114.3	114.29	114.21	114.28	114.15
Hog slaughter	46.16	46.16	46.14	46.12	46.28	53.32	53.32	53.3	53.34	53.32
Cull sow	36.65	36.65	36.64	36.63	36.73	41.59	41.59	41.57	41.61	41.59
Lamb slaughter	67.99	67.77	67.23	67.12	67.08	69.63	69.63	69.63	69.63	69.63
Lamb feeder	54.17	54.17	54.17	54.17	54.17	69.63	69.63	69.63	69.63	69.63
Cull ewes	40.22	40.22	40.22	40.22	40.22	41.16	41.18	41.22	41.18	41.18
Wool	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53	1.53
Broilers	0.34	0.34	0.34	0.34	0.34	0.37	0.37	0.37	0.37	0.37
Heifer calf	70.75	70.77	70.83	70.93	71.01	83.91	83.9	83.87	83.82	83.69
Steer yearl	83.89	83.9	83.81	83.82	83.9	96.79	96.75	96.64	96.61	97.53
Heifer yearl	66.02	66.04	66.09	66.19	66.26	78.21	78.2	78.17	78.12	78
Eggs	0.62	0.62	0.62	0.62	0.62	0.68	0.68	0.68	0.68	0.68
Vealers	60.72	60.72	60.68	60.65	60.65	60.56	60.54	60.51	60.5	60.48
Dairy calves	38.23	38.23	38.23	38.23	38.23	38.23	38.23	38.23	38.23	38.23
Beef hef yearl	68.23	68.23	68.23	68.23	68.23	77.43	77.42	77.39	77.33	77.26
Beef str yearl	73	73	73	73	73	83.74	83.72	83.69	83.62	83.54
Turkeys	0.4	0.4	0.4	0.4	0.41	0.45	0.45	0.45	0.45	0.45

[1] Dollars are in constant terms based on 1997 values.

Table 11.
Projected Changes in U.S. National Farm Commodity Prices
Under Alternative Carbon Permit Prices for Years 2000 and 2010
(Percentage)

Commodity	Alternative Carbon Permit Price Year 2000				Alternative Carbon Permit Price Year 2010			
	$10	$25	$50	$100	$10	$25	$50	$100
Cotton	0	0	0	0.58	-0.01	-0.26	-0.4	-1.32
Corn	0	0	0	1.11	0.05	0.11	0.23	0.57
Soybeans	-0.18	-0.4	-0.74	-0.58	-0.22	-0.57	-0.51	-1.75
Wheat	-0.27	-0.53	-1.01	-0.49	0	0	0	0
Sorghum	0.02	1.22	1.11	-0.34	0.22	1.2	3.42	3.46
Rice	0.93	2.53	4.24	5.11	0.22	1.2	3.63	4.52
Barley	0	0	0	0	0	0	0	0
Oats	0	0	0	0	0	0	0	0
Silage	0.51	1.45	2.91	5.4	0.41	1.02	2.08	3.97
Hay	0.04	0.62	1.33	1.33	0.13	0.41	0.4	1.48
Sugarcane	-0.48	-1.24	-1.77	-0.49	0	0	0	0
Sugarbeets	-0.48	-1.24	-1.77	-0.49	0	0	0	0
Potatoes	0.84	0.89	0.89	0.89	0	0	0	0
Tomato=frsh	0	0	0	0	-0.37	-1.76	0.88	0.24
Tomato-proc	0.14	-0.15	0.97	2.07	0.25	1.36	0.05	0.13
Orange-frsh	0	-0.29	-0.62	3.32	0	0	0	0
Orange-proc	0	0	0	0	0	0	0	0
Grpfrt-frsh	0	0	0	0	-0.07	0.1	5.11	6.29
Grpfrt-proc	-0.15	-0.28	0.17	6.08	0	0	0	0
Nonfed beef	0	0	0	0	-0.03	-0.08	-0.19	-0.34
Fed beef	0	0.02	0.03	0.17	0	0	0	0
Beef yearling	0	0	0	0	-0.02	-0.06	-0.14	-0.24
Calf slaughter	0	-0.06	-0.12	-0.12	-0.03	-0.08	-0.1	-0.13
Cull beef cow	0	0	0	0	-0.03	-0.08	-0.19	-0.34
Milk	0.02	0.11	0.25	0.44	0.04	0.08	0.16	0.32
Cull dairy	0	0	0	0	-0.03	-0.08	-0.19	-0.34
Feeder pig	-0.01	-0.05	-0.11	0.06	-0.02	-0.08	-0.02	-0.13
Hog slaughter	0	-0.03	-0.08	0.25	-0.01	-0.04	0.04	0.01
Cull sow	0	-0.03	-0.07	0.22	-0.01	-0.04	0.04	0.01
Lamb slaughter	-0.33	-1.12	-1.28	-1.34	0	0	0	0
Lamb feeder	0	0	0	0	0	0	0	0
Cull ewes	0	0	0	0	0.05	0.14	0.05	0.06
Wool	0	0	0	0	0	0	0	0
Broilers	0	0.02	0.02	0.17	0	0	0.08	0.04
Heifer calf	0.03	0.11	0.27	0.37	-0.02	-0.05	-0.11	-0.26
Steer yearl	0.01	-0.09	-0.08	0.02	-0.05	-0.16	-0.19	0.77
Heifer yearl	0.03	0.11	0.26	0.36	-0.02	-0.06	-0.12	-0.27
Eggs	0	0.03	0.02	0.22	0.01	0.03	0.12	0.14
Vealers	0	-0.06	-0.12	-0.12	-0.03	-0.08	-0.1	-0.13
Dairy calves	0	0	0	0	0	0	0	0
Beef hef yearl	0	0	0	0	-0.02	-0.05	-0.13	-0.22
Beef str yearl	0	0	0	0	-0.02	-0.06	-0.14	-0.24
Turkeys	0	0.03	0.02	0.2	0	0	0.09	0.05

Table 12.
Projected U.S. National Farm Production
under Alternative Carbon Permit Prices for 2000 and 2010
(Million units)

Commodity	Alternative Carbon Permit Price Year 2000					Alternative Carbon Permit Price Year 2010				
	Zero	**$10**	**$25**	**$50**	**$100**	**Zero**	**$10**	**$25**	**$50**	**$100**
Cotton	17.3	17.3	17.2	17.1	17	17.8	17.8	17.8	17.8	17.8
Corn	9822.8	9822.3	9819	9804	9796.3	10270.8	10262.5	10261.3	10253.2	10245.6
Soybeans	2130.4	2130.4	2130.4	2130.4	2130.4	2093.9	2095	2094.9	2094.4	2094
Wheat	2370.9	2370.9	2371.3	2371	2370.9	2385	2387.5	2384.2	2389.5	2387.7
Sorghum	781.5	781.5	777.3	779.5	780.1	782.1	782.1	781.9	781	780.2
Rice	196	196	196	196	196	202.5	202.5	202.5	202.5	202.5
Barley	380.4	380.7	380	383.3	382.5	383.6	383.6	383.7	383.4	383.4
Oats	279.2	279.3	279.3	280.9	278.2	256.2	255.8	255.6	255.4	255.1
Silage	86.8	86.8	86.7	86.7	86.6	85.3	85.3	85.3	85.2	85.1
Hay	125.5	125.4	125.2	125	124.7	121.9	121.9	121.9	121.6	121.4
Sugarcane	4.2	4.2	4.2	4.2	4.2	4.6	4.6	4.6	4.6	4.6
Sugarbeets	5.9	5.9	5.9	5.9	5.9	6.5	6.5	6.5	6.5	6.5
Potatoes	396.2	396.2	396	395.5	395.1	388.6	388.6	388.6	388.6	388.6
Tomato=frsh	172.7	172.7	173.1	170.7	171.2	188.4	188.4	188.4	188.4	188.4
Tomato-proc	10.2	10.2	10.2	10.2	10.2	12.4	12.4	12.4	12.4	12.4
Orange-frsh	57.1	57.1	57.1	57.1	57.1	59.4	59.4	59.4	59.3	59.3
Orange-proc	184.1	184.1	184.1	186.6	185.3	172	172	172	172	172
Grpfrt-frsh	34.1	34.1	34	33.9	34	31.1	31.1	31.1	31.1	31.1
Grpfrt-proc	35.1	35.1	35.1	35.1	35.1	38.3	38.3	38.2	38.3	38.3
Nonfed beef	98.1	97.8	96.6	95.4	94.1	77.5	77.5	77.5	77.5	77.5
Fed beef	320.5	320.5	320.5	320.5	320.5	351.5	351.6	351.3	349.6	348.1
Beef yearling	208.3	208.3	208.3	208.3	208.3	228.5	228.5	228.4	227.3	226.2
Calf slaughter	5.4	5.4	5.4	5.4	5.4	3.6	3.6	3.6	3.6	3.6
Cull beef cow	38.4	38.4	38.3	38.1	37.9	38.9	38.9	38.9	38.7	38.6
Milk	1482.5	1482.5	1482.5	1482.5	1482.5	1439.8	1439.8	1439.8	1439.8	1439.8
Cull dairy	35.9	35.9	35.9	35.9	35.9	34.9	34.9	34.9	34.9	34.9
Feeder pig	45.6	45.6	45.6	45.6	45.6	45.5	45.4	45.1	45.9	46.7
Hog slaughter	236.3	236.3	236.3	236.3	236.3	214.8	214.8	214.8	214.9	214.9
Cull sow	11.6	11.6	11.6	11.6	11.6	10.4	10.4	10.4	10.4	10.4
Lamb slaughter	3.2	3.2	3.2	3.2	3.2	2.9	2.9	2.9	2.9	2.9
Lamb feeder	1.7	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.6	1.6
Cull ewes	2.3	2.3	2.3	2.3	2.3	2	2	2	2	2
Wool	8.3	8.3	8.3	8.3	8.3	7.5	7.5	7.5	7.5	7.5
Broilers	33698.4	33698.4	33698.4	33698.4	33698.4	39782.8	39782.8	39782.8	39782.8	39782.8
Heifer calf	36.2	36.2	36	35.9	35.7	36.7	36.7	36.7	36.5	36.4
Steer yearl	48.2	48.2	48	47.8	47.6	48.8	48.8	48.8	48.5	48.4
Heifer yearl	33.8	33.8	33.6	33.5	33.4	34.2	34.2	34.2	34	33.9
Eggs	5877.3	5877.3	5877.3	5877.3	5877.3	5877.3	5877.3	5877.3	5877.3	5877.3
Vealers	5.4	5.4	5.4	5.4	5.4	3.6	3.6	3.6	3.6	3.6
Dairy calves	3.9	3.9	3.9	3.9	3.9	3.7	3.7	3.7	3.7	3.7
Beef hef yearl	98.4	98.3	97.9	97.5	97	99.6	99.6	99.6	99.1	98.7
Beef str yearl	144.4	144.2	143.7	143.1	142.5	146.3	146.3	146.2	145.6	145.1
Turkeys	7093.7	7093.7	7093.7	7093.7	7093.7	8674	8674	8674	8674	8674

Table 13.
Projected Changes in U.S. National Farm Commodity Production Under Alternative Carbon Permit Prices for Years 2000 and 2010 (Percentage)

Commodity	Alternative Carbon Permit Price Year 2000				Alternative Carbon Permit Price Year 2010			
	$10	**$25**	**$50**	**$100**	**$10**	**$25**	**$50**	**$100**
Cotton	-0.03	-0.05	-0.88	-1.45	0	0	0	0
Corn	-0.01	-0.04	-0.19	-0.27	-0.08	-0.09	-0.17	-0.24
Soybeans	0	0	0	0	0.05	0.05	0.03	0.01
Wheat	0	0.02	0	0	0.11	-0.03	0.19	0.12
Sorghum	0	-0.54	-0.26	-0.18	0	-0.03	-0.14	-0.25
Barley	0.08	-0.13	0.76	0.53	0	0.01	-0.05	-0.07
Oats	0.03	0.04	0.62	-0.35	-0.18	-0.24	-0.33	-0.45
Silage	-0.02	-0.1	-0.18	-0.27	0	-0.02	-0.1	-0.19
Hay	-0.04	-0.21	-0.42	-0.65	-0.01	-0.04	-0.25	-0.47
Sugarcane	0.04	0.82	0.27	0.57	-0.05	-0.03	0	0
Sugarbeets	-0.03	-0.59	-0.19	-0.41	0	0	0	0
Potatoes	0	-0.07	-0.18	-0.29	0	0	0	0
Tomato=frsh	-0.03	0.19	-1.17	-0.88	0	0	0	0
Orange-frsh	0	0	0	-0.04	0	-0.01	-0.03	-0.03
Orange-proc	0	0	1.36	0.69	0	0.02	0	0
Grpfrt-frsh	0.02	-0.11	-0.56	-0.23	0	0	-0.1	-0.1
Grpfrt-proc	0	0	0	0	0	-0.08	-0.02	-0.02
Nonfed beef	-0.3	-1.54	-2.78	-4.13	0	0	0	0
Fed beef	0	0	0	0	0.01	-0.06	-0.55	-0.99
Beef yearling	0	0	0	0	0.01	-0.06	-0.55	-0.99
Cull beef cow	-0.07	-0.42	-0.89	-1.41	-0.01	-0.07	-0.47	-0.9
Feeder pig	0	-0.01	-0.01	-0.01	-0.32	-0.95	0.87	2.58
Hog slaughter	0	0.01	0.01	0.01	0	0	0.01	0.01
Cull sow	0	-0.16	-0.16	-0.17	-0.02	-0.13	-0.2	-0.26
Heifer calf	-0.1	-0.52	-0.94	-1.36	0.01	-0.06	-0.48	-0.89
Steer yearl	-0.11	-0.52	-0.84	-1.18	-0.01	-0.06	-0.51	-0.87
Heifer yearl	-0.1	-0.53	-0.9	-1.31	-0.03	-0.08	-0.53	-0.93
Beef hef yearl	-0.1	-0.53	-0.93	-1.34	-0.01	-0.07	-0.51	-0.9
Beef str yearl	-0.1	-0.49	-0.88	-1.3	0.02	-0.04	-0.45	-0.81

Table 14.
Projected Regional U.S. Agricultural Welfare for Year 2000 by Group under Alternative Carbon Permit Prices ($U.S. Millions[1])

Region	Welfare Group	Alternative Carbon Permit Price				
		Zero	$10 per ton	$25 per ton	$50 per ton	$100 per ton
NORTHEAST	CS	275,060	275,058	275,059	275,060	274,975
	PS	2,333	2,331	2,322	2,310	2,287
	TS	277,393	277,389	277,381	277,369	277,262
LAKESTATES	CS	90,624	90,624	90,624	90,624	90,596
	PS	6,047	6,016	5,968	5,894	5,807
	TS	96,671	96,639	96,592	96,518	96,404
CORNBELT	CS	176,991	176,990	176,990	176,991	176,936
	PS	15,158	15,068	14,942	14,729	14,546
	TS	192,149	192,058	191,932	191,720	191,482
NORTHPLAIN	CS	26,876	26,876	26,876	26,876	26,868
	PS	8,740	8,691	8,638	8,547	8,472
	TS	35,616	35,567	35,514	35,423	35,339
APPALACHIA	CS	114,549	114,549	114,549	114,549	114,514
	PS	3,144	3,130	3,107	3,073	3,043
	TS	117,693	117,679	117,656	117,623	117,557
SOUTHEAST	CS	131,819	131,818	131,818	131,819	131,778
	PS	2,299	2,290	2,275	2,255	2,253
	TS	134,118	134,109	134,093	134,073	134,031
DELTASTATE	CS	47,387	47,387	47,387	47,387	47,372
	PS	2,572	2,562	2,549	2,524	2,489
	TS	49,958	49,948	49,935	49,911	49,861
SOUTHPLAIN	CS	102,313	102,313	102,313	102,313	102,282
	PS	4,087	4,074	4,070	4,046	4,012
	TS	106,401	106,387	106,383	106,359	106,294
MOUNTAIN	CS	67,893	67,892	67,893	67,893	67,872
	PS	5,743	5,737	5,713	5,678	5,644
	TS	73,636	73,629	73,606	73,571	73,516
PACIFIC	CS	178,667	178,666	178,666	178,667	178,611
	PS	7,922	7,918	7,898	7,875	7,861
	TS	186,589	186,584	186,564	186,542	186,473

[1] Dollars are in constant terms based on 1997 values.

**Table 15.
Projected Use of Selected Farm Sector Inputs
under Alternative Carbon Permit Prices for Year 2000
(Thousand units)**

Farm Input	Alternative Carbon Permit Price				
	Zero	$10 per ton	$25 per ton	$50 per ton	$100 per ton
Cropland (1000 acres)	275,548	275,548	275,559	275,574	275,428
Animal Unit Grazing (1000 months)	112,973	112,897	112,494	112,120	111,816
Irrigation Water (1000 acre feet)	98,506	98,411	98,160	97,593	97,050
Labor (1000 hours)	3,894,976	3,893,582	3,887,094	3,879,177	3,874,779
Nitrogen Fert (mill $)	4,046	4,045	4,043	4,032	4,025
Potassium Fert (mill $)	2,326	2,325	2,326	2,325	2,321
Phosphorous Fert (mill $)	1,372	1,372	1,372	1,371	1,370
Pesticides & other Chem (mill $)	3,866	3,866	3,865	3,860	3,856

**Table 16.
Potential Change in Use of Selected Farm Inputs
under Alternative Carbon Permit Prices for Year 2000
(Percentage)**

Farm Input	Alternative Carbon Permit Price			
	$10 per ton (%)	$25 per ton (%)	$50 per ton (%)	$100 per ton (%)
Cropland (1000 acres)	0	0	0.01	-0.04
Animal Unit Grazing (1000 months)	-0.07	-0.42	-0.76	-1.02
Irrigation Water (1000 acre feet)	-0.1	-0.35	-0.93	-1.48
Labor (1000 hours)	-0.04	-0.2	-0.41	-0.52
Nitrogen Fert (mill $)	-0.03	-0.07	-0.34	-0.51
Potassium Fert (mill $)	-0.01	0.02	-0.05	-0.18
Phosphorous Fert (mill $)	0	0.02	-0.07	-0.17
Pesticides & oth Chem(mill $)	-0.01	-0.04	-0.16	-0.27

Table 17.
Projected Percentage Changes in Regional Farm Land and Water Use under Alternative Carbon Permit Prices for Year 2000
(Percentage)

Region	Farm Input	Alternative Carbon Permit Price			
		$10 per ton (%)	$25 per ton (%)	$50 per ton (%)	$100 per ton (%)
NORTHEAST					
	CROPLAND	0	0	0.02	0.03
	WATER	0	0	-0.63	-1
LAKESTATES					
	CROPLAND	0	-0.01	0.01	0.01
	WATER	0	0	0	-8.18
CORNBELT					
	CROPLAND	0	0	0	0
	WATER	-0.08	-4.95	-6.6	-7.04
NORTHPLAIN					
	CROPLAND	0	-0.03	0.01	-0.1
	WATER	0	-0.05	-0.03	-0.66
APPALACHIA					
	CROPLAND	0	0.05	0.17	0.17
	WATER	0	0	-0.01	-0.01
SOUTHEAST					
	CROPLAND	0	0	0	0.01
	WATER	0	0	-0.51	-0.62
DELTASTATE					
	CROPLAND	0	-0.01	-0.02	-0.01
	WATER	0	0	-1.45	-1.72
SOUTHPLAIN					
	CROPLAND	0	0.1	0.08	0.01
	WATER	-0.05	-1.23	-2.24	-2.5
MOUNTAIN					
	CROPLAND	-0.02	-0.03	-0.02	-0.1
	WATER	-0.08	-0.11	-0.33	-0.76
PACIFIC					
	CROPLAND	0	0	-0.32	-0.8
	WATER	-0.31	-0.18	-0.92	-1.48

Affects on National Land Management Policies

Impacts on U.S. Farm Tillage Practices

One result of introducing higher energy prices through imposing a carbon permit system in the country is a shift in tillage methods (Tables 18 and 19). The results indicate that:

1. ***Farmers Shift to Conservation and Zero Tillage***

    - Acres treated by current tillage methods, declines significantly, while increased use of conservation and/or zero tillage occurs uniformly across the results. Zero tillage is the larger growth item. It has been found that zero till practices are probably only slightly more expensive than conservation tillage under current conditions (USDA 1993) and the increase in energy costs tips the scales.

    - For some soil types, conservation tillage is replaced by zero tillage.

    - In general, less energy intensive tillage methods are used as a consequence of the permit system.

2. ***U.S. Farm Sector Soil Erosion Losses Decrease: High Environmental Benefits***

    - This shift to low tillage practices has immediate implications for erosion as given in Table 20, where soil erosion is reduced by 0.2%, 1.4%, 6% and 11.5% at the fours carbon permit price levels.

    - Currently, soil erosion costs the U.S. economy about $2.06 per ton of soil lost in the agricultural sector (updated from Ribaudo USDA 1996 by NRCS). From these findings, one may conclude that there are potentially large **off-site environmental benefits** to the U.S. economy in the farm sector alone from the introduction of a carbon permitting system. According to this analysis, these may be in the order of $3 million, $30 million, $135 million, and up to $231 million for the respective carbon permit prices ($10, $25, $50, and $100 per ton) via the reduced incidence of erosion in waterways, ditches etc.

    - The United States is engaged in a number of policies regarding soil erosion control and resource conservation on agricultural lands. The carbon cost program would likely reduce the costs of reducing erosion levels.

Table 18.
Projected Changes in Usage of Tillage Methods by U.S. Farm Sector under Alternative Carbon Permit Priced for Year 2000
(1000 acres)

Land Type	Tillage Method	Alternative Carbon Permit Price				
		Zero	$10 per ton	$25 per ton	$50 per ton	$100 per ton
W3-8LAND						
	VENT	22,970	21,222	19,471	19,179	17,124
	CONS	3,235	4,995	5,462	5,471	5,707
	ZERO	7,151	7,139	8,430	8,714	10,534
LOEILAND						
	VENT	102,001	96,872	87,615	82,796	76,095
	CONS	45,016	45,073	49,135	41,197	35,635
	ZERO	31,982	37,054	42,265	54,849	67,173
MDEILAND						
	VENT	27,888	25,970	25,200	20,533	16,733
	CONS	7,618	7,660	7,057	7,380	8,717
	ZERO	10,703	12,579	13,940	18,466	20,766
SVEILAND						
	VENT	10,836	10,006	8,609	7,606	6,800
	CONS	2,227	2,568	2,346	1,745	1,809
	ZERO	3,921	4,410	6,028	7,638	8,335

Note:

- VENT identifies the existing tillage system which does contain a mixture including conventional and reduced tillage.
- CONS identifies acres shifted to conservation tillage
- ZERO identifies acres shifted to no till
- W3-8 is wetlands
- LOEILAND is land with low erodibility index
- MDEILAND is land with medium erodibility index
- HIEILAND is land with high erodibility index

Table 19.
Projected Changes in Usage of Tillage Methods by U.S. Farm Sector under Alternative Carbon Permit Priced for Year 2000
(Percentage)

Land Type	Tillage Method	Alternative Carbon Permit Price			
		$10 per ton (%)	$25 per ton (%)	$50 per ton (%)	$100 per ton (%)
W3-8LAND					
	VENT	-7.61	-15.23	-16.5	-25.45
	CONS	54.44	68.85	69.14	76.45
	ZERO	-0.17	17.89	21.86	47.31
LOEILAND					
	VENT	-5.03	-14.1	-18.83	-25.4
	CONS	0.13	9.15	-8.48	-20.84
	ZERO	15.86	32.15	71.5	110.03
MDEILAND					
	VENT	-6.88	-9.64	-26.37	-40
	CONS	0.54	-7.37	-3.13	14.42
	ZERO	17.53	30.24	72.52	94.02
SVEILAND					
	VENT	-7.66	-20.55	-29.8	-37.25
	CONS	15.3	5.34	-21.64	-18.78
	ZERO	12.47	53.75	94.8	112.58

Table 20.
Projected National Soil Erosion Related Items in U.S. Farm Sector under Alternative Carbon Permit Prices for Year 2000

Measure		Alternative Carbon Permit Price				
		Zero	$10 per ton	$25 per ton	$50 per ton	$100 per ton
Quantity	**(1000 tons)**	1,018,146	1,016,551	1,003,620	952,675	901,013
Change	**(1000 tons)**	--	-1,595	-14,526	-65,472	-117,133
Percent Change			-0.16	-1.43	-6.43	-11.5
Offsite Cost Chg (mill $)			-3.29	-29.92	-134.87	-241.29

Note : Offsite cost figured at $2.06 per ton via USDA estimates (Ribaudo 1996).

Conclusions on Carbon Permit Price Impacts on U.S. Farm Sector

Over a wide variety of farm welfare and price measures, the study shows that a carbon permit price system causes potentially minimal U.S. agricultural sector impacts according to the results from the model. Across different levels of carbon permit prices and five time periods, this in-depth analysis suggests that the U.S. farm sector will not face serious negative impacts, and the nation possibly gain in terms of natural resource management, from a carbon cap and trade system.

In general, this study found that:

- ***Minimal Welfare, Commodity Price, and Farm Factor Use Impacts:*** Across the analysis, it appears that the U.S. agricultural sector is not very sensitive to the introduction of carbon permit prices because energy makes up a relatively low part of the total costs of production for the farming sector. The results show that the annual permit price revenues generated under the most extreme -- $100/ton carbon permit price -- are about $1.8 billion per year, which causes an agricultural sector welfare reduction of about $2.0 billion. All of these results are relatively small when compared with the projected farm sector income effects of the 1996 farm bill, which, once payments are fully phased out, is expected to induce losses three to five times as large ($7-10 billion per year) as these potential permit system impacts.

- ***Important National Environmental Benefits Gained in Soil Erosion Control and Water Use:*** Soil erosion across all farming states in the U.S. is substantially reduced when carbon permit prices are internalized into the farm sector. In addition, irrigation water use declines. However, cropland and chemical (pesticide and fertilizer) use are marginally expanded, at least initially. Carbon prices would make attainment of U.S. soil erosion goals cheaper. The carbon permit price revenues that would be raised are large enough to fund expansion in soil conservation or CRP programs.

- ***Impacts Not Affected by Year Carbon Permit System Introduced:*** Although assessments were conducted for the years 2000, 2005, 2010, 2015, and 2020, no significant changes in these farm sector results appear to occur when the timeline for introducing a carbon trading system is altered.

Given the consistency of these results across time, this study suggests that the U.S. agricultural welfare impacts from the introduction of a carbon cap and trade system will be partially compensated by environmental gains in terms of factor use, erosion control, and greenhouse gas emissions reductions.

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