The Kyoto Protocol: Economic Effects of Energy Prices on Northern Plains Dryland Grain Production

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This study examined possible economic impacts on Northern Plains grain producers of policies that could be undertaken by the United States to comply with the Kyoto Protocol. The paper begins with a discussion of the potential effects of the Kyoto Protocol on prices of energy and inputs used in agricultural production. The next section describes the data and econometric models that were used to develop a field-scale, stochastic simulation model of the crop production system typical of the Northern Plains. This model is based on econometric production models estimated with a spatially referenced, statistically representative sample of farmers in Montana. The simulation analysis shows that the impacts of higher energy prices would tend to discourage the use of fallow, raise variable costs of production by 3 to 13%, and reduce net returns above variable cost by 6 to 18% in the case of spring wheat grown on fallow. Under the higher cost scenarios assumed in an analysis conducted by the Farm Bureau, production costs for spring wheat on fallow would increase by 15 to 27% and net returns would decline by 15 to 24%.

The recently completed Kyoto protocol to the United Nations Framework Convention on Climate Change would require that total emissions of greenhouse gases (GHG) from the developed countries be at least 5% less than 1990 levels by the 2008–2012 period (United Nations Framework Convention on Climate Change, 1998). In the case of the United States, emissions of GHGs (carbon dioxide, methane and nitrous oxide) would have to be reduced by 7% below 1990 levels. For carbon dioxide this translates into a 31% emissions reduction from the estimated baseline without the protocol (U.S. Department of Energy, Energy Information Administration 1997). Depending on what policy mechanisms are assumed to be used to implement these GHG emissions reductions, U.S. compliance with the protocol is estimated by different analysts to increase energy costs by as little as 5% and by as much as 50% or more.

Agricultural production in the United States is energy-intensive, with fertilizers, pesticides and fuel representing a substantial share of variable costs of production. Even in the land-intensive Northern Plains grain production systems studied here, these energy-related costs typically comprise about half of the short term variable costs of production. Agricultural producers are concerned that the impact of cost increases associated with compliance with the Kyoto protocol could adversely impact their competitiveness, especially because their competitors in the developing countries are not subject to emissions reductions under the protocol.

The objective of this study is to examine possible economic impacts on Northern Plains grain producers of energy price policies undertaken by the United States to comply with the Kyoto protocol. First, we discuss the potential effects of higher energy prices on agricultural costs of production. Second, we describe the data and econometric models that were used to develop a field-scale, stochastic simulation model of a crop production system typical of the Northern Plains. This model is based on a spatially referenced, statistically representative sample of farms, and incorporates both land use and management adjustments to price changes. The model is used to estimate the impacts of energy price changes on costs and returns in regions of Montana with differing productivity levels. The spatial organization of the data allows the analysis to examine the possible distributional consequences of price changes on farms with more and less productive resource endowments. These distributional consequences are significant in the Northern Plains region where there is a relatively large number of farms whose long-term economic viability may be threatened by adverse changes in economic conditions. Third, we present results of simulations, and compare these results to the analysis by the Farm Bureau conducted in anticipation of the development of the Kyoto protocol.

The Kyoto Protocol, Energy Prices, and Cost of Production

The Kyoto protocol provides several mechanisms for implementation of emissions reductions, including tradeable emissions allowances, incentives to encourage investment in greater energy efficiency in developing countries, and the use of carbon sinks in developed countries to offset their GHG emissions. The Clinton Administration has proposed an international emissions trading system as an efficient way to implement the protocol. Tradeable emissions allowances would ration energy production, thereby raising prices. Thus, to meet commitments in the Kyoto protocol, the U.S. economy would have to adjust to an effective energy price increase. As far as CO_2 emissions are concerned, this energy price increase would have effects similar to a tax on carbon emissions.

Wiese and Tierney (1996) estimated the effects of carbon emissions taxes on the production cost of a number of products, including agricultural inputs and fuels. They considered two scenarios, a $110 (1987 dollars) per metric ton carbon tax that stabilized emissions at 1990 levels by 2020, and a $162 (1987 dollars) per metric ton carbon tax that reduced emissions by 20% from their 1990 levels by 2020. These taxes were levied on the production of coal and on the production and imports of crude oil and natural gas. Their results for agricultural inputs are presented in table 1.

Experience with the SO_2 trading program that was initiated under the 1990 clean air legislation suggests that the cost of reducing carbon emissions may be less than what economists and their models predict. Before SO_2 trading began, economists estimated that an emissions credit would trade for over $300 per ton. Recently, the price has been below $100 per ton on the Chicago Board of Trade (Joskow, Schmalensee and Bailey 1998). This experience shows that the costs of meeting emissions reductions targets may be substantially lower than the costs derived from economic models. One explanation for this situation is that the input-output models and econometric models used to make these estimates are based on historical data that fail to account for the adjustments that can be made when economic agents are rewarded for reducing emissions efficiently.

Table 1. Industry Production Cost Impacts of Carbon Taxes

	Percentage Change in Production Cost	
	$110 (per metric ton carbon)	$162
N and P Fertilizers	7.53	12.27
Fertilizers, Mixing Only	3.33	6.00
Pesticides and Ag. Chemicals	2.84	4.26
Products of Petroleum and Coal	29.87	44.00
Motor Vehicles	2.58	3.82

Source: Wiese, A.M. and B. Tierney (1996)

Another significant factor in determining the cost of meeting emissions targets is the policy mechanism that is used. The Clinton Administration estimated that under a global emissions trading system, U.S. compliance with the Kyoto protocol would require only a 3 to 5% increase in energy prices for U.S. households in the period 2008–2012 (Yellen 1998; Council of Economic Advisers 1998). This energy cost estimate corresponds to a carbon emissions tax in the $14 to $23 per ton range. As observed by Kopp and Anderson (1998), this outcome is not likely given the various practical considerations that may limit the effectiveness of a global emissions trading system. Moreover, under the Kyoto protocol, only emissions trading among the developed countries whose emissions are restricted would be allowed. Analysis shows that with trading only among the developed countries, carbon emissions costs would be at least $72 per ton. Under the assumption that the United States would meet a larger share of its emissions reductions commitments through reductions in energy consumption, the estimated costs of compliance are even higher, as indicated by the Wiese and Tierny study discussed above.

The only previous study dealing with the potential impact of the Kyoto Protocol on costs and returns in U.S. agriculture was conducted by the Farm Bureau prior to the final negotiation of the Kyoto Protocol (Francl 1997). The Farm Bureau projections were generated by selecting a baseline and incorporating the impacts of higher energy prices into cost of production budgets. Adjustments in variable input use and capital and crop production in responses to higher energy prices were not modeled. The study examined six representative commodities and the agricultural sector. Two scenarios were considered, a "low cost" scenario corresponding to an increase of 25 cents per gallon in fuel prices and related energy products, and a "high cost" scenario corresponding to a 50 cent increase per gallon of fuel and related energy products. Agricultural chemical costs were assumed to increase from 15 to 20% in the low scenario, and were assumed to increase 30 to 40% in the high scenario. Costs of hauling increased 15% in the low scenario and increased 30% in the high. Other costs increased 5% in the low scenario and 10% in the high. In the analysis that follows, we use this range of cost estimates, as well as the lower ones in the Wiese and Tierny study, to investigate the range of possible impacts on grain producers in the Northern Plains region.

Econometric Estimation and Simulation of the Cost of Production of Montana Grain Crops

This section describes econometric production models that were estimated using farm-level production data collected for statistically representative samples of Montana dryland grain farms. These models were used to construct a stochastic simulation model of a dryland cropping system in Montana that is typical of the Northern Plains. Data from the previous section are used to construct scenarios for analysis of the possible economic impacts of U.S. compliance with the Kyoto protocol on grain producers in this region.

Conceptual Model of Crop Choice and Management Decisions

The model used in this paper is based on the approach developed by Antle (1996) and Antle, Crissman and Capalbo (1998) to model agricultural production systems. Here this approach is adapted to multiple crops and crop rotations. Following Just, Zilberman and Hochman (1983) we assume that each crop production function is nonjoint in inputs. Let $\mathbf{v}$ denote a vector of variable inputs, $\mathbf{z}$ a vector of fixed inputs, and $\mathbf{e}$ a vector of bio-physical parameters describing soil and climate conditions of a field. The production function for crop $j = 1, \ldots, n$ at location i is $q_{ij} = f(\mathbf{v}_{ij}, \mathbf{z}_{ij}, \mathbf{e}_{ij})$, with corresponding profit functions $\pi_{ij} = \pi(p_{ij}, \mathbf{w}_{ij}, \mathbf{z}_{ij}, \mathbf{e}_{ij})$, where p_{ij} is the expected output price and $\mathbf{w}_{ij}$ is a vector of input prices. Define $\delta_{ij} = 1$ if the jth crop is grown at location i and zero otherwise, and let $\delta_i = \Sigma_j \delta_{ij}$. Also define π_{ci} as the returns to a non-crop land use such as pasture or a conserving use. The farmer's land use decision is made to solve

(1)
$$\max_{\delta_{i1}, \ldots, \delta_{in}} \sum_{j=1}^{n} \delta_{ij} \pi(p_{ij}, \mathbf{w}_{ij}, \mathbf{z}_{ij}, \mathbf{e}_{ij}) + (1 - \delta_i)\pi_{ci}.$$

The solution takes the form $\delta_{ij}(\mathbf{p}_i, \mathbf{w}_i, \mathbf{z}_i, \mathbf{e}_i, \pi_{ci})$, where $\mathbf{p}_i$ is a vector of the p_{ij} and likewise for the other vectors. This model shows that the distribution of land uses in the population of farm fields will reflect the distribution of prices, capital, and bio-physical conditions.

The dynamics of crop rotations can be readily incorporated into the above model. In the application to Montana crops presented below, a crop/fallow rotation is incorporated by specifying the profit function to include the appropriate costs and returns. The key feature of the crop rotation system is that fallowing a field for one season allows soil moisture to be accumulated leading to higher yields in the following growing season. For each crop and location (deleting subscripts i and j for notational convenience) the production function takes the form $q_t = f(\mathbf{v}_t, \mathbf{z}_t, \mathbf{e}_t, \lambda_t)$ where $\lambda_t = 1$ if the previous use was a crop and equals zero otherwise. If a unit of land was cropped last season, the decision to fallow it this season and crop it again next season would involve the net returns calculated as

$$\text{(2)} \quad \pi_{t,fal} = (p_{t+1}q_{t+1} - vc_{t+1})/(1 + r) - fc_t$$

where vc_{t+1} is variable cost of crop production, r is the relevant interest rate for discounting from period t + 1 to period t, and fc_t is the variable cost associated with fallow. Equation (2) implies that the profit function takes the form $\pi_{t,fal}(p_{t+1}, w_{t+1}, r, \mathbf{z}_{t+1}, \mathbf{e}_{t+1}, \lambda_{t+1}, fc_t)$. Likewise, the returns to growing a crop in period t after a crop was grown in period t − 1 (i.e., to recrop the field) is $\pi_{t,rec} = p_tq_t - vc_t$, giving the profit function $\pi_{t,rec}(p_t, w_t, \mathbf{z}_t, \mathbf{e}_t, \lambda_t)$. The farmer will fallow the crop if $\pi_{t,fal} > \pi_{t,rec}$. Thus, by treating fallowing and recropping as different crops, the crop rotation decision can be placed into the framework of equation (1). The same logic can be applied to the case where the field was fallowed in the previous period. In this case, the choices are to grow a crop in the current period with expected returns $(p_tq_t - vc_t) - (1 + r)fc_{t-1}$ or to fallow again and then grow a crop next season with returns $(p_{t+1}q_{t+1} - vc_{t+1})/(1 + r) - fc_t - (1 + r)fc_{t-1}$

Econometric Production Model

An econometric model was formulated to estimate expected production and variable costs of production associated with fertilizers, pesticides, seed, crop insurance, and machinery operation. The general form of this model is:

$$
\begin{aligned}
y &= s(p, w_f, w_p, area, fal, mlra) \\
mc &= m(p, w_f, w_p, area, fal, mlra) \qquad (3) \\
vc &= c(y, w_f, w_p, area, fal, mlra)
\end{aligned}
$$

where

y = crop output (bu)
mc = machinery operating costs ($)
vc = fertilizer and pesticide costs ($)
p = expected crop price ($/bu)
w_f = fertilizer price ($/lb)
w_p = pesticide price ($/lb active ingredient)
area = size of field managed (acres)
fal = dummy variable indicating whether field was fallowed
mlra = regional dummy variables

For estimation, the system of equations was specified in log-linear form, and first-order conditions (share equations) from the cost function were included with linear homogeneity of the cost function and zero-degree homogeneity of the supply function. The system of equations (3) was estimated for winter wheat, spring wheat, and barley crops, based on the data described above.

When land is fallowed in the dryland grain production system, typically several management operations are required to control weeds. The fallow systems observed in the 1995 survey were either pure mechanical fallow (i.e., tillage of the soil to control weeds), chemical fallow (use of herbicides to control weeds), or a combination of these two. To estimate the costs of these fallow operations, equations for the cost of mechanical fallow and mixed mechanical/chemical fallow were estimated as functions of acreage, input prices, and a dummy variable for pure chemical fallow. Parameter estimates of these models are provided in Antle et al. (1998).

Data

The data were collected by Montana State University in collaboration with the Montana Agricultural Statistics Service (Johnson et al. 1997). The survey was designed to be statistically representative of the grain producing areas of the state, stratified by the Major Land Resource Areas (MLRA) shown in figure 1. Respondents operated farms with 1,000 or more acres of cropland, to represent commercially viable grain farms. Detailed production practice data were collected for up to five fields on each farm. The survey provided useable data for 425 farms. These data are described in detail in Johnson et al. (1998a, 1998b, 1998c, 1998d). Table 2 presents summary statistics by crop (winter wheat, spring wheat, barley), by cropping system (fallow or recrop), and by MLRA. The practice of planting crops on land that was cropped the prior year is referred to as recropping in much of the Northern Plains region, and we shall utilize this terminology here. There is very little cropland in the semi-arid areas of this region that is continuously planted to crops as would be the usual practice in the Corn Belt and other higher rainfall regions of the country. The data in table 2 show substantial spatial variation in yields and costs of production between cropping systems (after fallow versus recropped), and among MLRAs. Within an MLRA the per acre yield for a crop produced after fallow is generally three to five bushels greater per acre than the same crop produced under recrop conditions.

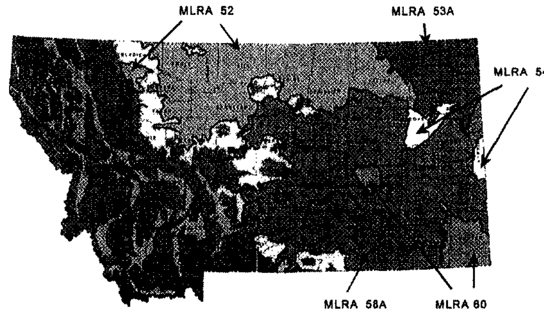

Figure 1. Grain Producing Areas in Montana Stratified by the Major Land Resource Areas (MLRA)

The short term variable costs of production per acre are usually $5 to $8 greater for a crop produced under recrop conditions than for the same crop produced after fallow. Most of this per acre difference in short term variable costs is associated with higher per acre costs for fertilizer for crops produced under recrop conditions. When the variable production costs associated with fallowing the cropland in the prior year are added to the current year's cost of production, the per bushel variable costs for crops produced after fallow are similar to the variable costs for the crop produced under recrop conditions.

The MLRAs are delimited by the United States Department of Agriculture on such criteria as prevailing land use, elevation and topography, climate water, soils and natural vegetation, so yields, production costs, and returns vary by MLRA. The total acres in farms that were devoted to annually-planted crops ranged from a low of 40% in MLRA 58A to a high of 67% in MLRA 52 (Johnson et al. 1997). At the individual crop level, 25.7% of the

Table 2. Summary Statistics of the Montana Cropping Practices Survey by Crop and MLRA

	Crop					
	Winter Wheat		Spring Wheat		Barley	
MLRA/Item	Fallow	Recrop	Fallow	Recrop	Fallow	Recrop
MLRA 52						
Average Yield (bushel/acre)	46.6	37.3	39.1	35.4	61.4	59.2
Average STVC ($1998/acre)	40.41	47.17	32.84	38.35	34.55	40.78
Pesticides	5.48	5.43	3.73	5.57	3.44	5.65
Fertilizer	10.12	15.72	6.36	10.60	7.55	11.47
Machinery Operating Cost	18.41	19.96	16.60	18.23	17.27	18.77
MLRA 53A						
Average Yield (bushel/acre)	N/A	N/A	28.4	19.9	34.9	29.9
Average STVC ($1998/acre)	N/A	N/A	27.64	31.79	25.47	30.69
Pesticides	N/A	N/A	3.60	2.88	1.22	2.05
Fertilizer	N/A	N/A	4.06	8.68	2.24	7.65
Machinery Operating Cost	N/A	N/A	13.79	14.54	15.23	15.33
MLRA 54						
Average Yield (bushel/acre)	22.6	N/A	19.3	13.9	26.1	23.6
Average STVC ($1998/acre)	26.38	N/A	27.56	29.14	25.32	25.74
Pesticides	2.43	N/A	2.65	2.64	2.22	2.12
Fertilizer	6.05	N/A	5.08	8.08	3.29	5.01
Machinery Operating Cost	11.89	N/A	6.17	12.79	12.75	12.09
MLRA 58A						
Average Yield (bushel/acre)	35.6	34.7	27.2	22.7	42.9	39.3
Average STVC ($1998/acre)	40.10	48.18	32.78	40.79	34.15	42.38
Pesticides	5.17	2.10	5.79	9.10	6.37	10.18
Fertilizer	12.29	20.38	6.27	10.96	7.09	10.43
Machinery Operating Cost	16.70	21.38	15.12	15.35	14.73	16.94

Source: 1996 Montana Cropping Practices Survey.

annually-planted cropland in MLRA 52 was in spring wheat after fallow as compared to 29.4% in MLRA 53A, 28.7% in MLRA 54 and only 14.4% in MLRA 58A (Johnson et al. 1998a, 1998b, 1998c, 1998d). Table 2 shows that yields for spring wheat planted after fallow in 1995 varied from 39.1 bu/acre in MLRA 52 to 19.9 bu/acre in MLRA 54. County average data show that the yields for all MLRAs except MLRA 54 are within the variation observed in recent experience.

Expected returns were estimated using expected crop prices combined with expected output and costs of production. Expected crop prices were defined as average prices received in a farmer's region in 1995 net of transportation costs to the nearest grain elevator. Crop price data were collected from USDA Market News, Montana Weekly Grain Summary (various editions) on an area basis within Montana. Farm gate prices were estimated as the area price net of transportation costs to the nearest grain elevator, using a minimum value of $0.10 per bushel for grain transported 30 miles or less and increasing to around $0.15 per bushel for grain hauled from 30 to 80 miles. This transport cost estimate was an average value obtained from a survey of grain haulers in the region. This relationship also provided the basis for estimation of the farmgate price under the alternative cost scenarios discussed below.

Stochastic Simulation of Crop Choice, Costs, and Returns

Using these econometric models and data, a stochastic simulation model was constructed according to the scheme presented in figure 2. Because it is based on the stochastic properties of the econometric models and the sample data, this stochastic simulation model is interpreted as generating a statistical representation of the *population* of production units in a spatial region. A production unit is defined as a field, i.e., a parcel of land that is managed as a unit over time. The model simulates the farm manager's crop choice, and the related output and cost of production conditional on that crop choice, at the field scale, over a specified number of growing seasons. By operating at the field scale, the simulation can represent spatial differences in crop rotations and productivity that give rise to different economic outcomes in the region.

Following figure 2, each field in the data is described by total acres, location, and an associated set of location-specific prices paid and received by

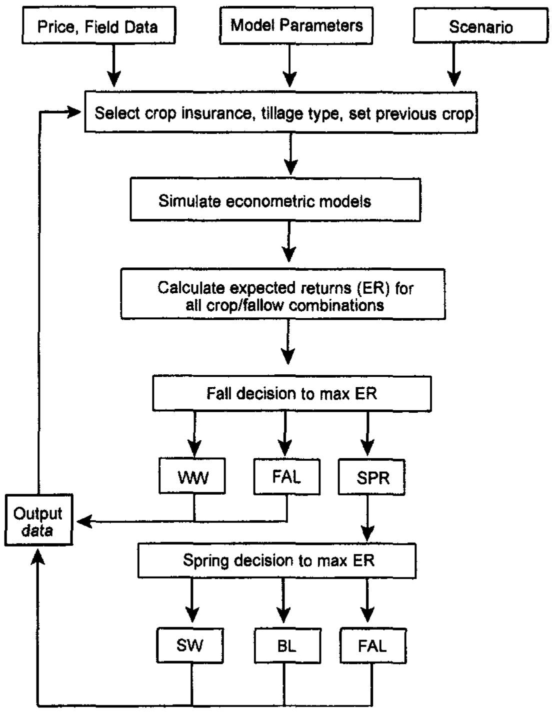

Figure 2. Simulation Model Structure

the farmer. Based on draws from sample distributions estimated from the data, a type of tillage, use of crop insurance, and previous land use (crop or fallow) are selected to initialize the model. The econometric models are simulated to estimate expected output and cost of production, and to then calculate expected returns above short run variable costs of production for each crop alternative. Thus, these expected returns are interpreted as returns to family labor and management and capital ownership. It should be noted that there was little evidence of differences in yield risk associated with different cropping systems, thus providing support for the use of the risk-neutrality assumption in the modeling of farmer behavior. Further details of the simulation model, including its validation, are found in Antle et al. (1998).

Analysis of the Kyoto Protocol Impacts

The simulation model described above was used to estimate costs and returns under a set of assumptions regarding crop prices and factor prices. In the base case, crop prices were set to correspond to those prevailing in the 1998 crop year, and 1995 factor prices from the survey were inflated to 1998 dollars assuming a 6% cost increase over this time period based on prices paid by farmers reported in *The Economic Report of the President.*

In addition to the base case, four scenarios were simulated, based on the studies reviewed above. In these scenarios, fertilizer, pesticide, machinery operating, and grain shipping costs were increased by the increments defined in table 3. Using the percentage increases reported in table 1, the first two scenarios were designed to represent the range of values corresponding to the $110 per metric ton carbon tax (scenario C110) and $162 per metric ton carbon tax (scenario C162). The third (scenario FB1) and fourth (scenario FB2) increments are designed to fall into the higher range of cost increases assumed in the Farm Bureau analysis. Note that machinery costs were not explicitly represented in the data presented in table 1, so the share of machinery costs associated with fuels was used to estimate the impact of fuel price increases on machinery costs. In addition, it should be recalled from the earlier discussion that there is reason to believe that the cost of carbon reduction could be less than $100 per ton. Estimates of input prices under these lower-cost scenarios are not available, so one can interpret the C110 scenario as an upper bound on the impact that smaller increases in energy costs would have. Tables 4 through 6 present results of the simulations.

Table 4 shows the simulated crop land alloca-

Table 3. Energy Cost Scenario Definitions (percent increases in costs)

Scenario	Fertilizers	Pesticides	Machinery	Transport
Base	0	0	0	0
C110, $110/ton carbon cost	6.5	2.5	10	5
C162, $162/ton carbon cost	13	5	20	10
FB1, Farm Bureau low cost scenario	19.5	7.5	30	15
FB2, Farm Bureau high cost scenario	26	15	40	30

Table 4. Simulated Cropland Allocation for Energy Cost Scenarios

	Percent Of Cropland Allocated To:						
Scenario	WWR	WWF	SWR	SWF	BLR	BLF	FAL
Base	0.063	0.078	0.122	0.235	0.152	0.024	0.325
C110	0.060	0.074	0.150	0.219	0.175	0.016	0.308
C162	0.060	0.058	0.171	0.241	0.174	0.014	0.282
FB1	0.063	0.052	0.198	0.208	0.187	0.013	0.279
FB2	0.057	0.043	0.207	0.228	0.173	0.016	0.276

Note: WW, SW, BL, FAL = winter wheat, spring wheat, barley, fallow
R, F = recropped, fallow
C110 = $110/ton carbon cost
C162 = $162/ton carbon cost
FB1 = low Farm Bureau scenario
FB2 = high Farm Bureau scenario

tions for the base scenario and the four Kyoto scenarios defined in table 3. The crops are winter wheat, spring wheat and barley, with each being grown on land that was previously cropped or fallowed, e.g., (SWF) spring wheat after fallow or (SWR) recropped spring wheat. In addition to these crops, land can also be allocated to fallow in the current period (FAL). These data suggest that the increase in costs could substantially alter the crop rotations and the allocation of land between the principal crops. With increasing energy costs, there will be less land fallowed, fewer acres of crop produced after fallow, and more acres of crop produced under recropped conditions. As table 5 shows, on average, costs of production rise with the increases in energy costs. A key factor appears to be the increase in fallow costs (mostly mechanical fallow) associated with higher energy costs. This increase in the cost of fallow is shown in table 5. The C162 scenario would increase fallow costs by almost 20%. The FB2 scenario would increase fallow costs by about 39% relative to the base scenario. With the increased energy costs and the consequent increase in fallow costs, in many situations crops produced under recrop conditions become more profitable than crops produced after fallow.

Table 6 shows the impacts of the energy cost scenarios on average net returns per acre by MLRA for fields that are allocated by the model to each crop. It must be remembered that for the crop year that these data were collected (1995), MLRA 54 had below-average yields due to weather. MLRAs 52, 53A and 58A had yields that are more typical of long-run averages, so their net returns should be more representative. Table 6 shows that the higher energy cost scenarios are generally associated with a decrease in expected

Table 5. Simulated Mean Cost of Production for 1995 Crop Land ($1998 per acre, percent increases from base in parentheses)

	Crop						
Scenario	WWR	WWF	SWR	SWF	BLR	BLF	FAL
Base	40.0	35.2	34.7	30.4	31.0	26.1	5.1
C110	41.5	38.0	36.8	32.4	32.0	27.7	5.7
	(3.8)	(8.0)	(6.1)	(6.6)	(3.2)	(6.1)	(11.8)
C162	43.5	39.7	38.7	33.6	33.6	29.5	6.1
	(8.8)	(12.8)	(11.5)	(10.5)	(8.4)	(13.0)	(19.6)
FB1	45.9	42.2	40.8	35.8	35.3	32.1	6.4
	(14.8)	(19.9)	(17.6)	(17.8)	(13.9)	(23.0)	(25.5)
FB2	47.7	44.4	42.8	37.7	37.6	33.1	7.1
	(19.3)	(26.1)	(23.3)	(24.0)	(21.3)	(26.8)	(39.2)

Note: C110 = $110/ton carbon cost
C162 = $162/ton carbon cost
FB1 = low Farm Bureau scenario
FB2 = high Farm Bureau scenario
WW, SW, BL, FAL = winter wheat, spring wheat, barley, fallow
R, F = recropped, fallow

Table 6. Simulated Returns above Variable Cost by MLRA ($1998 per acre) (number of fields in parentheses)

MLRA/Scenario	WWR	WWF	SWR	SWF	BLR	BLF
MLRA 52						
Base	50.4 (25)	83.6 (17)	84.6 (30)	121.0 (93)	89.2 (63)	106.0 (12)
C110	49.7 (25)	88.9 (13)	83.5 (34)	108.1 (87)	90.4 (72)	104.5 (10)
C162	41.3 (24)	81.3 (11)	76.9 (35)	103.1 (103)	70.4 (69)	98.7 (8)
FB1	40.3 (17)	60.8 (11)	73.8 (48)	103.5 (89)	78.4 (77)	83.2 (9)
FB2	28.5 (17)	75.5 (14)	65.4 (50)	96.5 (95)	75.9 (67)	83.4 (10)
MLRA 53A						
Base	22.7 (10)	42.7 (7)	44.8 (42)	66.6 (57)	40.1 (12)	
C110	18.2 (11)	51.8 (5)	39.5 (50)	61.1 (51)	39.8 (10)	43.0 (1)
C162	16.0 (5)	33.2 (5)	38.3 (58)	55.4 (56)	36.0 (13)	
FB1	10.9 (7)	27.6 (4)	37.3 (70)	54.4 (43)	35.9 (14)	
FB2	7.4 (5)	29.3 (3)	33.2 (66)	54.4 (50)	31.7 (14)	
MLRA 54						
Base	22.4 (17)	44.7 (30)	32.8 (16)	58.5 (13)	42.6 (25)	44.2 (2)
C110	20.9 (11)	42.6 (30)	31.2 (27)	51.6 (11)	38.5 (34)	29.6 (1)
C162	17.1 (10)	48.0 (36)	30.8 (26)	44.6 (13)	31.3 (27)	41.9 (1)
FB1	19.3 (11)	34.3 (39)	28.7 (24)	48.2 (8)	31.2 (32)	40.2 (1)
FB2	15.6 (8)	33.7 (32)	23.0 (28)	40.8 (10)	30.3 (37)	24.6 (1)
MLRA 58A						
Base	27.2 (24)	61.6 (8)	51.0 (31)	74.8 (65)	51.9 (48)	64.1 (10)
C110	21.9 (25)	54.5 (11)	47.5 (35)	69.9 (63)	50.5 (53)	59.9 (3)
C162	21.0 (18)	39.9 (7)	43.8 (46)	62.8 (62)	47.2 (60)	56.5 (6)
FB1	17.1 (16)	31.6 (7)	40.3 (50)	61.1 (63)	44.6 (60)	51.7 (4)
FB2	17.8 (13)	30.4 (8)	38.2 (56)	57.1 (66)	38.6 (50)	59.8 (5)

Note: See Tables 4 and 5 for definitions.

returns, ranging from a few percent in the case of the C110 scenarios, to as high as 50% for winter wheat fallow in MLRA 58A under the FB2 scenario.

As noted earlier, the only other study of the impacts of the Kyoto Protocol on U.S. agriculture was conducted by the Farm Bureau in anticipation that the Kyoto Protocol would be put in place (Francl 1997). The Farm Bureau analysis was based on U.S. average 1994 revenues and input prices. 1994 costs for fertilizer, pesticides, custom operations and fuels and power were estimated to be about $34 per acre, which adjusted for inflation is about $37 in 1998 dollars. This figure is in the range of the variable costs for wheat production presented in table 2. These costs were estimated to increase to about $44 and $51 ($1998 dollars) per acre under the low and high energy price scenarios of the Farm Bureau. These figures are consistent with the cost data reported in table 5 for the FB1 and FB2 scenarios. The Farm Bureau analysis also included an "Other" variable cost category that included seed, repairs, hired labor and other variable cash expenses. Hired labor was not included in the cost data presented in tables 2 and 5 (little hired labor is used on Montana farms). These differences must be kept in mind when the results of the Farm Bureau analysis and this analysis are compared.

Using the Farm Bureau cost and returns data (and, for comparability, excluding from the cost calculations the category of "fixed cash expenses"), we find that net returns above variable cost in the Farm Bureau analysis decreased by about 15 and 29% in the low and high cost scenarios, respectively. In table 6, using data for the most important crop, spring wheat fallow from MLRAs 52, 53A and 58A as representative, we see that returns decrease by 14 to 18% in the FB1 scenario and by 18 to 24% in the FB2 scenario. Thus, under comparable energy price assumptions, the Farm Bureau analysis and this analysis produce comparable results. However, under the lower energy price scenarios (C110 and C162), the estimated impacts on cost of production and on net returns are estimated to be substantially lower, with reductions in net returns in the range of 6 to 17%.

In concluding it should be noted that implementation of the Kyoto Protocol could have impacts on output markets and prices. It is beyond the scope of this analysis to estimate such output price effects. In qualitative terms, to the extent that the Protocol does affect the major wheat producing and exporting countries (the United States, Canada, and Europe) it could have the effect of reducing production and increasing world prices which would in turn counteract the effects of higher costs of production. However, other major wheat producing and exporting regions such as Australia and Argentina, and potential exporters such as Russia and Brazil, are not affected by the Protocol and could expand production in response to output reductions in the affected exporting countries. Thus, it appears that the effects of higher costs of production in the United States would be likely to result in expanded production in other regions. An analysis of the impacts of changes in output prices on grain production in the northern plains region can be found in Antle et al. (1999).

Conclusions

Using a range of cost impacts derived from the literature, a spatially explicit stochastic stimulation model of dryland grain production in Montana was used to estimate the impacts of higher energy prices on land allocation decisions, costs of production, and net returns. This simulation model incorporates economic adaptations to higher energy prices in the form of changes in variable input use and machinery. However, the analysis does not incorporate farmers' long-run adaptations to higher energy prices, such as the utilization of more energy efficient machinery. Thus, the estimated impacts of complying with the Kyoto protocol presented here should be interpreted as representative of short-run to medium-run adaptations by farm decision makers to higher energy costs. Previous experience with increases in energy costs in the 1970s suggest that in the longer-term farmers may be able to mitigate these impacts through adjustments in their capital stocks.

The analysis in this paper showed that the impacts of higher energy prices would raise the cost of using a crop-fallow rotation, particularly for spring wheat, the principal crop in the region. Energy cost increases in the ranges implied by studies of greenhouse gas emissions reductions that would be associated with the Kyoto Protocol—corresponding to a range of $100 to $200 per ton of carbon emissions—would raise variable costs of production by 3 to 13% and reduce net returns above variable cost by 6 to 18% for spring wheat on fallow. Under the higher cost scenarios assumed in the earlier Farm Bureau analysis, production costs would increase by 15 to 27% and net returns for spring wheat fallow would decline by 15 to 24%.

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