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How Would Cap-and-Trade Climate Policy Affect Agricultural Producers in North Dakota? An Economic Analysis

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ABSTRACT

The purpose of this study is to examine the possible impacts of cap-and-trade climate policy on agricultural producers in North Dakota. In this study, we focused on carbon sequestration potential and production cost impacts of carbon prices, and explicitly considered farmer preferences and adaptation behavior to estimate the benefits and costs of greenhouse gas cap-and-trade. Based on empirically estimated farmer behavior models, a policy simulation with agricultural census data identified farmer acreage allocation for carbon sequestration, carbon offset supplies and revenues, the production cost impacts of carbon prices, and impacts on net farm income and their distributions among heterogeneous farmers. Our analysis found that: 1) farmer ex ante preferences in general were biased against carbon sequestration participation although farmer involvement increased with carbon prices; 2) with the fertilizer industry exempted from cap-and-trade regulation, the production cost impact would be small, and more than half of the farms would gain with a carbon price possibly greater than $10 per metric ton of carbon; and 3) the production cost impact with a caped fertilizer industry would be 2 times higher, and more than half of the farms or farmland would lose unless the carbon price could reach more than $55 per metric ton of carbon.

Keywords: cap-and-trade, climate change, agricultural impacts, economics, carbon sequestration

HIGHLIGHTS

Many factors can affect farmer decision on participating in carbon credit programs. Farmers generally are reluctant to enroll land in carbon credit programs with a 5-year contract. Available carbon prices could increase the odds of farmer participation, but their effect is small. If a farmer has land in CRP, manages rangeland, owns cropland, is less than 45 years old, is concerned about climate change, or supports climate policy, he is more likely to participate in carbon credit programs.

For ND, the total acreage enrolled in carbon credit programs was estimated at about 8.5-22.4 million acres for a carbon price of $5-70 per metric ton of carbon. Conservation tillage and tree planting would be the major possible source of ND supply of carbon offsets with their contributions at 46-51% and 31-34%, respectively, depending on the carbon price. Rangeland management would also deserve consideration due to its significant amount of land potentially available for providing carbon credits.

Energy prices are highly correlated with agricultural production costs. Historical observations find that variation in energy prices accounts for 91% of the variation in variable production costs in North Dakota. The relationship between variable production costs and energy prices are nonlinear and vary between crude oil and natural gas.

The impact of carbon prices on production costs via energy prices depends on specific regulation on GHG emissions from the fertilizer industry. If the fertilizer industry is exempted from cap-and-trade regulation, the production cost impact will come largely from the consumption of crude oil, with an estimated cost increase ranging from $0.54 to $7.62 per acre (or a 0.69- 9.69% increase relative to the variable production cost per unit land in 2009) for a carbon price between $5 and $7 per metric ton. If the fertilizer industry is not exempted from cap-and-trade, the production cost impact will be 2 time higher.

At the state aggregate level, if the fertilizer industry is not exempted from cap-and-trade, the production cost will exceed the carbon revenue from farmer participation in carbon sequestration unless the carbon price is greater than $55 per metric ton of carbon. If the fertilizer industry is exempted from cap-and-trade, the carbon revenue is sufficient enough to offset the increase in production costs for any carbon prices greater than $10 per metric ton of carbon. These estimates may vary depending on the base year selected as the comparison benchmark.

At the disaggregate farm level, if the fertilizer industry is not exempted from cap-and-trade, about 73% of ND farms will incur a loss if the carbon price is $5 per metric ton. This percentage will reduce to 41% for a carbon price of $65 per metric ton. If the fertilizer industry is exempted from cap-and-trade, 69% of ND farms will be negatively affected for a carbon price of $5 per metric ton. For a high carbon price of up to $65 per metric ton, only 15% of farms will suffer a loss. More active involvement in carbon sequestration may lower the negative impact of cap-and-trade climate policy on farm income.

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INTRODUCTION

In June 2009, the U.S. House of Representatives passed a bill titled The American Clean Energy and Security Act (HR 2454) which is also known as the Waxman-Markey climate bill. Intended to achieve the U.S. goal in energy security and climate change adaption, this bill proposed a cap-and trade (CAT) program to curb and reduce U.S. greenhouse gas (GHG) emissions while promoting improvement of energy efficiency and development of renewable energy. As an economy-wide CAT program on GHG emissions would impose a carbon cost on any economic activities that release carbon, the CAT climate legislation could affect many sectors in the U.S. economy.

To the U.S. agricultural sector, the impact of GHG CAT is subject to debate with different views. As CAT would increase the prices for energy and energy-intensive agricultural inputs such as fertilizer, there are concerns that agriculture would suffer from increased production costs (Francl et al. 1998, Doane Advisory Services 2008). Many resource economists, however, appear more optimistic and believe that a CAT climate policy could bring many benefits, including on-farm carbon sequestration, increased demand for bio-energy feedstocks from agriculture, and higher commodity prices due to land competition, such that the potential revenue may be sufficient enough to more than offset the increase in production costs (Babcock 2009, McCarl 2009, Murray et al. 2009, Baker et al. 2010).

While the current debate on the agricultural impact of CAT reflects varying focus on the potential benefits and costs, different assumptions on farmer behavior and policy design affect estimation of those benefits and costs that may lead to different conclusions on the policy impact. On the cost side, as agriculture is likely to be exempted from GHG emission regulation in any final legislation, the most direct agricultural impact boils down to production cost increases due to rising input prices to cover carbon costs. With changing and increasing prices for energy and energy-related inputs, would farmers be indifferent and still follow the same production practices as before the price change without changing their consumption of inputs? If farmers are to reduce the use of energy and energy-related inputs by production adjustment, they will effectively mitigate the cost impact of carbon prices. On the benefit side, if agriculture is allowed to provide carbon emission offsets in the carbon market, then the direct agricultural impact of CAT includes on-farm carbon sequestration potential in addition to the market effects of CAT-induced demand expansion for agriculture-based bio-energy feedstocks and higher commodity prices. Similarly, farmer responses to the opportunities brought by a federal CAT program and their market consequence can affect estimation of the potential benefits.

This study attempts to develop an economic analysis on some of the possible local impacts of a CAT climate policy on local agricultural producers in North Dakota (ND). In this study, we consider a CAT climate policy that exempts agriculture from GHG emission regulation and that allows agriculture to provide carbon emission offsets in a carbon market. This study is focused on two direct impacts on net farm income: potential revenue from carbon sequestration participation and rising production costs due to societal carbon regulation. We assume that farmers incur no additional costs for participating in carbon sequestration programs. Explicitly considering farmer behavior with respect to carbon sequestration potential and production cost management, this study intends to address four policy-relevant questions, including: 1) how farmer would respond to on-farm carbon sequestration, 2) what would be the production cost impact with farm ability of adaptation, 3) to what extent the potential revenue from carbon sequestration participation could offset the increase in production costs so as to increase farm income, and 4) how the CAT impact would be distributed among heterogeneous farmers.

Farmer Preferences and Adaptation

To estimate the impact of CAT on agricultural producers, the key is to understand farmer behavior under expected changes in economic and market conditions. Under CAT, one important opportunity for farmers is the potential to sequester carbon on farm by adjusting production practices and sell carbon emission offsets in the market. Yet, on-farm carbon sequestration is a new concept in which farmers have no experience. Farmers may be risk-averse and may not be fully responsive to new market opportunities like carbon sequestration, which requires certain production practices with a commitment of at least 5 years. How likely farmers would participate in carbon sequestration will affect how much benefit farmers could derive from CAT while subject to production cost increase.

Farmer behavior in production cost management is equally important as well. Farmers are responsive and can adapt to mitigate the negative impact of policy that affects their production costs or revenue. When CAT increases prices for energy and energy-related inputs, profit-maximizing farmers will adjust their production to reduce consumption of these inputs substituted by other inputs with relatively lower prices. Farmer adaptation in production cost management will mitigate the cost impact of carbon prices although increased production costs may still be expected resulting from CAT.

A third challenge for analyzing the local impacts of CAT is the heterogeneity among farmers. U.S. agriculture is characterized by high heterogeneity. As not all farmers are the same in terms of their farming attributes, it is likely that some farmers would gain while others would lose. While an estimate of the aggregate impact of CAT provides useful information on the economic efficiency of the policy, decision-makers are also concerned with how the impact of CAT is possibly distributed and what would be the magnitudes of economic gains or losses for individual farmers. Given the larger number of farmers with high heterogeneity, estimating the welfare effect of CAT has never been easy and can only be done by statistically simulation with approximation since modeling hundreds of thousands of farmer individually is impossible.

In this study, we conducted a mailing survey to elicit farmer preferences to carbon sequestration. We use farmer stated preferences to calibrate a farmer behavior function that can predict the probabilities that farmers with given attributes would enroll land in carbon sequestration with different carbon prices. We draw on economic theory to specify farm production costs, and use historical observations on how production costs varied with energy prices to capture farmer adaptation to manage production costs with changing energy prices. We apply the estimated farmer behavior models to agriculture census data to simulate acreage enrollment in carbon sequestration, carbon supply and revenue, production cost impacts, and more importantly, the impact on net farm income and its distributions for ND farms.

Farmer Preference Survey and Data

The survey questionnaire is composed of three sections. Section 1 is intended to elicit farmer willingness to enroll in carbon sequestration programs. Table 1 lists the carbon sequestration programs included in the survey. Section 2 is designed with questions to collect information on farmer social economic background and their attitudes to climate change and legislation. In section 3, questions are raised on farmer current production practice. Data collected by sections 2 and 3 are intended to be used as surrogates to measure farmer perceived costs for sequestering carbon on their land.

Table 1. Example of carbon sequestration programs included in survey questionnaire[a]

Carbon credit program[b]	Available carbon credits	Market return rate (carbon credits earned × carbon price[f])
Conservation tillage[c]	0.4 metric ton/acre/year	$10/acre/year
Cropland conversion to grass	1.0 metric ton/acre/year	$25/acre/year
Rangeland management	0.12 metric ton/acre/year	$3/acre/year
Tree planting[d]	0.7-1.8 metric ton/acre/year[e]	$17.5-45/acre/year
Methane management	21 metric ton/metric ton methane/year	$525/metric ton methane/year

a. Carbon credit programs are adopted from the voluntary programs managed by the NFU (2009)
b. All programs require at least 5 year commitment.
c. Including planting methods commonly referred to as: no till, strip till, direct seed, zero till, slot till, and zone till.
d. Tree planting may require a contract longer than 5 years.
e. Depending on tree age and species; at least 20 acres enrollment required.
f. Assume a carbon price of $25/metric ton.

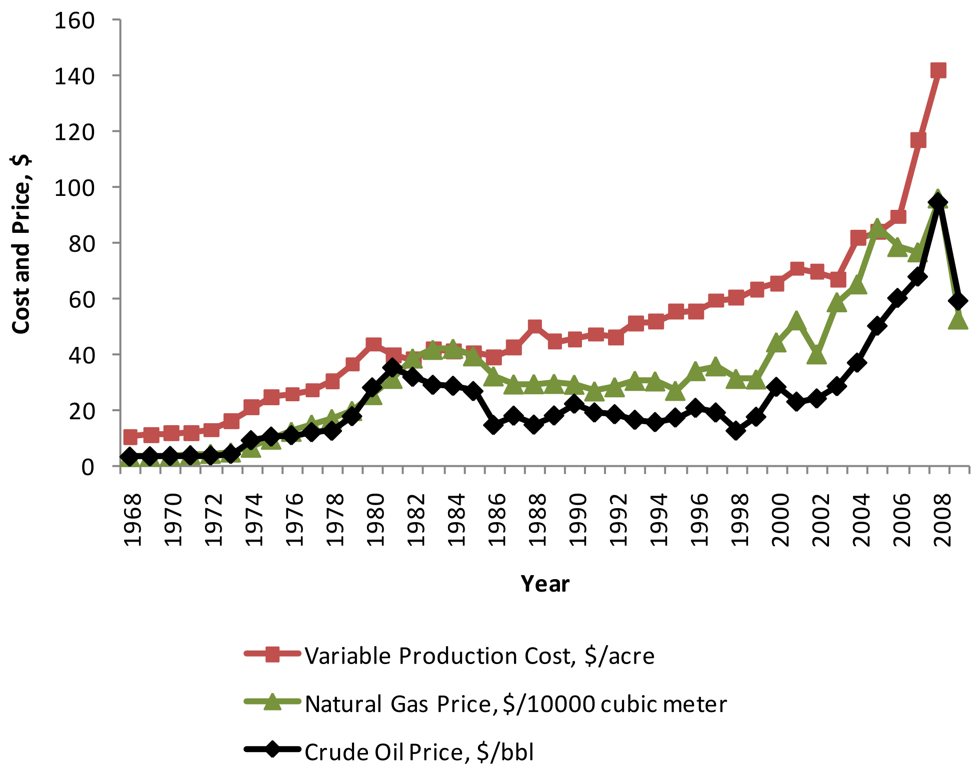
The survey was administered by the U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) field office in ND. We designed six different versions of survey questionnaire to incorporate different levels of the carbon price ranging from $5/metric ton to $70/metric ton. For each version of the questionnaire, a sample of 500 farmers across ND was randomly selected from the USDA NASS database. The survey questionnaires were mailed out on January 15, 2010, followed by a postcard reminder after two weeks. A total of 316 survey questionnaires were returned. Among those returned questionnaire, 35 are not filled out and the remaining 281 have at least one question answered. Table 2 summarizes the survey responses.

Table 2. Summary of survey responses

Attribute	Level	Percentage
Assigned carbon price	$5/metric ton	14%
	$15/metric ton	18%
	$25/metric ton	17%
	$35/metric ton	15%
	$50/metric ton	16%
	$70/metric ton	20%
Carbon program enrollment	Currently enrolled	7%
	Not enrolled but willing to enroll	46%
Farm region	North Central	19%
	West Missouri Slope	27%
	South Central	31%
	Red River Valley	18%
Age	≤45 years old	18%
	46-60 years old	46%
	≥60 years old	33%
Farming experience	≤10 years	11%
	11-20 years	13%
	≥20 years	72%
Major source of household Income	Farming	60%
Education	High school or less	20%
	Technical training beyond high school	20%
	4 year college or some college	39%
	Graduate degree or coursework	19%
Attitude to climate change and legislation	Concerned about climate change	44%
	Support climate legislation	18%
Land tenure by land use type	Own cropland	85%
	Rent cropland	50%
	Own rangeland	58%
	Rent rangeland	31%
Land use/management	Farming	67%
	no till or potential	76%
	CRP	43%
	expect to renew	58%
	Rangeland management	59%
	Rental	26%

Other data needed for this study include production costs, total acreages of planted cropland and rangeland, and energy prices to estimate the production cost function. Although county level data are desirable, they are not available. Instead, we collected state-level annual variable cash expenses and acreages of production farmland over the period of 1968-2008 from the U.S. Department of Agriculture Economic Research Service (USDA 2010a).

We collected prices for two major energy sources – natural gas and crude oil – that are directly or indirectly consumed in agricultural production. Natural gas accounts for the majority of the production cost of fertilizers, which is an important input for agriculture. Crude oil is the raw material for diesel and gasoline, which are directly consumed in agricultural production operations. Natural gas prices are nominal prices for industrial sector. Crude oil prices are combined nominal refiner acquisition costs of domestic and imported crude oil. All energy prices are annual averages for the period of 1968-2008 from the U.S. Department of Energy Information Administration (EIA 2010). Figure 1 depicts the variable production costs and the energy prices. As shown in the figure, production costs are highly correlated with natural gas and crude oil prices.



Data Source: energy prices from EIA (2010), production costs from USDA (2010a)

Figure 1. Historical observations of annual averages of energy prices and variable production cost for per unit land in ND.

Model Estimation

<u>Farmer choice on carbon sequestration participation</u>

We use the discrete choice method to model farmer choice on carbon sequestration participation. Table 3 defines independent variables used in farmer choice modeling. Table 4 presents the results of our econometric modeling, including estimates of elasticity of the likelihood that farmers would enroll land in carbon sequestration programs with respect to different factors. As demonstrated by Table 4, the binary logit model fits farmer choices reasonably well and it predicts 75% of the farmer choices in the survey sample.

Table 3. Definition of independent variables

Independent Variable	Definition
EnrollDummy	Choice specific dummy, 1 indicating carbon program enrollment and 0 otherwise
Price	Specified market price for per metric ton of sequestered carbon
Farming	Land use dummy, 1 denoting land in crop farming and 0 otherwise
Rangeland	Land use dummy, 1 denoting rangeland management and 0 otherwise
CRP	Land use dummy, 1 denoting CRP land and 0 otherwise
NW	Farm location dummy, 1 denoting the northwest region of ND and 0 otherwise
NC	Farm location dummy, 1 denoting the north central region of ND and 0 otherwise
NE	Farm location dummy, 1 denoting the northeast region of ND and 0 otherwise
WC	Farm location dummy, 1 denoting the west central region of ND and 0 otherwise
CT	Farm location dummy, 1 denoting the central region of ND and 0 otherwise
EC	Farm location dummy, 1 denoting the east central region of ND and 0 otherwise
SW	Farm location dummy, 1 denoting the southwest region of ND and 0 otherwise
SC	Farm location dummy, 1 denoting the south central region of ND and 0 otherwise
SE	Farm location dummy, 1 denoting the southeast region of ND and 0 otherwise
Ownland	Land tenure dummy, 1 denoting owning farmland and 0 otherwise
Rentland	Land tenure dummy, 1 denoting renting farmland and 0 otherwise
Agel45	Age group dummy, 1 denoting the group of 45 years old or younger and 0 otherwise
Age4659	Age group dummy, 1 denoting the group of 46 to 59 years old and 0 otherwise
Ageg60	Age group dummy, 1 denoting the group of over 60 years old and 0 otherwise
FExpl10	Farming experience dummy, 1 denoting less than 10 years of experience and 0 otherwise
FExp11-19	Farming experience dummy, 1 denoting 11 to 19 years of experience and 0 otherwise
FExpg20	Farming experience dummy, 1 denoting 20 or more years of experience and 0 otherwise
ClimA	Farmer attitude dummy, 1 denoting being concerned about climate change and 0 otherwise
ClimAP	Farmer attitude dummy, 1 denoting supporting climate legislation and 0 otherwise

Table 4. Estimated coefficient parameters of the binary logit model of farmer choice to participate in carbon sequestration and estimated elasticities of carbon sequestration probability with respect to farmer attributes.

Independent Variable	Estimated Coefficient	Standard Error	Choice Elasticity[a]
EnrollDummy	-4.8371***	0.9673	
Price	0.0329***	0.0087	0.5381***
Farming	0.5386	0.4278	0.2538
CRP	1.1145***	0.3741	0.5103***
Rangeland	1.2091***	0.3664	0.5562***
NW	0.2307	0.6290	0.1083
NC	-1.4858**	0.7084	-0.6367**
NE	-0.3916	0.6349	-0.1850
WC	0.8428	0.7508	0.3735
EC	0.0315	0.6893	0.0149
SW	-0.0654	0.6856	-0.0309
SC	0.7058	0.6855	0.3196
SE	-0.8671	0.6358	-0.4007
Ownland	1.5954***	0.6609	0.6779***
Rentland	-0.7575**	0.4113	-0.3513**
Agel45	1.3405***	0.5428	0.5784***
Ageg60	-0.2815	0.3784	-0.1331
FExpg20	0.9280**	0.4712	0.4306**
ClimA	0.8139**	0.3675	0.3783**
ClimAP	0.8038*	0.4879	0.3642*
Log-likelihood	-121.066		
Sample prediction	75%		

Note: *** denotes significance level at 0.01, ** at 0.05, and * at 0.1

a. For dummy variables, the elasticity estimates were calculated as:

$$\varepsilon = (\mathrm{Pr}_1 - \mathrm{Pr}_0) / \mathrm{Pr}_0$$

where Pr_1 is the probability estimated with the focal variable being 1 and all other variables at their sample means; and Pr_0 is the probability estimated with the focal variable being 0 and all other variables at their sample means. For carbon price, the elasticity estimate was calculated as:

$$\varepsilon = \frac{(\mathrm{Pr}_1 - \mathrm{Pr}_0) / \mathrm{Pr}_0}{1 / p_0} / 100$$

where Pr_1 is the probability estimated with the carbon price being 1 plus its sample mean and all other variables at their sample means; and Pr_0 is the probability estimated with all variables at their sample means.

Many factors can affect farmer choice regarding carbon sequestration participation. As expected, available carbon prices could significantly increase the odds of farmer involvement in carbon sequestration. Farmer current land use practices, land tenure, ages, and attitudes toward climate change and legislation could also affect the probability of carbon program participation. Specifically, if a farmer has land in CRP, manages rangeland, owns cropland, is less than 45 years old, is concerned about climate change, or supports climate policy, the farmer is more likely to participate in carbon sequestration.

Interestingly, farmers in general are biased against participating in carbon programs as indicated by the negative and significant coefficient for the dummy variable denoting carbon program enrollment. From the perspective of farmer profit-maximizing behavior, the negative coefficient means a threshold level of private costs perceived by farmers for enrolling in carbon programs. This private cost threshold may be attributed to farmer perceptions of uncertainties associated with program enrollment or simply the loss of flexibility in land use and management with a 5 year commitment once enrolled in the carbon program.

To understand the effects of different factors, Table 4 also reports in the fourth column the elasticities of the probability of farmer enrollment in carbon programs. Specifically, ownership of cropland has the strongest effect that increases the probability of carbon program participation by approximately 68%. The effects of farmer age, engagement in rangeland management and CRP, farming experience, and farmer attitude to climate change are also sizable that increase the probability of carbon program participation by 58%, 56%, 51%, 43%, and 37%, respectively. As to the effect of carbon prices, Table 4 shows that the probability of carbon program enrollment on average would increase 0.54% for a 1% increase in the carbon price at $34/metric ton.

Farmer production costs with respect to energy prices

Our empirical estimation of farmer production cost function reveals a quadratic relationship between variable production costs and energy prices on a per acre basis. As demonstrated by Table 5, all the estimated coefficients for the independent variables are significant at the 0.01 level. The adjusted R-square statistic indicates that variation in energy prices can account for up to 91% of the variation in variable production costs for the considered time period. Table 5 suggests different marginal cost effects between energy sources: for natural gas, it is positive and decreasing; for crude oil, it is negative and increasing.

Table 5. Estimated production cost function for per unit farmland for ND

Independent variable	Coefficient estimate	Standard error
Intercept	11.0934***	3.5023
Natural gas price	21.9175***	3.2773
Natural gas price square	-1.2955***	0.3323
Crude oil price	-1.3347***	0.4405
Crude oil price square	0.0191***	0.0042
Adjusted R square	0.91	

Note: *** denotes significance level at 0.01, ** at 0.05, and * at 0.1

The estimated production cost function has important implications on farmer vulnerability or ability to adapt to the price impacts of different energy sources. When crude oil prices are low, agricultural consumption of crude oil may be extensive with low energy efficiency. Consequently, when crude oil prices rise, farmers may be able to easily cut crude oil consumption by improving energy efficiency so as to mitigate the production cost impact. However, farmer ability to mitigate the cost impact of energy prices appears not as strong for natural gas as for crude oil. Farmers will see increased production costs with rising natural gas prices. It is worth noting that, with a quadratic production cost function, the marginal cost impact of energy prices depends on the level of energy prices in the base year. In this study, the base year for estimating the CAT impact on production costs is 2009.

Policy Simulation

We apply the estimated farmer behavior models to agricultural census data to simulate farmer acreage enrollment in carbon sequestration, carbon supply and revenue, production cost impacts with farmer adaptation, and impacts on ND farm income for different carbon prices. Table 6 presents the 2007 agricultural census data for ND used in the simulation.

Table 6. Summary of 2007 ND agricultural census data used in policy simulation

Agricultural attributes	Number of farms	Total acreage
Farms	31,970	37,830,203[a]
Land use and management		
Harvested cropland	20,408	22,035,717
Cropland only used for pasture or grazing	4,025	812,553
Cropland failed or abandoned	2,855	530,496
Cropland in cultivated summer fallow	3,443	598,516
Permanent pasture and rangeland	14,964	10,418,885
Land in conservation	15,253	3,434,036
Land tenure		
Own land	29,099	19,977,605
Rent land	15,667	19,696,981
Principle operator age group		
Less than 45 years	6,376	NA
45 to 59 years	12,707	NA
60 years and over	12,887	NA

Data source: USDA (2010b)

a. Only include the land in the listed land use and management, which accounts for 95% of the total farmland in ND.

<u>Acreage enrollment in carbon sequestration and carbon supply</u>

Table 7 presents simulation results on farmer acreage enrollment in carbon credit programs for ND. As expected, the acreage of farmland enrolled in carbon credit programs increases with carbon prices. The total acreage in carbon programs expands from around 8.5 million to 22.4 million when the carbon price rises from $5 to $70 per metric ton of carbon. The contributions to the total acreage are uneven across carbon programs and vary depending on the carbon price. Conservation tillage constitutes nearly half of the acreage in carbon sequestration, and its contribution increases from 45% to 52%. Although accounting for around 42% of the acreage in carbon sequestration for a carbon price of $5/metric ton, rangeland management contributes less than conservation tillage with a decreasing share as the carbon price increases. Cropland conversion to grass accounts for a small share of 2-3% of the enrolled farmland and its contribution goes up for a high carbon price. Farmland enrolled in tree planting makes up around 10% of the total land enrolled, and its percentage decreases with carbon prices.

Table 7. Simulated acreages of farmland enrolled in carbon credit programs for different carbon prices

Carbon Price $/metric ton	Conservation tillage acres (%)	Cropland to grass acres (%)	Rangeland manage. acres (%)	Tree planting acres (%)	Total acreage, acres (%)
5	3,838,603 (45.16)	219,064 (2.58)	3,541,668 (41.67)	900,610 (10.60)	8,499,944 (100)
15	4,750,463 (46.15)	270,359 (2.63)	4,185,504 (40.67)	1,086,089 (10.55)	10,292,416 (100)
25	5,789,990 (47.17)	328,622 (2.68)	4,866,208 (39.65)	1,289,166 (10.50)	12,273,986 (100)
35	6,948,875 (48.21)	393,328 (2.73)	5,564,773 (38.61)	1,505,683 (10.45)	14,412,660 (100)
50	8,871,016 (49.80)	500,112 (2.81)	6,598,593 (37.04)	1,842,960 (10.35)	17,812,681 (100)
70	11,614,935 (51.87)	651,478 (2.91)	7,843,993 (35.03)	2,279,955 (10.18)	22,390,362 (100)

Table 8 presents the amounts of carbon sequestered for different carbon prices. The total amount of carbon sequestered increases from around 3.3 million metric ton to 9.1 million metric ton as the carbon price rises from $5 to $70 per metric ton of carbon. The share of the contribution from each program varies. Conservation tillage still is the major source for sequestered carbon with its share ranging from 46% to 51%, which is consistent with their acreage contribution. In contrast, rangeland management provides only 10-13% of carbon although its acreage contribution accounts for 35-42%. Tree planting and cropland conversion to grass provide, respectively, about 31-34% and 7% of the total sequestered carbon, more than their acreage contributions.

Table 8. Simulated amounts of carbon sequestered in ND for different carbon prices

Carbon Price, $/metric ton	Conservation tillage metric ton/year (%)	Cropland to grass metric ton/year (%)	Rangeland manage. metric ton/year (%)	Tree planting metric ton/year (%)	Total carbon metric ton/year (%)
5	1,535,441 (46.45)	219,064 (6.63)	425,000 (12.86)	1,125,762 (34.06)	3,305,267 (100)
15	1,900,185 (47.15)	270,359 (6.71)	502,260 (12.46)	1,357,612 (33.68)	4,030,417 (100)
25	2,315,996 (47.85)	328,622 (6.79)	583,945 (12.06)	1,611,457 (33.29)	4,840,021 (100)
35	2,779,550 (48.57)	393,328 (6.87)	667,773 (11.67)	1,882,104 (32.89)	5,722,755 (100)
50	3,548,406 (49.67)	500,112 (7.00)	791,831 (11.08)	2,303,700 (32.25)	7,144,049 (100)
70	4,645,974 (51.12)	651,478 (7.17)	941,279 (10.36)	2,849,944 (31.36)	9,088,675 (100)

In all, conservation tillage and tree planting represent the major source of ND supply of carbon emission offsets. Although conservation tillage may not sequester as much carbon as tree planting does, it can be applied to harvested cropland - the majority of farmland - without incurring significant opportunity costs. The acreage available for planting tree may be limited due to significant conversion costs, uncertainties in carbon markets, or loss of option value. However, tree planting appears to be a significant option for carbon sequestration since the large amount of carbon can be sequestered in tree. Both rangeland management and cropland conversion to grass deserve consideration by their sizable amounts of carbon sequestration potential without incurring significant opportunity costs.

CAT impact on farm income and distributional effect

Table 9 summarizes the impact of CAT on the production costs for ND farms. Note that the estimates of energy price increase relative to the 2009 level were based on the carbon contents of energy sources without considering the market equilibrium effect of carbon prices. As the carbon cost for energy consumption is likely to be shared jointly between energy producers and consumers, the estimated energy price increase represents an upper bound for the price impact of carbon pricing. However, given that energy consumption is less elastic than energy supply, those estimates are likely to be close to those accounting for the market equilibrium price effect.

Table 9. Changes in agricultural production costs for ND for different carbon prices

Carbon price, $/metric ton	Energy price increase[a]		Production cost increase, $/acre (%)[b]	
	Natural gas	Crude oil	Fert. industry exempted	Fert. industry capped
5	1%	1%	0.54 (0.69)	1.14 (1.45)
15	4%	3%	1.63 (2.08)	3.43 (4.36)
25	7%	5%	2.72 (3.46)	5.71 (7.26)
35	10%	7%	3.81 (4.84)	7.99 (10.17)
50	14%	10%	5.44 (6.92)	11.42 (14.53)
70	19%	14%	7.62 (9.69)	15.99 (20.34)

a. Energy price increases are relative to the 2009 price levels. The estimates are based on the carbon content of energy sources as if a carbon tax was posed on energy prices without considering the market equilibrium effect of carbon pricing.
b. The percentage in parenthesis is relative to the 2009 annual average of viable production costs for per unit land for ND.

As illustrated by Table 9, carbon prices appear to have a relatively stronger effect on natural gas prices than on crude oil prices. The differential effects between natural gas and crude oil tend to be more prominent when the carbon price is higher. For a carbon price of $5/metric ton, prices for natural gas and crude oil both increase 1% relative to their 2009 levels. However, when the carbon price reaches $70/metric ton, the natural gas price will increase 19% while the crude oil price will increase 14% relative to their 2009 levels.

Historical observations have revealed that farmers are less able to mitigate the production cost impact for a price increase for natural gas as compared to for crude oil. Farmer vulnerability to natural gas prices, combined with the stronger effect of carbon costs on natural gas prices, suggests that farmers would suffer more severe cost impact for any price increase for natural gas than for crude oil. Indeed, our estimates of the production cost impact confirm the reasoning. Agricultural consumption of natural gas is indirectly through fertilizer use. If the fertilizer industry is exempted from CAT regulation, the production cost impact will come largely from the consumption of crude oil, with an estimated cost increase ranging from $0.54 to $7.62 per acre (or a 0.69% to 9.69% increase relative to the variable production cost for per unit land in 2009) for a carbon price between $5 and $70 per metric ton of carbon. However, if the fertilizer industry is not exempted from CAT, the production cost impact for ND farmers will be 2 times higher, with an estimate cost increase ranging between $1.14 and $15.99 per acre (or a 1.45% to 20.34% increase relative to the variable production costs for per unit land in 2009) for the same range of carbon prices.

Figure 2 compares aggregate carbon sequestration revenues and production cost impacts for ND farms. If the fertilizer industry is not exempted from CAT, the production cost impact will exceed the carbon revenue unless the carbon price is greater than $55 per metric ton of carbon. As the carbon revenue is not sufficient to offset the increase in production costs for a carbon price below $55 per metric ton, ND farms in aggregate would suffer a loss from CAT. However, if the fertilizer industry is exempted from CAT, the production cost impact on ND farms will be much smaller. In this case, for any carbon prices greater than $10 per metric ton, the carbon revenue is sufficient enough to offset the increase in production costs such that ND farms in aggregate would gain from CAT by participating in carbon sequestration. It is worth noting that the production cost impacts were estimated relative to the 2009 ND production costs for different carbon prices. These estimates may vary depending on the base year selected as the comparison benchmark.

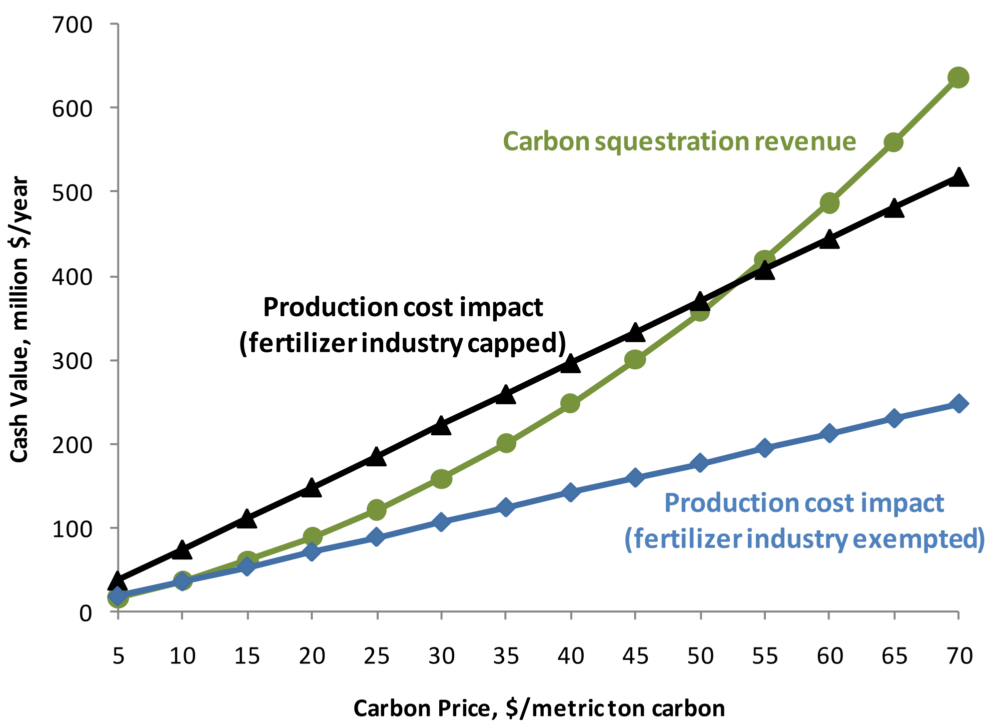
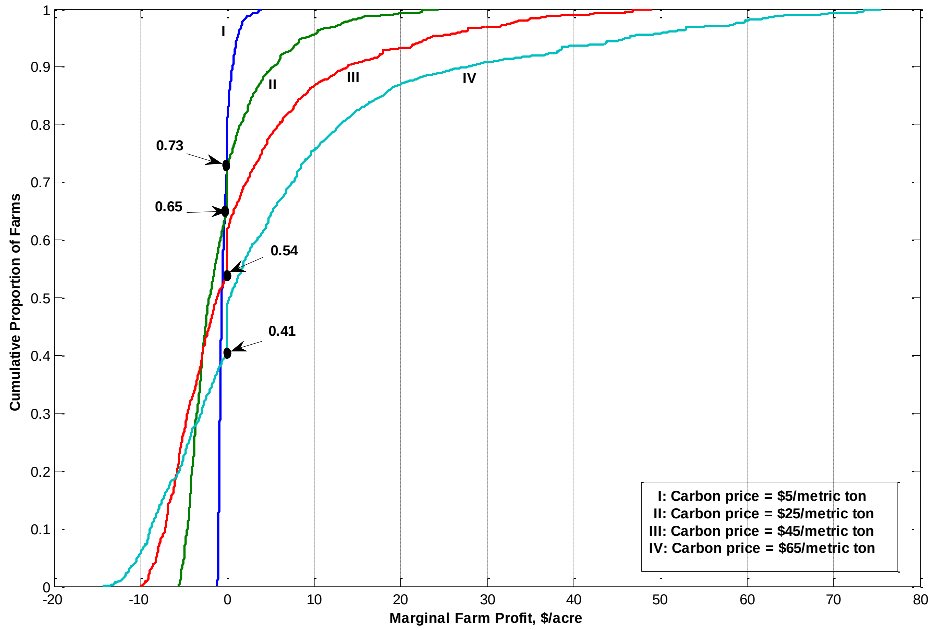
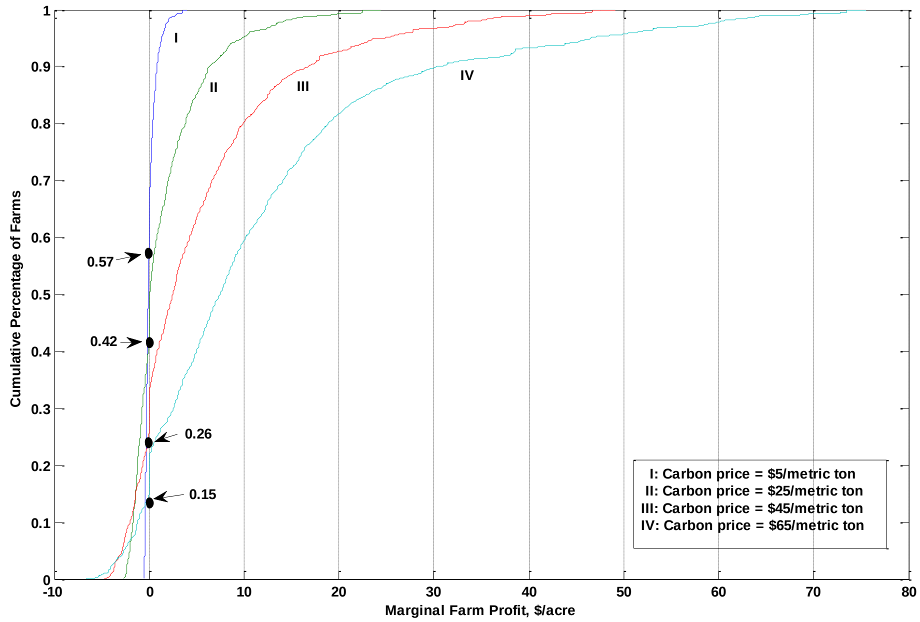


Figure 2. Demonstration of aggregate carbon sequestration revenues and production cost impacts to ND farms for different carbon prices.

The impact of CAT on individual farms can be different, depending on specific farmer attributes including their production practices. Figure 3 depict the cumulative distributions of net farm profits by farms for different carbon prices and CAT regulation on the fertilizer industry. One type of information delivered by the cumulative distributions of net farm profits is the percentage of farms that would suffer a loss from CAT. If the fertilizer industry is not exempted from CAT, as demonstrated by panel a in Figure 3, around 73% of ND farms will incur a loss if the carbon price is $5 per metric ton. The percentage of farms with a non-positive net profit is reduced from 73% to 41% if the carbon price is $65 instead of $5 per metric ton of carbon.



a. Fertilizer industry capped



b. Fertilizer industry exempted

Figure 3. Cumulative distributions of marginal farm profits for different carbon prices

If the fertilizer industry is exempted from CAT, panel b in Figure 3 shows the percentage of farms that will suffer a loss falls dramatically as compared to panel a for each carbon price. For a low carbon price of $5 per metric ton, 69% instead of 73% of ND farms will be negatively affected by CAT. For a high carbon price of up to $65 per metric ton, the percentage of ND farms that will see negative net farm profits drops from 41% with a capped fertilizer industry to 14% if the fertilizer industry is exempted. Both carbon prices and fertilizer industry regulation significantly affect the distributional effect of CAT among heterogeneous farmers.

The cumulative distributions of net farm profits also show the magnitudes of possible economic gains or losses to ND farms. As illustrated by Figures 3, for a carbon price between $5 and $65 per metric ton of carbon, the economic loss on a per acre basis ranges between $0 and $15 with the fertilizer industry capped or between $0 and $8 with the fertilizer industry exempted from CAT. However, the effects of the carbon price are not symmetric between economic gains and losses. The economic gain from CAT can increase dramatically as compared to the economic loss. Figures 3 shows that, the economic gain for some farms can reach up to $80 per acre for a carbon price of $65 per metric ton, which is in contrast with a maximum economic loss of around $15 or $8 per acre depending CAT regulation on the fertilizer industry. The asymmetric effects of carbon prices reflect farmer capacity of adaptation to manage production costs while benefiting from on-farm carbon sequestration.

Conclusion

This study is motivated to examine the possible local impacts of CAT climate policy on agricultural producers in ND. It draws on economic theory and the existing literature attempting to develop an economically sound analysis of possible CAT impacts, particularly potential revenue from carbon sequestration and the production cost impact of carbon pricing. It focuses on farmer production behavior and explicitly considers farmer preferences to carbon sequestration potential, adaptation to manage production costs, and heterogeneity among farms. Based on empirically estimated farmer behavior models, a policy simulation with agricultural census data provides important implications on agricultural potential to adapt to climate change mitigation.

Farmers are reluctant ex ante to participate in carbon sequestration. With agriculture exempted from GHG emission regulation, CAT creates opportunities for farmers to make additional income by providing carbon emission offsets. Based on our survey, however, we found that farmers in general had a bias against participating in carbon sequestration. This may be attributed to farmer unfamiliarity with the carbon sequestration concept and perceived high private costs of farm management to sequester carbon while maintaining commodity production. Indeed, it was quite common that survey respondents expressed their concerns over regulation on farm management and loss of control of farmland. Better education and extension to explain on-farm carbon sequestration are needed for agriculture to adapt to societal climate change mitigation. Nonetheless, conservation tillage and tree planting appear promising to play a major role in the Northern Plains to contribute a large portion of carbon emission offsets without incurring significant opportunity costs.

Farmers have the ability to mitigate the production cost impact of a CAT climate policy. Our theory-driven, production cost approach based on historical observations reveal that farmers can effectively manage their operation costs to mitigate the impact of energy price increase by improving production efficiency. However, farmer ability of production cost management varies among energy sources and the level of energy prices. From a local perspective, our study confirms existing findings that CAT has limited impact on agricultural production costs. With their ability to manage production costs, farmers may gain from CAT by optimal farm management to produce food while sequestering carbon. System design and integration are needed to reconstruct agricultural production to better adapt to an energy efficient, low carbon economy.

Policy design can affect the agricultural impact of CAT. While fertilizer costs make up an important portion of farmer production costs, a CAT policy with an exempted fertilizer industry could dramatically reduce its cost impact on agriculture. On a per acre basis, the production cost impact for ND farms is about 2 times higher with a capped fertilizer industry than with an exempted fertilizer industry. In aggregate, with an exempted fertilizer industry, ex ante carbon sequestration revenues would be greater than the production cost impact for a carbon price over $10/metric ton for ND farms even if farmers are in general not willing to participate in carbon sequestration. Without the exemption of the fertilizer industry, the carbon price needs to reach approximately $55/metric ton for ND farms to break even with ex ante carbon sequestration revenues offsetting increased production costs. A policy design to allow the exemption of the fertilizer industry from CAT may help the U.S. agricultural sector adapt to government efforts to mitigate climate change.

The impact of CAT on ND farm income is unevenly distributed. With the fertilizer industry exempted, the CAT impact on production costs would be small. Most farms in ND would gain for a carbon price over $20 per metric ton of carbon even if farmers are reluctant to participate in carbon sequestration. With the fertilizer industry being capped, the CAT impact on production costs would be greater. Most farms in ND would lose for any carbon prices below $50/metric ton. In both cases, on a per acre basis, the economic losses are limited as compared to the economic gains across farms.

While we strive to develop an economically sound analysis of some of the possible local impacts of CAT on agriculture, this study like many others comes with some caveats which arise mainly due to our local focus in research scale. First, in this study, we did not consider two other effects that can affect the assessment of GHG CAT. Some existing studies indicate that CAT may have economy-wide market consequences including increased demand for bio-energy feedstock and rising prices for agricultural commodities, both of which can increase farm income (Schneider and McCarl 2005, Murray et al. 2009). To quantify these market equilibrium effects, an equilibrium analysis is required at the national scale, which is beyond the scope of this study. We understand that it is highly challenging to accurately quantify the benefits from both effects with complex market dynamics interacting with farmer behavior and US energy and agricultural policies, including the indirect land use effect. Focused on carbon sequestration potential without considering the market equilibrium effects, this study likely underestimates the benefit that CAT would bring to agriculture.

Second, it would not be surprising if this study underestimated the agricultural potential of carbon sequestration. The estimation of on-farm carbon sequestration is based on our survey of farmer ex ante preferences to carbon sequestration participation. As mentioned above, the on-farm carbon sequestration potential is a new concept for which farmers do not have much experience. A risk-averse farmer might overweight the uncertainty and risk for involving in a new production option that requires a long-time commitment while subject to regulation. As a result, farmers were less willing to being involved in carbon sequestration, as indicated by the survey. With this recognition, it is also economically reasonable to expect more active farmer involvement when the production cost impact becomes a sunk cost with an effective CAT climate policy and when farmers become familiar with on-farm management that can produce both crop or livestock and carbon offsets. After all, sequestering carbon does not have to compete with crop or livestock production (although they could under high carbon prices) and may more than offset the sunk cost of production cost increase under CAT while also bring other joint farm benefits such as increased soil fertility.

Third, this study did not consider the environmental benefits of CAT. Studies have suggested that carbon sequestration can bring many other environmental benefits due to its implication on changes in land use and production practices (Elbakidze and McCarl 2007, Feng et al. 2007). These environmental benefits include improved soil fertility and water quality with reduced soil erosion and water pollution plus wildlife benefit. We did not incorporate these benefits because this study is from the farmer perspective to maximize farm profits and there is no market (except CRP or WRP) that currently exists to reward farmers for providing those environmental benefits. If a market in combination with the carbon market can also be established for other environmental credits jointly produced by sequestering carbon, farmers may see higher benefits from the CAT program.

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