Assessment of Carbon Tax Policies: Implications on U.S. Agricultural Production and Farm Income

Jerome Dumortier, Amani Elobeid

Working Paper 20-WP 606
July 2020

Center for Agricultural and Rural Development
Iowa State University
Ames, Iowa 50011-1070
www.card.iastate.edu

Jerome Dumortier is Associate Professor, Paul H. O'Neill School of Public and Environmental Affairs, Indiana University-Purdue University Indianapolis, Indianapolis, IN 46202. E-mail: jdumorti@iupui.edu.

Amani Elobeid is Adjunct Assistant Professor, Iowa State University, Ames, IA 50010. E-mail: amani@iastate.edu.

For questions or comments about the contents of this paper, please contact Jerome Dumortier, jdumorti@iupui.edu.

Assessment of Carbon Tax Policies: Regional Implications on U.S. Agricultural Production and Farm Income

Jerome Dumortier and Amani Elobeid

July 16, 2020

Abstract

We assess the regional differences of three carbon tax scenarios on U.S. agriculture in terms of commodity prices, crop production, and farm income. Our model covers corn, sorghum, soybeans, and wheat between 2018 and 2030 and carbon prices ranging from \$62 to \$144 t^{-1} CO_2-e at the end of the projection period. The basis for the analysis are the carbon tax projections from the 2020 Annual Energy Outlook produced by the U.S. Energy Information Administration. Our county-level results indicate the smallest percentage decline in terms of net revenue in the U.S. Midwest despite the operating cost for corn increasing the most. We find that the increase encourages the reduction in corn area which raises corn prices such that the overall decline in net returns is small relative to other crops. Net returns for wheat in Kansas, Montana and the Dakotas decline the most. From a policy perspective, it is important to note that crop prices together with input cost are increasing and thus, the decline in net returns for farmers is offset to a certain degree. We hypothesize that the presence of the Conservation Reserve Program (CRP) dampens some of the declines in net returns because the retirement of cropland increases commodity prices for counties remaining in crop production.

1 Introduction

In the United States, multiple carbon tax proposals have been put forth to reduce greenhouse gas (GHG) emissions. The Energy Innovation and Carbon Dividend Act of 2019 (EICD Act) stipulates a carbon tax starting at $15 per metric ton of carbon dioxide equivalent (t^{-1} CO_2-e) and increasing by $10 per year until GHG emissions reach a preset target. The EICD Act is designed to be revenue neutral and includes the establishment of a Carbon Dividend Trust Fund to distribute the tax revenue back to eligible U.S. households. A second proposal, i.e., the American Opportunity Carbon Fee Act of 2019 (AOCF Act), specifies a carbon tax starting at $52 and increasing by 6% annually. In both proposals, the carbon tax is adjusted for inflation each year and includes border adjustments for imported energy-intensive goods. The latter stipulation is designed to avoid circumventing the carbon tax by importing goods whose production is not subject to carbon pricing. The carbon tax rates after 10 years are $105 and $88 t^{-1} CO_2-e for the EICD and AOCF Act, respectively. The EICD Act specifically exempts fuels used for farming purposes and non-fossil fuel emissions from agriculture such as from agricultural soil and livestock management. The AOCF Act offers a tax credit of 6.2% of earned income up to the maximal tax credit amount of $900. This provision is similar to the redistribution of tax revenue back to eligible households under the EICD Act but limits the recipients to low-income households.

Currently, the only carbon tax in North America is found in Canada where a carbon price floor was established in 2018 (Slade, 2018). The price floor starts at CAD $10 t^{-1} CO_2-e and rises by CAD $10 per year until it reaches CAD $50 t^{-1} CO_2-e. Imposing a carbon tax as opposed to a cap-and-trade system has the advantage that the price on emissions is deterministic, which results in planning security for stakeholders (Weitzman, 1974). However, of all the carbon pricing schemes implemented globally, there is an equal split between cap-and-trade systems and carbon taxes (World Bank, 2019). As aforementioned, the U.S. discussion over the last decade has focused on a cap-and-trade policy whereas the current debate focuses on a carbon tax.

Any carbon tax proposal will likely include exceptions and special provisions for agriculture. As mentioned before, the EICD Act excludes emissions from livestock management and fuel used for farming purposes. In addition, the American Power Act of 2010 — which would have established a cap-and-trade system in the United States — included carbon offset credits for agriculture. That is, farmers and landowners engaging in carbon sequestering activities would have received payments in accordance with the prevailing carbon price. The eligible offsets would have included afforestation and reforestation projects as well as other agricultural, grassland, and rangeland sequestration and management practices. Other mitigation options from agricultural crop management entail reducing tillage intensity, changing crop rotations, reducing fertilizer application rate, or shifting from fall to spring application of fertilizer (ICF International, 2013). Emission reductions from livestock focuses on digesters for manure management or diet changes to reduce methane emissions from enteric fermentation (ICF International, 2013).

A deterministic carbon offset payment, which would result from a carbon tax increases the adoption rate for farmers because farmers would know in advance and over multiple years how much revenue would be generated. Under a cap-and-trade policy, the offset payments may fluctuate from year to year, which results in lower adoption rates of mitigation or offset options. Dumortier (2013b) finds that afforestation carbon credits under an uncertain carbon price would not result in a substantial amount of forest carbon credits generated because of the option value resulting from uncertain returns in agriculture. Given the current proposals of implementing a carbon tax, which has no uncertainty associated with potential offset payments, would change those results and possibly lead to more afforestation. The same would be true for other mitigation and sequestration activities.

The Conservation Reserve Program (CRP) will play an important role in the agricultural sector under various carbon tax policies. Currently, there is a cap of around 10 million hectares (ha) as well as a maximum of 25% of a county's cropland that can be enrolled in CRP . Under a carbon tax, CRP land could serve multiple purposes. First, there are environmental benefits from retiring cropland (Hellerstein, 2017). Second, enrollment in the CRP could serve as a price support mechanism for (1) farmers remaining in crop production, and (2) landowners having their land enrolled instead of being exposed to low profitability.

In view of the policy proposal and growing support for a carbon tax, we analyze the effects of three carbon price policy scenarios on the agricultural sector in the United States. We assess changes in average farm income at the county-level until 2030 under the carbon tax simulations from the 2020 Annual Energy Outlook (AEO) produced by the U.S. Energy Information Administration (EIA, 2020). The three carbon tax scenarios do not differ in their annual growth rate of 5% but differ in their starting prices. The carbon prices start are \$15, \$25, and \$35 t^{-1} CO_2-e in the GHG 15, GHG 25, and GHG 35 scenarios, respectively. In addition, the effects on commodity prices and land-use are quantified. There are different effects on farmers depending on the location due to spatial differences in production cost and yields. A previous carbon tax study was conducted over a decade ago at the national level but did not include consequences at the regional level (Schneider and McCarl, 2005). Our model will inform policy makers, farmers, and other stakeholder on the effects of the carbon tax and can contribute to a better understanding of the consequences at the regional/local level.

2 Model

We use a dynamic rational expectations model for corn, sorghum, soybeans, and wheat at the county level in the United States. Each county is characterized by a representative farmers who allocates land to the modeled commodities based on net returns. Agriculture is a perfectly competitive market and hence, all farmers are price takers and do not account for the effect of their acreage decision on output prices into account. In aggregate, the dynamics of the net returns are endogenous to the model and commodity prices are set at the national level. Specifically, the profit maximization problem of the representative farmer in county i in time period t can be expressed as:

$$\pi_{it} = \max_{a_{itk}} \sum_{k=1}^{K} p_{tk} y_{itk} a_{itk} - \sum_{k=1}^{K} \beta_{itk} a_{itk} - \frac{1}{2} \sum_{k=1}^{K} \theta_{ik} a_{itk}^2 \qquad (1)$$

where π_{it} represents the county- and year-specific profit and k denotes the commodity. On the revenue side, p_{tk}, y_{itk}, and a_{itK} represent the price, yield, and area, respectively. On the cost side, β_{itk} and θ_{ik} represent cost parameters. The specification of the cost function is such that β_{itk} is year specific whereas θ_{ik} is independent of time. In the simulation part of the analysis, the carbon tax cost increases will be implemented through changes in the parameter β_{itk}. In addition, note that the cost function exhibits increasing marginal cost. This specification is similar to Dumortier (2013a), Dumortier (2013b), and (Dumortier et al., 2020) with the exception of the new time aspect in Equation (1). The behavioral profit maximization function needs to be solved subject to the fixed land constraint and the non-negative constraint, i.e.:

$$\sum_{k=1}^{K} a_{itk} = \bar{a}_{it} \tag{2}$$

$$a_{itk} \geq 0 \tag{3}$$

Setting up the Lagrangian and deriving the first-order conditions is straightforward (i and t dropped for notational ease):

$$p_k y_k - \beta_k - \theta_k a_k - \lambda_i + d_k = 0 \quad \forall k \tag{4}$$

And then first-order conditions associated with the land and non-negativity constraints:

$$\sum_{k=1}^{K} a_{itk} - \bar{a}_i = 0 \tag{5}$$

$$a_i d_1 = 0 \tag{6}$$

The last condition ensures that the area allocation is non negative. It is important to point out that our model assumes a fixed stock of land which does not change over the projection period. Future work should relax this assumption and include idle cropland and/or land in CRP as a pool (1) to which land can be placed into or (2) from which land can be drawn if market conditions change. The advantage of assuming a fixed pool of land is twofold: First, extreme expansion or contraction of land during the simulation process is limited. And second, estimation of acreage allocation as a function of net returns for each county and crop is not necessary. The land allocation module also includes the possibility to enroll land into the CRP program. We are making some simplifying assumptions for our analysis. We do not impose an overall upper limit on total CRP land enrolled. However, we impose a limit of a maximum of 25% of cropland in a county being enrolled in CRP. If the enrollment is over 25%, the model allocates the excess land to the crops ensuring that the cap of 25% is met. The decision to enroll in the CRP is based on the average rental rate between the years 2013 to 2018. We implicitly assume that land can be put in and taken out of CRP on an annual basis.

Demand for each crop is composed of food, feed, and the export sector ($m = 1, 2, 3$). In addition, corn also faces demand from the biofuel sector. For each sector, demand is modeled as a constant elasticity function depending on commodity prices (own price and cross-prices) and a time trend. The time trend is later used to calibrate the model with data from the U.S. Department of Agriculture. We model the demand for a total of four commodities ($k = 1, \ldots, 4$) and in its most general form, it can be written as

$$\ln(Q_{mtk}) = \upsilon_{mk} + \alpha_{mk} \cdot t + \sum_{k=1}^{4} \gamma_{mk} \cdot \ln(p_{tk}) \tag{7}$$

Given the land allocation model and the demand functions, the simulation model solves for the market clearing price such that excess demand is zero for each commodity and each year. The solution consists of a time series of commodity prices for corn, sorghum, soybeans, and wheat for the baseline as well as the three carbon tax scenarios.

3 Data and Model Calibration

In the following sections, we describe the data and model calibration to construct the simulation baseline and incorporate the carbon tax scenarios. The approach follows closely Dumortier (2013a), Dumortier (2013b), and Dumortier et al. (2017). The model represents an extension of the framework used in Dumortier et al. (2017). The macroeconomic assumptions and carbon tax projections are based on the 2020 AEO (EIA, 2020). For the contiguous U.S., our model projects county-level agricultural production, net returns, and from 2018 to 2030 with the carbon tax scenarios starting in 2021. All prices are expressed in 2018 dollars.

3.1 Yield and Area Data

Yield data is obtained from USDA's National Agricultural Statistics Service (NASS). For the four crops and each county, we use the yield data from 2005 to 2017 to linearly project the yield until 2030. Counties that were not active in crop production for at least six years between 2005 and 2017 were dropped from the analysis. We assume that the yield is exogenous and does not change between the carbon tax scenarios. To obtain the base area allocated to the four crops in each county, we use the average area harvested for each crop from 2010 to 2017. The total area in each county available for production of the four crops is the sum of the individual areas. We assume that the total area is fixed at the county-level and there is no expansion or contraction (e.g., from land retirement) over the projection period.

3.2 Cost of Production

The USDA's Economic Research Service (ERS) from the USDA provides data on the historical operating cost for commodities and agricultural regions. The operating costs are composed of chemicals, custom operations, fertilizer, energy (fuel, lube, and electricity), interest on operating capital, purchased irrigation water, repairs, and seed. Furthermore, the U.S. is subdivided into nine Farm Resource Regions to capture the dominant agricultural practices in the various parts of the country (USDA, 2000). In order to project the impact of the carbon tax on these cost components, we use the Center for Agricultural and Rural Development modelling framework (CARD Model). More specifically, the CARD Model includes a cost of production module, which projects future operating cost subdivided in the various cost components mentioned. The operating cost projections in the CARD Model are based on the components of the Producer Price Index (PPI). For example, the fertilizer price index is coupled to the evolution of the index PPI Utility Natural Gas. The CARD Model uses a total of eleven PPI indices to project future cost. The AEO does not project all components of the PPI needed in the CARD Model to estimate cost of production for crops in the projection period but focuses on the energy components of the PPI and energy prices. Because energy prices are affected the most under a carbon tax, we can make some simplifying assumptions without introducing a bias in our results.

The 2020 AEO projections consider a reference case with status-quo energy policies as well as three carbon tax scenarios. It projects three components of the Wholesale Price Index (WPI):[1] (1) WPI All Commodities, (2) WPI Fuel and Power, and (3) WPI Metals and Metal Products. WPI Fuel and Power is used to project the PPI Gas Fuels and PPI Fuels, Related Products & Power. WPI Metals and Metal Products can be directly used on the CARD Model. We use the price of diesel, jet fuel, and gasoline to projected the PPI Refined Petroleum Products. The price of electricity is used for the PPI Electric Power and the price of natural gas is used for PPI Utility Natural Gas. The other PPI components are linked to WPI All Commodities (Dumortier and Elobeid, 2020).

Note that we only use every third year of the WPI because our projection model ranges over a shorter time period (until 2030) than the AEO Outlook (until 2050). We assume U.S. cost of production for missing regional values.[2] The operating cost for the baseline and the three carbon tax scenarios represent the parameters β_{itk} in Equation (1). We assume that for every county within USDA's Farm Resource Region (FRR), β_{itk} is identical. The parameters θ_{ik} are calibrated based on the first order conditions and are constant across the baseline and the scenarios.

3.3 Commodity Demand

To calculate the domestic demand in the United States, we rely on the elasticity estimates from the literature as well as from the Food and Agricultural Research Policy Institute (FAPRI) at the University of Missouri (Table 1) FAPRI (2011); Chen et al. (2011). To calculate the constant $\upsilon_{j,m}$ and the time coefficient, we calibrate the model to the long-term projections from USDA (2020). The projections extend to 2029 and we linearly extrapolate to 2030 for the crops and sectors covered in our model. Given the yield projections, profit and demand function, we calculate the equilibrium prices over the projection period for the baseline. To implement the three carbon tax scenarios, the cost parameters β_{itk} are adjusted based on the cost of production module from the CARD Model. The carbon tax affects energy intensive inputs such as fertilizer and fuel. This

[1]Note that in 1978, the Bureau of Labor Statistics changed the name from WPI to PPI but the index methodology remained unchanged.

[2]For the following regions (commodities), U.S. cost of production values were used: Basin and Range (corn, sorghum, and soybeans), Eastern Uplands (wheat), Fruitful Rim (corn, sorghum, and soybeans), Mississippi Portal (corn), Northern Crescent (sorghum), Northern Great Plains (sorghum), Southern Seaboard (sorghum).

	p_{CO}	p_{SG}	p_{SB}	p_{WH}	$\upsilon_{j,m}$	t
Corn						
Food	-0.230				7.128	-0.001
Feed	-0.201		0.110		-20.420	0.013
Exports	-0.570			0.120	-40.444	0.023
Sorghum						
Food		-0.430			5.525	-0.001
Feed	2.140	-2.530			32.053	-0.014
Exports		-2.360			1.015	0.006
Soybeans						
Domestic	0.120		-0.434		-20.403	0.013
Exports	0.030		-0.630	0.020	-42.192	0.025
Wheat						
Food				-0.300	-4.253	0.005
Feed	1.610			-2.150	12.269	-0.004
Exports	0.170		0.040	-1.230	-15.492	0.012

Table 1. Demand parameters used in Equation (7). Price elasticities are based on FAPRI (2011) and Chen et al. (2011). The parameters $\upsilon_{j,m}$ and t are calibrated using USDA (2020).

may lead to farmers moving between crops resulting in changes in supply, commodity prices, and net returns.

4 Results and Discussion

In the presentation of our results, we focus on (1) cost of production, (2) commodity prices and land allocation at the county level, and (3) farm income. Except for the commodity prices, the results are presented for 2030 but yearly results are available upon request from the authors. The carbon prices at the end of our projection period are \$62, \$103, and \$144 t^{-1} CO_2-e for the GHG 15, GHG 25, and GHG 35 scenario, respectively.

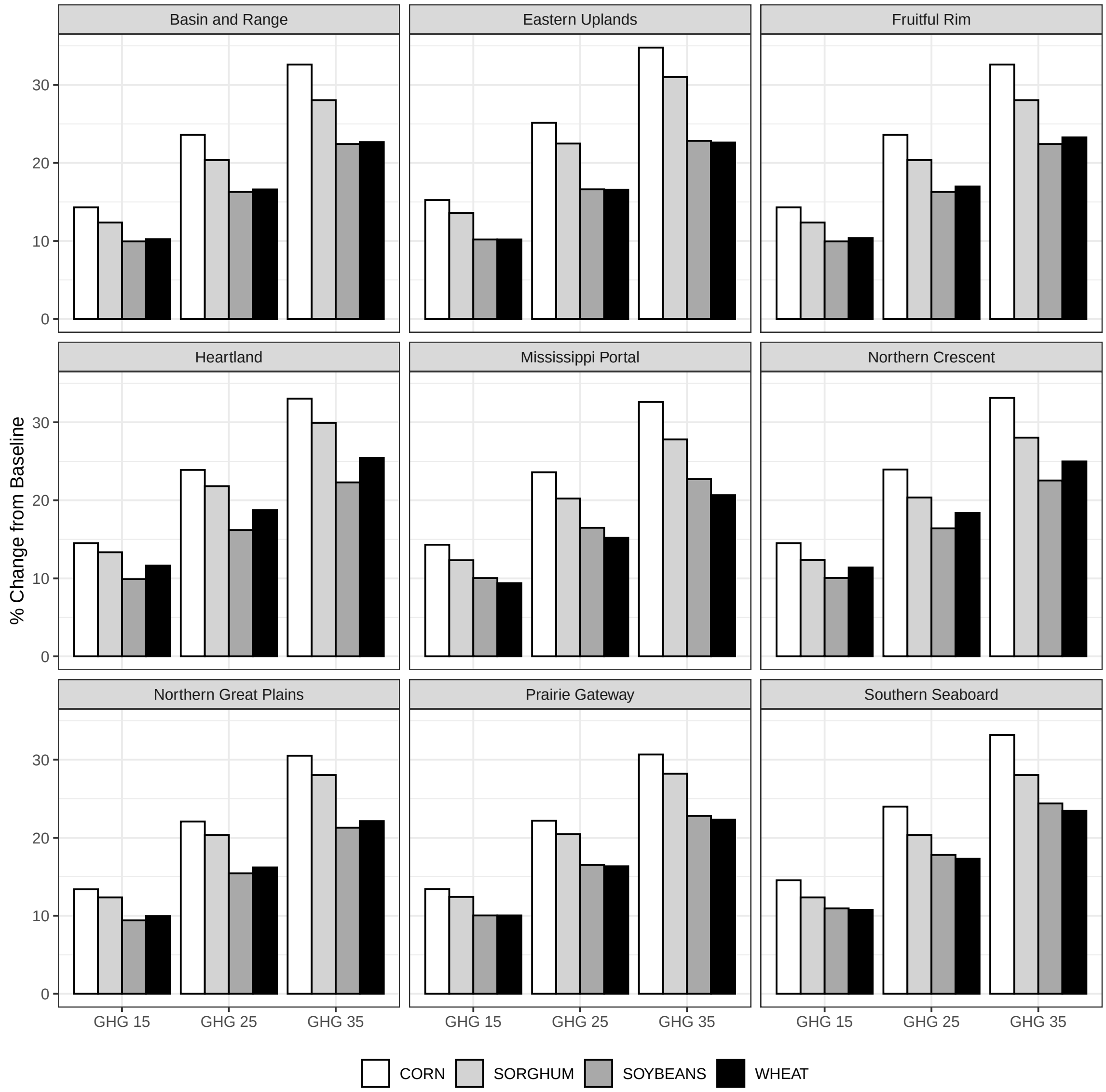

Figure 1. Cost of production increase in the USDA Farm Resource Regions in 2030 under the various carbon price scenarios. The price increase is relative to the baseline.

4.1 Cost of Production

The increase in the cost of production in the GHG 35 scenario ranges from 20.7% for wheat in the Mississippi Portal to 34.8% for corn in the Eastern Uplands (Figure 1). Corn and soybean production dominates the Heartland. Corn production cost increases by 14.% and 33.0% at a carbon price of $62 and $144, respectively. The price increase for soybean production is lower because the crop is less fertilizer intensive and the increase is limited to 9.9% and 22.3% for the carbon price of $62 and $144, respectively. The cost of production for soybeans in the Mississippi Portal — a region of high soybean production — increases 0.1-0.3 percentage points compared to costs in the Heartland.

Spring wheat production is mostly concentrated in the Northern Great Plains and cost of production increases range from 10.0% (GHG 15) to 22.1% (GHG 35). This is comparable to the increase in the Prairie Gateway where winter wheat production is concentrated with an increase between 10.0% to 22.3%. Sorghum cost of production in the Prairie Gateway increases by 12.4% and 28.2% in the cases GHG 15 and GHG 35, respectively. Note that all of these cost increases are based on operating cost per hectare and difference in farm income occur based on land productivity.

4.2 Commodity Prices and Land Allocation

Our results suggest commodity price increases for all crops in the magnitude of 1.8%-6.3% (GHG 15), 3.2%-10.6% (GHG 25), and 4.4%-14.7% (GHG 35). The highest price increases are observed for corn in all scenarios whereas soybeans prices increase the least. Wheat prices increase by 5.2%, 9.6%, and 14.5% in the scenarios GHG 15, GHG 25, and GHG 35, respectively. For sorghum, price increases are 3.0% (GHG 15), 5.7% (GHG 25), and 7.6% (GHG 35). The land allocation changes under the carbon taxes help to better understand the price effects. Compared to the baseline, total U.S. corn area decreases by 1.5%, 2.3%, and 3.1% in the GHG 15, GHG 25, and GHG 35, respectively. For the same scenarios, sorghum area decreases by 4.7%, 7.3%, and 8.0%, respectively (Table 2). The decrease in both cases is explained by the high fertilizer and other energy-intensive input use of these crops compared to soybeans and wheat (Figure 1). Thus, the increase in production costs leads to a decrease in area for these crops. Area for soybeans decreases

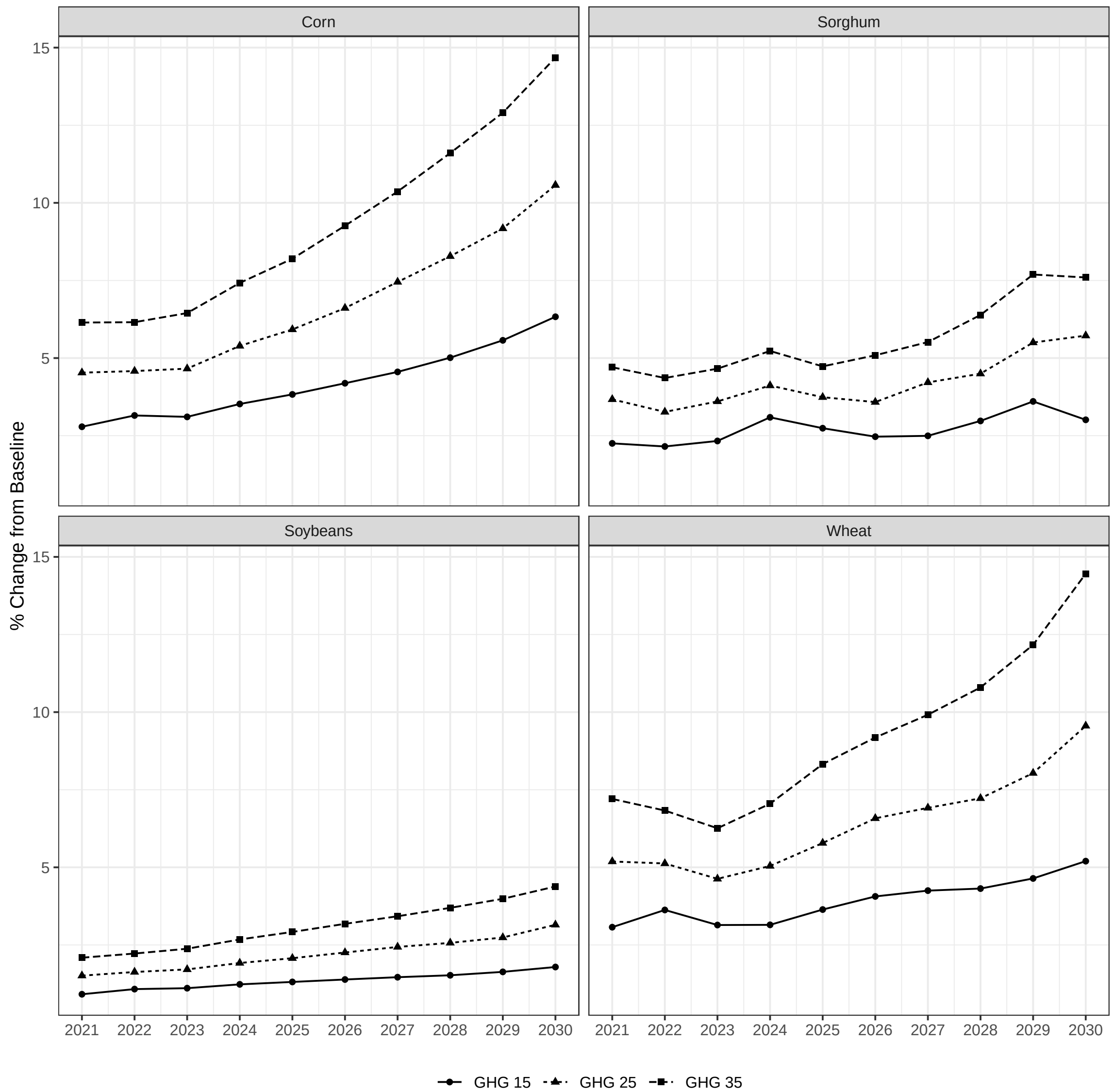

Figure 2. Change in scenario prices over the projection period for corn, sorghum, soybeans, and wheat.

State	GHG 15	GHG 25	GHG 35
Corn			
Illinois	-0.5%	-1.1%	-1.7%
Indiana	-3.4%	-5.4%	-7.4%
Iowa	-0.8%	-1.2%	-1.7%
Minnesota	-0.8%	-1.3%	-1.9%
Missouri	-5.1%	-8.6%	-11.8%
Nebraska	-0.8%	-1.4%	-1.9%
North Dakota	0.0%	-0.3%	-1.4%
Ohio	-2.8%	-4.8%	-6.9%
South Dakota	-0.6%	-1.0%	-1.4%
Wisconsin	-5.2%	-8.5%	-11.3%
Sorghum			
Kansas	-7.3%	-10.0%	-14.0%
Texas	-6.3%	-9.1%	-17.9%
Soybeans			
Arkansas	-0.2%	-0.3%	-0.5%
Illinois	-0.3%	-0.7%	-1.4%
Indiana	-1.7%	-2.6%	-3.6%
Iowa	-1.4%	-2.2%	-3.1%
Kansas	-4.3%	-6.2%	-7.5%
Minnesota	-1.2%	-2.0%	-3.1%
Missouri	0.3%	0.1%	-0.4%
Nebraska	-1.1%	-1.6%	-2.2%
North Dakota	-1.5%	-2.5%	-4.1%
Ohio	-1.1%	-1.9%	-2.9%
South Dakota	-0.8%	-1.5%	-2.3%
Wheat			
Kansas	-2.3%	-2.9%	-5.4%
Montana	-2.1%	-5.4%	-8.7%
North Dakota	-0.8%	-3.1%	-5.6%

Table 2. Change in area relative to the baseline for major states producing the crops covered in this analysis. For all commodities except sorghum, states with an area of more than 1 million ha in the baseline are included. For sorghum, the area threshold is set to 0.4 million ha.

by less than 2.2% at the end of our projection period even under the highest carbon price. Area for wheat decreases by up to 10.9% in the GHG 35 scenario. This decrease in wheat area is explained by farmers shifting away from wheat production, which already has low profitability compared to corn and soybeans in the baseline. A detailed break-down of the change in area reveals that in the case of wheat, the largest wheat producing states, i.e., Kansas and Montana, decreases their wheat area by 5.4% and 8.7%, respectively. Sensitivity scenarios show that the decrease in wheat area would be even more substantial without the 25% cap on CRP enrollment by county.

4.3 Farm Income

Given the increase in corn prices, the decrease in net returns for the Midwestern states is limited (Figure 3). For Illinois, Indiana, and Iowa, the median decrease (across the counties) in net returns is a maximum of 7.0% for Illinois in the case of the highest carbon tax scenario. For GHG 15 and GHG 25, the decrease in net return are 1.8%-3.9% and 2.6%-6.0%, respectively for the three states. Median net returns decrease by 11.4% and 18.7% in the wheat-producing states of Montana and North Dakota, respectively. A decrease in median net returns of 27.3% is found in Kansas in the case of GHG 35, which represents the largest decline for all states.

5 Conclusion

Increasing concern about climate change has sparked interest in implementing a carbon pricing scheme in the United States and elsewhere. After the introduction of a cap-and-trade policy proposal in 2009, more recent proposals favor a carbon tax on energy-intensive inputs derived from fossil fuels. In this paper, we use three carbon tax paths derived by the EIA for their Annual Energy Outlook to evaluate the effects on U.S. agriculture for four crops. The goal is to provide insights for policymakers, farmers, and other stakeholders of the financial implications associated with a carbon pricing policy. Our analysis also shows that there are significant regional differences from the effects of the carbon tax on net returns for farmers. The smallest decrease is found in the Midwest despite the fact that corn input costs increase the most of all the crops analyzed. This increase

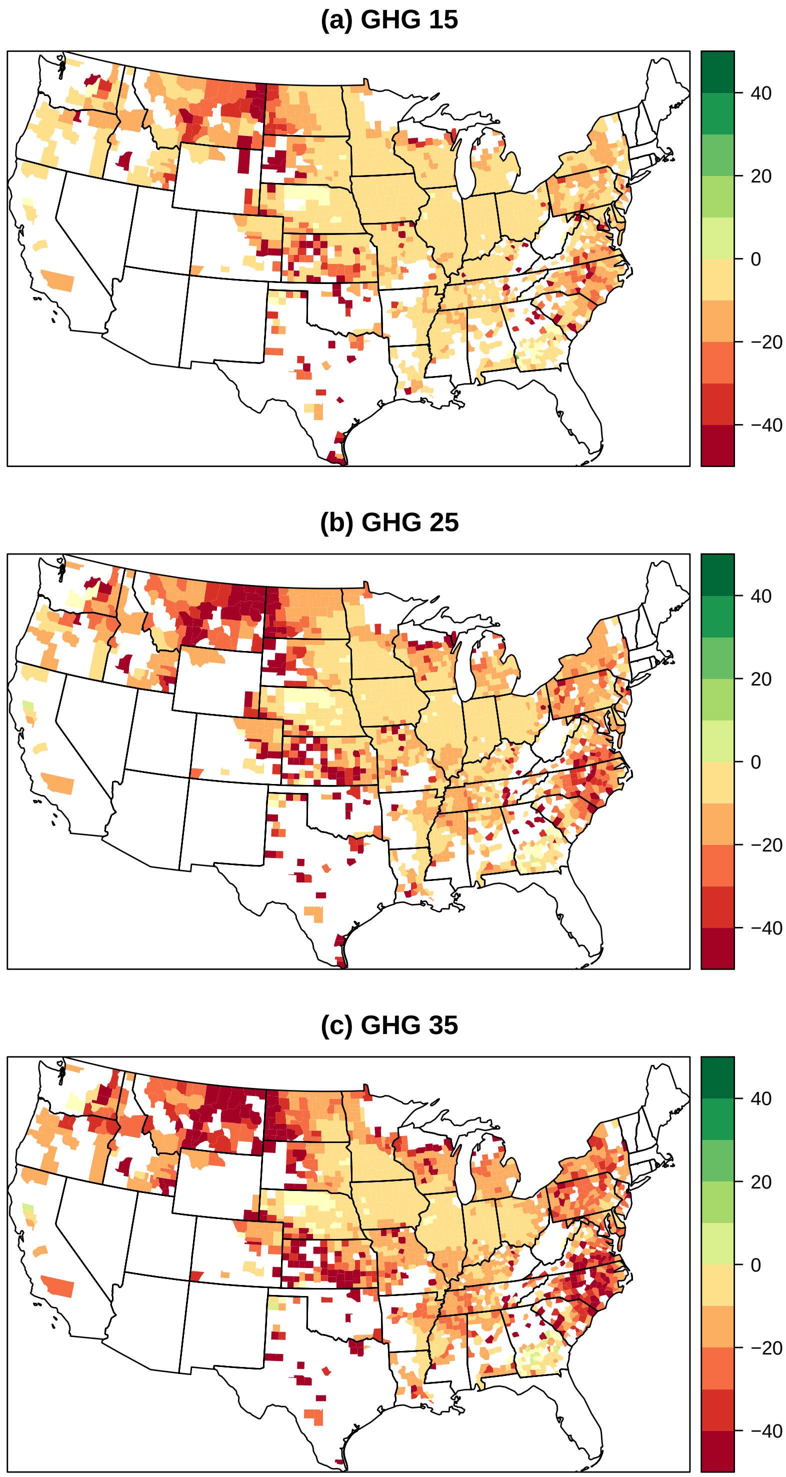

Figure 3. Changes in county net revenue (all crops) in 2030 for the three carbon tax scenarios considered.

in cost is followed by a contraction in area, which results in a price increase for corn, thus partly compensating for the rise in cost. Counties that rely on wheat production are the most affected by the carbon tax.

This paper does not evaluate the role of the CRP in stabilizing net returns and contributing to environmental goals. An increase in the enrollment limit in combination with higher CRP payments could potentially encourage farmers to enroll more land into the CRP and thus, reduce the supply of farmland. We hypothesize that this would dampen the effect of decreased net returns especially for wheat areas in Kansas, Montana, and the Dakotas. We also do not evaluate the effect of carbon tax payments to farm families. The effects will probably be small given that the payments are independent of farm size. Large farms in terms of area would see a large decline in net returns, which would not be compensated by payments. Thus a per hectare payment for conservation purposes such as the CRP would be more effective. Given the decline in net returns, some landowners would also find it unprofitable to remain in crop production and would abandon farmland. If farmland is not enrolled in CRP, the question remains on the future use of these abandoned acres.

Another aspect beyond the scope of this analysis are the effects of climate change on U.S. crop yields. Although our analysis projects cost, area, and net return over the next ten years, the adverse effects in terms of precipitation and temperature changes could potentially be felt within that period and certainly beyond. Evaluating the difference in the cost of a carbon tax versus the damages from climate change is left for future research. Corn yields in the Midwest are projected to be affected the most from climate change, which would probably be more costly than the effects of a properly designed carbon policy, e.g., carbon tax in combination with incentives for higher CRP enrollment.

Lastly, the role of offset options such as reduced tillage activity or afforestation must be examined more closely. The advantage of the carbon tax is the certainty of offset payments as opposed to the case of an uncertain carbon price under a cap-and-trade scheme. Changing management practices may also occur in the context of input substitutability due to the carbon tax on energy-intensive inputs.

Acknowledgements

We are also thankful for financial support from the Center of Rural and Agricultural Development (CARD) at Iowa State University.

References

Chen, X., Huang, H., Khanna, M., and Önal, H. (2011). *The Intended and Unintended Effects of U.S. Agricultural and Biotechnology Policies*, chapter Meeting the Mandate for Biofuels: Implications for Land Use, Food, and Fuel Prices, pages 223–267. University of Chicago Press.

Dumortier, J. (2013a). Co-firing in coal power plants and its impact on biomass feedstock availability. *Energy Policy*, 60:396–405.

Dumortier, J. (2013b). The effects of uncertainty under a cap-and-trade policy on afforestation in the United States. *Environmental Research Letters*, 8(044020):1–11. doi: 10.1088/1748-9326/8/4/044020.

Dumortier, J., Dokoohaki, H., Elobeid, A., Hayes, D. J., Laird, D., and Miguez, F. E. (2020). Global land-use and carbon emission implications from biochar application to cropland in the United States. *Journal of Cleaner Production*, 258(120684):1–10. DOI: 10.1016/j.jclepro.2020.120684.

Dumortier, J. and Elobeid, A. (2020). Effects of the Energy Innovation and Carbon Dividend Act on U.S. and Global Agricultural Markets. Working Paper 20-WP 598, Center for Agricultural and Rural Development, Iowa State University.

Dumortier, J., Kauffman, N., and Hayes, D. J. (2017). Production and spatial distribution of switchgrass and miscanthus in the United States under uncertainty and sunk cost. *Energy Economics*, 67:300–314. doi: 10.1016/j.eneco.2017.08.023.

EIA (2020). Annual Energy Outlook 2020 with projections to 2050. Technical report, U.S. Energy Information Administration.

FAPRI (2011). FAPRI-MU Stochastic U.S. Crop Model Documentation. FAPRI-MU Report 09-11, Food and Agricultural Policy Research Institute.

Hellerstein, D. M. (2017). The us conservation reserve program: The evolution of an enrollment mechanism. *Land Use Policy*, 63:601–610. doi: 10.1016/j.landusepol.2015.07.017.

ICF International (2013). Greenhouse gas mitigation options and costs for agricultural land and animal production within the United States. Report, ICF International prepared for U.S. Department of Agriculture Climate Change Program Office.

Schneider, U. A. and McCarl, B. (2005). Implications of a carbon-based energy tax for U.S. agriculture. *Agricultural and Resource Economics Review*, 34(2):265–279. doi: 10.1017/S1068280500008.

Slade, P. (2018). The effects of pricing Canadian livestock emissions. *Canadian Journal of Agricultural Economics*, 66:305–329. doi: 10.1111/cjag.12157.

USDA (2000). Farm resource regions. Agricultural Information Bullentin 760, U.S. Department of Agriculture Economic Reserach Service.

USDA (2020). USDA Agricultural Projections to 2029. Long-term Projections Report OCE-2020-1, U.S. Department of Agriculture.

Weitzman, M. L. (1974). Prices vs. quantities. *Review of Economic Studies*, 41(4):477–491. DOI: 10.2307/2296698.

World Bank (2019). State and trends of carbon pricing 2019. Technical report, World Bank Group.