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A Cost of Tractability? Estimating Climate Change Impacts Using a Single Crop Market Understates Impacts on Market Conditions and Variability

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Abstract

Scientists estimate that U.S. Corn Belt crop yields will increase or decrease, on average, and become more variable with climate change. Corn and soybean farming dominates this region, but studies typically do not assess the joint impact of new distributions of corn and soybean yields on markets. We use a structural economic model with projections of climate-driven yield changes to simulate these effects. Our findings suggest that a narrow focus on a single crop in this key growing region risks underestimating the impact on price distributions and average crop receipts, and can lead to incorrect signs on estimated impacts.

Key words: climate change adaptation, NARCCAP, Corn Belt yields, statistical yield model.

The possible impacts that climate change might have on crop yield levels and variability are a key area of scientific study (Rosenzweig et al. 2014). Indeed, the potential for climate change to lower the mean and increase the variance of crop yields implies that higher and more volatile crop prices are possible. Such a future scenario could lead to increased food prices and greater risks for consumers and producers. In light of the widespread concerns raised during the food price spikes of the last decade, as witnessed during the “food-versus-fuel” debate, decisions relating to climate change adaptation or response might be supported by estimates of how climate change could increase the mean of the agricultural commodity price distribution and widen the dispersion. As we show here, under at least some conditions, the impact that climate change has on price levels and variability might be underestimated in studies focused on a single crop.

Estimates of the impact that climate change might have on yields are insufficient for decision makers; additional input is required from applied economists who study crop markets (USDA 2010, 2013). The potential that mitigation and adaptation policies might be usefully informed by considering the market responses has been established (Antle and Capalbo 2010). The impacts on a particular crop market are complicated by the automatic responses of producers and consumers, as well as policy, to these changes. For example, a study predicting a dramatically lower yield for a crop in a key growing area implies rising prices for this commodity, followed by some combination of land reallocation, greater use of other inputs, and substitution by consumers and processors to other goods. Stocks can lessen the impacts of a negative yield shock unless prior events have depleted stocks (Wright 2010). Similarly, agricultural policy support can dampen the revenue effects from a change in yield distributions. Yield shocks, low stocks, and policies are some of the factors associated with the price spikes of the last decade (e.g., Abbott, Hurt, and Tyner 2008; Westhoff 2010), and decision making rests on our understanding of how these factors influence markets and, hence, human well-being.

The potential for stocks and policies to interact with market volatility induced by climate change has not been a focus of scientific study despite concerns of greater disruptions in the future. Scientists have begun to address the impacts of climate change on market volatility. Initial steps focus on the yield distribution of a single crop and rely mostly on models that do not explicitly represent year-to-year dynamics (Diffenbaugh et al. 2012b). We extend the research of these authors by broadening the analysis to include a second competing crop. In this article, we use a structural economic model with supply and demand specified to consider the implications of mid-twenty-first century climate change-induced shifts in the level and variability of both corn and soybean yields for corn and soybean prices, quantities, receipts, and government expenditures in the U.S. Corn Belt. We do not extend to all possible regions or crops, nor do we extend far enough into the future that estimated yield impacts of climate change seem likely to cause an entirely new mix of crops (Seo 2010). We apply a market model that is widely used for policy and market analysis and that represents more market responses to yield and price shocks than are typically considered, including stocks and policy interventions that depend on market conditions.

We focus our assessment of climate change impacts on a single emissions scenario, and the two dominant crops for a major growing region embedded in the larger global economy. We ask whether estimated near-term impacts of climate change on Corn Belt corn and soybean yields and markets depend on whether the two crops are considered jointly, in a common analysis, or singly. We test for robustness of the result to give some evidence that our finding remains valid even if broader, global impacts on the focal crop or crops add to market demand and volatility. Our goal was to determine whether narrowly-focused experiments might, at least under certain conditions, give biased results.

A key finding of this article that is relevant to scientists and decision makers is that climate change impacts on crop markets might be underestimated if researchers focus on a single crop in a growing region. In the present example, focusing only on corn yield shocks allows soybeans to absorb some of the effects. If corn and soybean yields are both shocked, then the cross-commodity effects cause yield-driven market changes to reinforce one another, and the overall price impacts are greater, both in terms of average level and the spread of the distribution. In the present case, the direction of area effects can be reversed. Soybean area decreases in the experiment when only the corn yield effects of climate change are included, but soybean area increases if soybean yield shocks are also present. We also find downward bias in crop receipt impacts if there is a narrow focus on one of the main competing crops in the region.

Scientists who focus on a single crop must acknowledge the risk that the cross-effects of competing crops might lead to larger impacts. For decision making, the results suggest caution when considering how to use single-commodity case studies, and also emphasize the need for climate change assessments of yield and market impacts that include the main crops, or perhaps even potential crops, in a growing region. Results pulled from individual studies, reviews of literature, or formal meta-analysis might be affected by this bias, leading to an understanding of climate change impacts that understates the potential outcomes.

Methods

Economic Analysis of Climate Change Impacts on Price Distributions

The economic analysis of climate change effects on crop markets often relies on General Equilibrium (GE) models based on Global Trade Analysis Project (GTAP) or Partial Equilibrium (PE) models, including those from the family of Forestry and Agricultural Sector Optimization Model (FASOM), Forestry and Agricultural Sector Optimization Model with Greenhouse Gases (FASOMGHG), and Agricultural Sector Model (ASM) (Chen, McCarl, and Adams 2001; Reilly et al. 2003; Avetisyan et al. 2011; Diffenbaugh et al. 2012a; Calzadilla et al. 2013; Nelson et al. 2014). A common characteristic of such analyses is the presence of explicitly represented supply- and demand-side variables, prices, and market-clearing conditions. The impact that agriculture has on greenhouse gas (GHG) emissions relies on a broader set of models as reviewed by Van der Werf and Peterson (2009). Both of these modeling approaches were originally developed to solve at less than annual frequency without representing stockholding and with stylized treatment of agricultural policies, although modifications can be undertaken to improve the applicability to specific research tasks (Beach et al. 2010; Diffenbaugh et al. 2012b). A consequence is that some of the reliable modeling approaches used to assess climate change impacts were not developed to include potentially important automatic market and policy response to yield shocks. If the normal responses of stock holders, producers, and consumers are ignored, then yield variability consequences for market volatility might consequently be overstated.

Diffenbaugh et al. (2012a) make a valuable contribution by using a market model to estimate how climate change can affect market volatility. These authors apply a version of GTAP that is simulated stochastically to estimate the climate-driven corn yield changes in terms of their impacts on corn market volatility, taking biofuel use mandates into account. These authors state that the abstraction of including stocks in total crop demand omits the moderating impact of climate change on year-on-year crop price fluctuations and that this abstraction also overstates the responsiveness (elasticity) of demand with respect to crop price changes. This representation might bias estimates of the effects of climate change on prices by omitting the greater potential for carry-over from high yields in some years to offset low yields in other years. Given the critical role that demand elasticity plays in determining how yield shocks affect producer market receipts, including even the direction of impact, the method for collapsing stock-holding into aggregate demand presumably has important repercussions for estimating producer impacts of climate change.

Diffenbaugh et al. (2012a) focus on Corn Belt corn yields. Climate change impacts on corn yields in this region are used to drive their experiment. As a necessary sacrifice to maintain tractability, yields in all other crops and all other regions are unchanged. An interesting question is whether anything is implicitly assumed. For example, if the model represents Corn Belt area allocation between corn and soybeans using historical price or returns data, then is there an implicit assumption that the levels or distributions of yields, prices, or receipts retain those historical patterns? If so, then the narrow focus on one of the two main crops grown in this region could be something of an artifice that does not quite hold the other crop exogenous, yet also does not represent the second crop yield changes induced by climate change explicitly. Here, we take the next step that is made possible by the research of Diffenbaugh et al. (2012a).

Analysis of Price Distribution Impacts

We build on this research by using climate change effects on corn and soybean yield levels and variability in the Corn Belt to determine changes in yield distributions drawn stochastically into a structural economic model, as described below. The economic model is used to estimate how these yield changes drive levels and variability of market prices and quantities, area, and crop receipts, all with internal consistency imposed by the behavioral equations and identities of the model. Relative to the important contribution of Diffenbaugh et al. (2012a), we add (a) changes in two competing crops in the Corn Belt, rather than restrict climate change impacts to yields of only one of these crops and (b) explicitly represent stocks to allow for this aspect of automatic market response to yield variations, as well as certain automatic policy responses. We focus on a mid-twenty-first century timeframe so that we may reasonably evaluate the impacts of climate change in the context of current policies.

We apply the Food and Agricultural Policy Research Institute at the University of Missouri (FAPRI-MU) stochastic model for this exercise. This model has been used to study how biofuel policy impacts on agricultural policies are sensitive to the market context (Thompson, Meyer, and Westhoff 2010; Meyer and Thompson 2012; Thompson and Meyer 2013), biofuel and related energy markets (Thompson, Meyer, and Westhoff 2009; Thompson, Meyer, and Whistance 2011; Whistance and Thompson 2010), and crop policies (Westhoff and Gerlt 2012, 2013). This model is summarized here, but described or documented elsewhere (Westhoff and Meyers 2010; Gerlt and Westhoff 2011; Thompson, Meyer, and Whistance 2011, Whistance and Thompson 2014). Relevant measures of model performance are provided in a supplement.

The model represents U.S. agricultural commodity markets at a fairly detailed level, with corn, soybean, soybean meal, and soybean oil being some relevant examples of represented markets with market-clearing prices. Other main crops and crop products are included. Crop stocks are endogenous. Feed demands are tied to endogenous livestock inventories and products. Final demands for crop products, livestock products, and biofuels are driven by own- and cross-prices, as well as by other factors such as income and trends in tastes or preferences. The FAPRI-MU model includes ethanol and biodiesel markets and some of the complications of the biofuel mandates, including the separate mandate for biodiesel and the potential for additional biodiesel use to displace sugar-cane ethanol or conventional ethanol (Thompson, Meyer, and Westhoff 2010). The focus of the model is on the United States, with other countries represented in aggregate import supply or export demand equations for most commodities. While this approach limits the model’s ability to provide detailed estimates of responses in other countries, the aggregate global market impact should be similar, and the method facilitates the stochastic analysis discussed below. The model is simulated over a 10-year projection period assuming a stable economic context with steady growth and a continuation of current or announced policies.

Stochastic Yields

Model simulations are partially stochastic, with values for energy prices, certain livestock and crop demand perturbations, and yield shocks drawn randomly rather than set at fixed values. Stochastic inputs are initially based on historical distributions, taking block-wise correlation among related variables into account (Westhoff, Brown, and Hart 2006; Gerlt and Westhoff

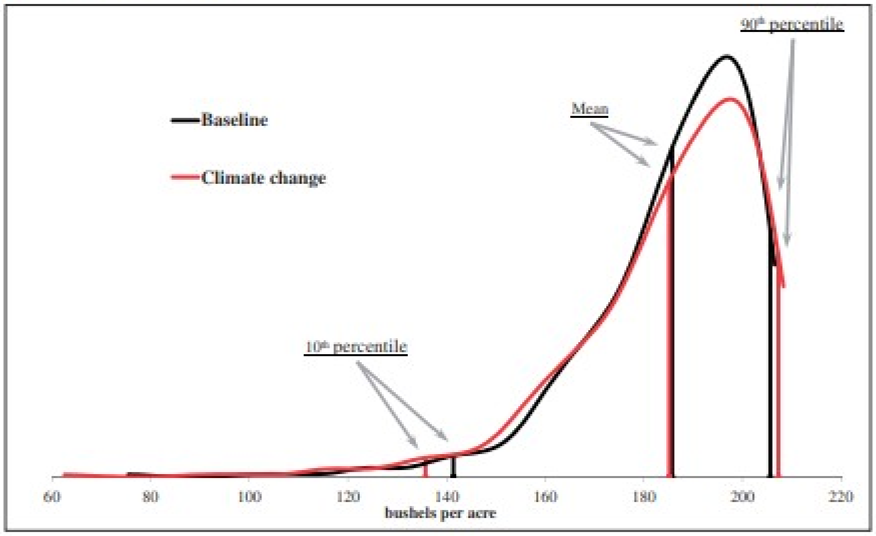
2011). Crop yield stochastic input, the key element of the present exercise, is summarized as follows.

The stochastic yield process is initiated by detrending corn, soybean, and wheat historical state yields for Arkansas, Georgia, Illinois, Indiana, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota, and Texas. The remaining production is aggregated into a rest-of-country category. Other commodities use national average yield without disaggregating area, yield, or production by state. Yields are projected as a function of current net returns, 10-year moving average net returns, U.S. total planted area, U.S. corn planted area (for corn only), and a linear trend.

The state yield distributions are joined through a Gaussian copula (Woodard et al. 2011; Goodwin and Hungerford 2014). The correlations are determined by the historical residuals; the marginals generally use a four-parameter beta distribution (Tolhurst and Ker 2014). An advantage of this approach is that it allows for a lower tail (figure 1). The parameters are determined using the method of moments with the residuals. As this method can fail, a kernel density estimator (KDE) is used where the beta parameters do not exist. The KDE uses a Gaussian kernel and has a correction for the biased second moment.

Figure 1. 2016 Iowa Corn Yield PDF

Source: Authors' calculations.



Climate Change Projections and Yield Impacts

The effects of climate change on corn and soybean yields in the U.S. Corn Belt are computed using ensembles of state-level statistical crop models. We parameterized statistical crop models for each state using state-level USDA National Agricultural Statistics Service (NASS) yield and aggregated county-level climate data for the years 1982 to 2012. We computed the climate most relevant to crop yield for a state by weighting the county-level monthly maximum temperature (tmax), monthly minimum temperature (tmin), and monthly precipitation (ppt) based on the acres harvested for each crop. Our regression models (equation 1) are functions of year, tmax, tmin, and ppt.

$$Yield = a_1 + a_2 year + a_3 year^2 + a_4 tmax^2 + a_5 tmax + a_6 tmin^2 + a_7 tmin + a_8 ppt^2 + a_9 ppt \tag{1}$$

The year term represents technological improvements (e.g., seeds, land management). For the future and historical projections, we used the same year terms, assuming no changes in the trajectory of technology improvements. Therefore, differences between projected future and historical yield are due to changes in tmax, tmin, and ppt. For each crop in each state, we selected the top five regression models from the full set of models using all combinations of climate variables (tmax, tmin, and ppt) from March to September. The coefficients for these five models for corn and soybeans in each state and their significance are listed in the supplementary online appendix. By using multiple models, we include uncertainty in the effects of climate change on crop yields.

To estimate climate change in each state, we used six regional climate models driven by different global climate models for historical (1969–1999) and future (2038–2069; SRES A2 emissions scenario) periods, all from the North American Regional Climate Change Assessment Program (NARCCAP) archive (Mearns et al. 2013). This source of climate change projections provides multiple high-resolution estimates, reflecting uncertainty in climate model simulations of climate change in the U.S. Corn Belt. We did not include uncertainty in emissions scenarios because these scenarios do not diverge substantively until mid-century, with the considerable emissions uncertainty in the latter half of the century beyond the time horizon of this study.

This analysis focuses on climate-driven corn and soybean yield impacts in seven states (Iowa, Illinois, Indiana, Minnesota, Missouri, Ohio, Wisconsin). Yields for other states, other countries, and other crops were left unchanged, but the U.S. Corn Belt accounts for a large share of global corn and soybean production. Estimated average yield impacts from the six climate models and among the seven states range from +2% to -18% for corn, and +5% to -18% for soybeans. The changes in corn yield standard deviation range from −1% to + 27%, and for soybeans from +13% to + 54%. Taking the relative weights of these states in national production historically, these changes amount to an average reduction in U.S. corn and soybean yields of about 4 bushels and 1 bushel per acre, respectively. These magnitudes are roughly equivalent to the average impacts found in previous work (e.g., Diffenbaugh et al., 2012a), so differences in reported market impacts do not come from any large differences in average yield impacts.

Simulation Experiments

The baseline market projection is developed using historical distributions of key input variables, including crop yield shocks relative to what is projected based on trends and short-run price effects alone. The crop yields are then adjusted based on estimates of climatic change impacts. These adjustments take two forms: average and dispersion. As a consequence of the modeled yield changes, the yield distribution shifts to the left and widens. The random draws are adjusted from the original baseline to reflect these two changes; all draws were reduced by the average change and the difference from the mean value was expanded to reflect the change in the standard deviation of yield shocks. By adjusting the original draws, each simulation from the scenarios is a matched pair to the original draw that would have been higher and closer to the trend value, facilitating analysis. To explore the importance of considering crops jointly, the corn and soybean yield shocks are conducted separately, as well as together.

To summarize, our empirical results are based on four cases: (i) baseline projections with historical corn and soybean yield trends and distributions; (ii) soybean yields unchanged, but corn yields changed by estimated climate change impacts; (iii) corn yields as in the baseline case, but soybean yields changed by estimated climate change impacts; and (iv) both corn and soybean yields changed according to estimated climate change impacts. The baseline projection spans a ten-year period under the assumption of current policies, such as crop programs and biofuel mandates, and reflects the expected evolution of macroeconomic conditions, including income and energy prices (Westhoff et al. 2016). The only distinction among scenarios relates to the distribution of yields. Corn and soybean yield shocks are either drawn according to historical distributions or are affected by estimated climate change impacts.

The focus on the United States reflects the limitation that only Corn Belt yields are shocked. These estimates do not measure overall climate change impacts that presumably affect other agricultural commodities, other sectors, and other regions. However, we subjected our results to sensitivity analysis, confirming our main finding even when the shocks to markets are much larger. We assume that the other factors that drive demand, such as income, are unchanged. Another limit is that the stochastic exercise is partial, not a complete representation of all sources of uncertainty. Despite this limit, this study improves on alternative methods such as no variation at all or focusing on the yield of one crop. The time frame is a limitation. The ten-year projection period is short relative to the time scale of climate projections. Nevertheless, the detailed representation of policy and market context adds an element that is not seen in other projections. A longer projection period or use of climate scenarios from the end of the twenty-first century requires the assumption of constant policy in the form of exogenous subsidies or price wedges, which might not be attractive if it defies experiences with changing rates of support observed over previous decades and, in particular, explicit dependence of support on market conditions and market variations.

Results

Results are presented primarily using averages and standard deviations over a 5-year period at the end of the projection period. We focus on corn and soybean market effects, but the economic model also represents other effects, such as land allocated to other uses, other crop and crop product markets, and livestock and fuel markets. The focus on corn and soybean markets reflects our focus on the yield impacts of the two crops that dominate a key growing region.

Corn Belt corn and soybean yield distributions are shifted to reflect the estimated impact of climate change in this region (table 1). The yields of the three scenarios are compared to the baseline case, which excludes any change in trend or distribution owing to climate change. The simulated changes in national average yields reported here depend somewhat on price changes as well, but the price effect is smaller than the estimated impact of the climate change. The yield impacts do not vary much between the one-crop and both-crop cases because of the design of the scenarios and impacts of prices on yields, at least for the scale of price change shown below and in a relatively modest period of time. For example, the corn yield impacts are almost the same in the corn-only scenario and the corn and soybean scenario. The soybean yield impacts are approximately the same in the soybean-only scenario and corn and soybean scenario. The corn-only scenario generates small changes in the soybean yield because of price effects and there is a similar impact on soybean yields in the corn-only scenario. These short-run price effects on yields are small.

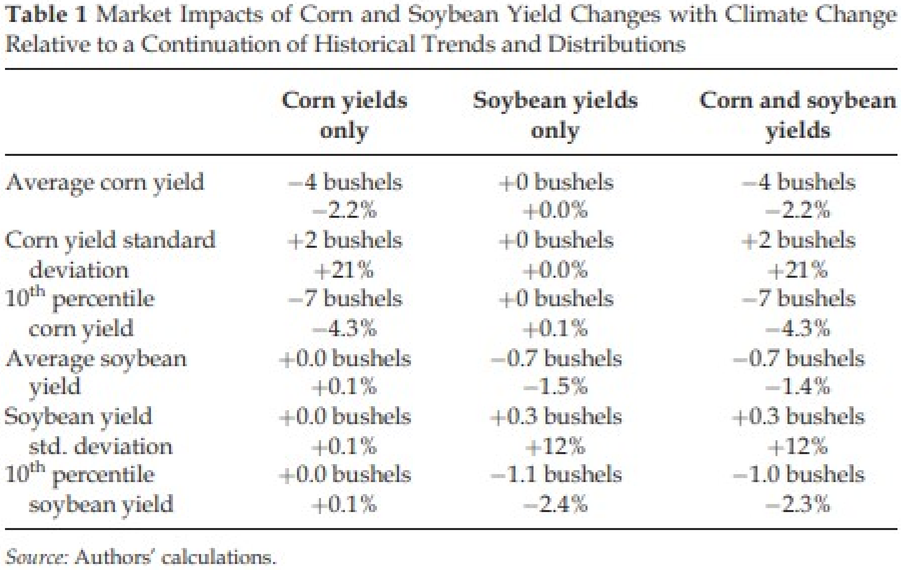


Table 1 Market Impacts of Corn and Soybean Yield Changes with Climate Change Relative to a Continuation of Historical Trends and Distributions

	Corn yields only	Soybean yields only	Corn and soybean yields
Average corn yield	−4 bushels −2.2%	+0 bushels +0.0%	−4 bushels −2.2%
Corn yield standard deviation	+2 bushels +21%	+0 bushels +0.0%	+2 bushels +21%
10th percentile corn yield	−7 bushels −4.3%	+0 bushels +0.1%	−7 bushels −4.3%
Average soybean yield	+0.0 bushels +0.1%	−0.7 bushels −1.5%	−0.7 bushels −1.4%
Soybean yield std. deviation	+0.0 bushels +0.1%	+0.3 bushels +12%	+0.3 bushels +12%
10th percentile soybean yield	+0.0 bushels +0.1%	−1.1 bushels −2.4%	−1.0 bushels −2.3%

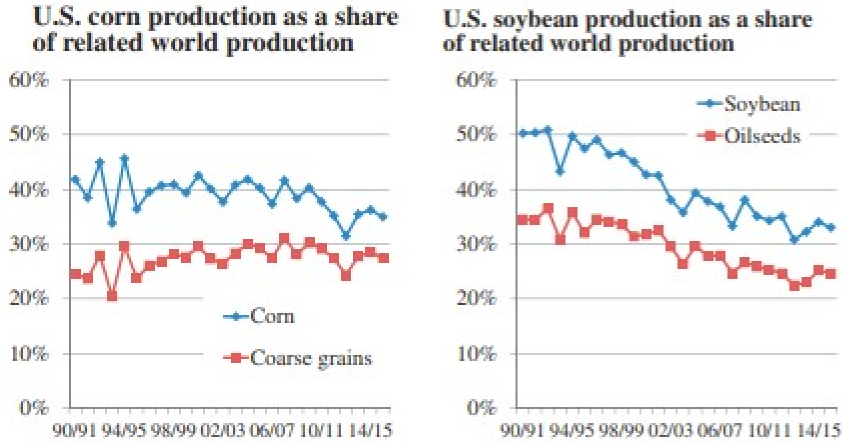
Source: Authors' calculations.

Estimated yield ranges in the scenarios are lower and more dispersed than in the baseline, with a larger impact on U.S. corn yields. The lower average and wider distribution leads to a more pronounced impact at the lower end of the distribution, as the 10th percentile values show. For corn, the 10th percentile yield is reduced from the baseline value by −4.3%, which is more than twice as much as the −2.2% decrease in average yield.

The market impacts depend on more than the size of the yield shock. Another factor is the importance of these shocks relative to the overall market (figure 2). The yield shocks apply to a part of global production of either crop, albeit a fairly large portion, so market impacts will be limited in part by the focus of this study on one growing region. Corn production in the United States accounts for about 35% of global corn production and almost 30% of global coarse grain production in recent years (USDA/FAS 2016). Moreover, U.S. soybean production accounts for less than 35% of global soybean production, and a quarter of global oilseed production (ibid). There are other possible substitutes that are not considered in these graphs and shares, such as wheat in feed, fish meal in certain animal rations, and palm oil in some uses. However, these data suggest that U.S. corn production accounts for a larger part in the relevant global market than U.S. soybean production represents in its market. The consequence is that these climate change scenarios affect yields in a region that accounts for larger shares of the global corn and coarse grain markets than for soybean and oilseed markets, so price effects from corn yield shocks might be expected to be larger than for soybean yield shocks.

Figure 2. U.S. market shares will influence results

Source: USDA/FAS (2016), and authors' calculations.

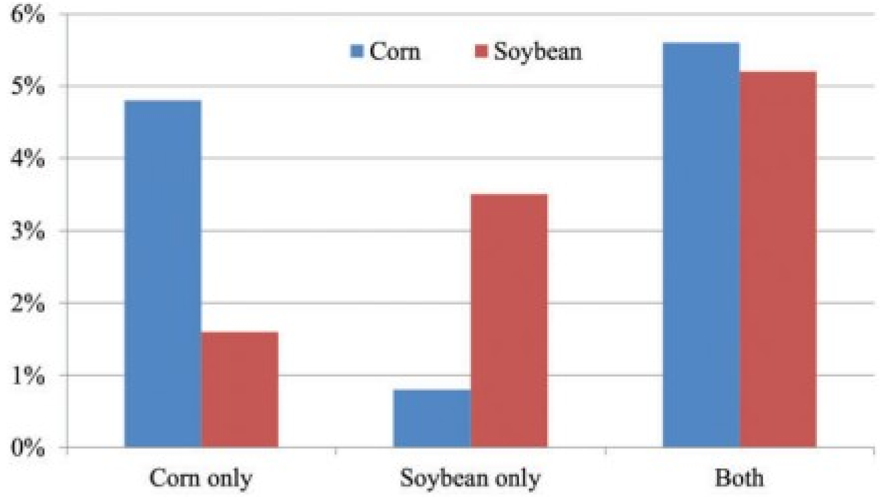


Price Impacts

The impacts of climate change on corn price relative to the baseline tend to be larger than the impacts on soybean price (figure 3). This result is expected given the size of the yield shocks and relative market shares. The potentially unexpected or unrecognized outcome is that, on average, price changes are bigger than the production changes. This is not a surprise if global demand for the crop is inelastic, as in this model, but it risks being overlooked in climate change analysis. The “natural hedge” of these markets leads to price changes from the baseline in opposite directions to the yield changes induced by climate change, and larger changes. We return to this point below.

Figure 3. Corn and soybean price impacts

Source: Authors’ calculations.



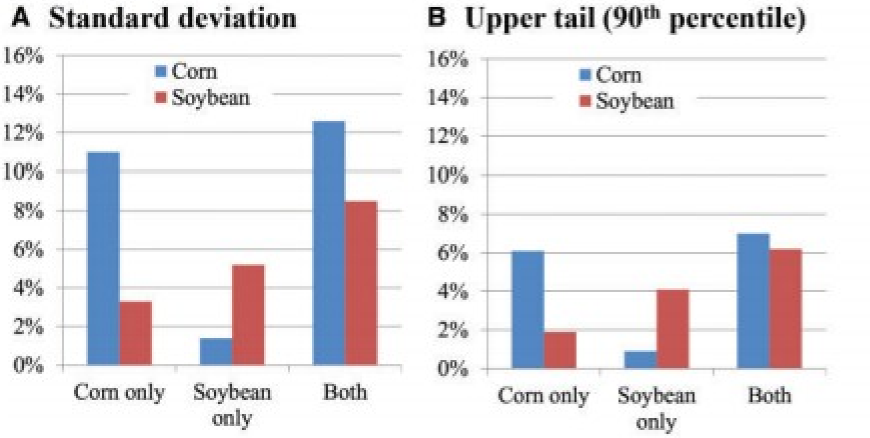
The impacts of climate change are different if corn-only or soybean-only yield effects are applied compared to the case where both are included in the analysis. Given that corn and soybean markets interact in supply (particularly through competition for area) and demand, a change in the price of one of these crops tends to affect the other market. Climate change impacts on one crop’s yield spill over onto other crops. For every 1% increase in the average corn price in the corn-only scenario, the average soybean price goes up by 0.3%, and for every 1% increase in the average soybean price in the soybean-only scenario, the average corn price rises by 0.2%. Looking at the average soybean price impacts, the estimated 1.6% impact of corn yield changes on soybean price is almost half as large as the 3.5% impact of soybean yield changes on soybean price. These results suggest that cross-market impacts are consequential compared to the own-market impacts of climate change.

The price change from a scenario that shocks only one crop’s yield underestimates the price impact of climate change relative to a case with the other crop yield impact included in the analysis. The average corn price impact rises from 4.8% in the corn-only case to 5.6% if soybean yield impact is also taken into account. The soybean-only case increases the average soybean price by 3.5%, but the estimated impact is 5.2% if soybean and corn yields both change. Both estimated price impacts are substantially larger if both crop yields are affected by climate change, rather than the yield of only one crop.

A wider standard deviation of yields leads to a wider standard deviation of price outcomes. For example, in the corn and soybean scenario, the implication of the wider yield distribution for key Corn Belt states is a 13% higher standard deviation of price outcomes, and the upper end of the distribution increases by 7% as measured by the 90th percentile observation (figure 4). Spill-over from one market to the other matters. For example, the effect of the corn yield changes on the soybean price standard deviation is more than half as large as the effect of soybean yield changes on this measure of the price range.

Figure 4. Impacts on the distribution of crop prices

Source: Authors' calculations.



A Standard deviation

B Upper tail (90th percentile)

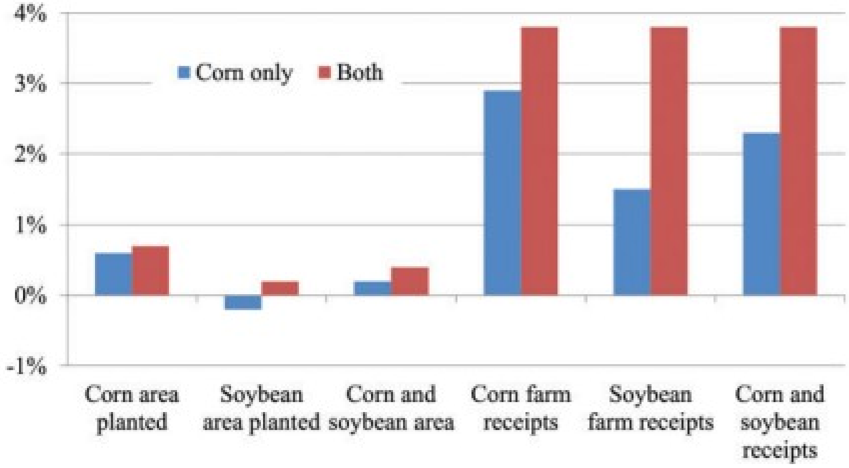
One key result from the estimates of climate change impacts on price is that a focus on a single crop risks underestimating the impact on price levels and ranges. The experiments here show that cross-impacts matter for price levels and also for price distributions. The impacts are not symmetric: the soybean shock has a smaller effect on corn than the corn shock has on soybeans. That is to say, the smaller yield shock applied to an area that accounts for a smaller share of the market (soybeans) has a smaller cross-impact compared to the larger yield shock applied to an area that represents a larger share of the relevant market (corn). This potential for underestimation is a concern if a goal of climate change analysis is to assess the frequency or degree of price spikes.

Area and Receipt Impacts

A focus on just one of the main crops grown in these five states rather than both has broader implications. These differences are demonstrated by comparing the corn-only scenario and the corn and soybean scenario (figure 5). The area planted to corn is similar in either case, but the impacts on the soybean area are opposite. If only the corn-yield distribution is reduced and broadened, then land tends to shift from soybeans to corn. However, if soybean yield distributions are also reduced and widened, then more land is drawn into these crops in aggregate, rather than diverted from one to the other. Climate change assessments that focus on land use can be affected by the choice of scope, even for relatively modest yield changes over the next several decades.

Figure 5. Area and receipts impacts

Source: Authors' calculations.



The usual result of a negative yield shock in the presence of inelastic demand is higher crop receipts, on average (Newbery and Stiglitz 1981), as in the case here. The corn-only scenario underestimates the impact on corn receipts relative to the corn and soybean scenario: instead of + 3% corn farm receipts, the case of corn and soybean yield changes causes +4% corn farm receipts. The corn-only case underestimates the impact on soybean receipts more seriously, by approximately three-quarters. With both corn and soybean yields affected by climate change, U.S. receipts for corn and soybean farmers rise by 4% relative to the baseline case.

Aggregate farm-receipt effects shown here do not address individual cases or the allocation of receipts among regions. Lower corn and soybean yields in some or several of these five states might cause higher prices that increase total U.S. receipts from these crops, but crop producers in the five states who suffer lower yields could still be worse off.

Estimated impacts on the variations in area and receipts can also be biased if the competing crop is excluded (table 2). A focus exclusively on corn understates the volatility in area by about one-third and receipts by one-quarter, if measured by the standard deviation. When considering the higher end of the distribution, as represented by the 90th percentile observation, the downward bias also appears pronounced.

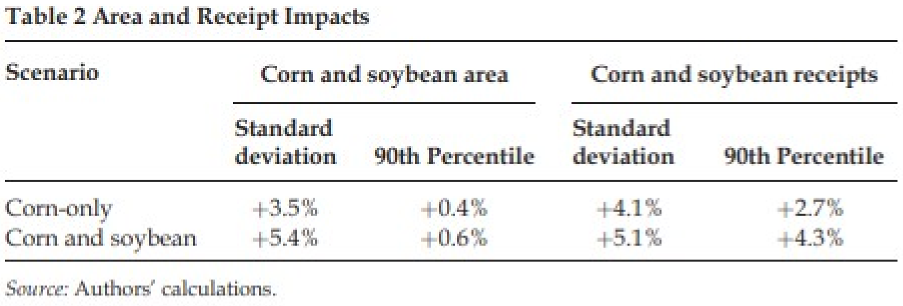


Table 2 Area and Receipt Impacts

Scenario	Corn and soybean area		Corn and soybean receipts	
	Standard deviation	90th Percentile	Standard deviation	90th Percentile
Corn-only	+3.5%	+0.4%	+4.1%	+2.7%
Corn and soybean	+5.4%	+0.6%	+5.1%	+4.3%

Source: Authors' calculations.

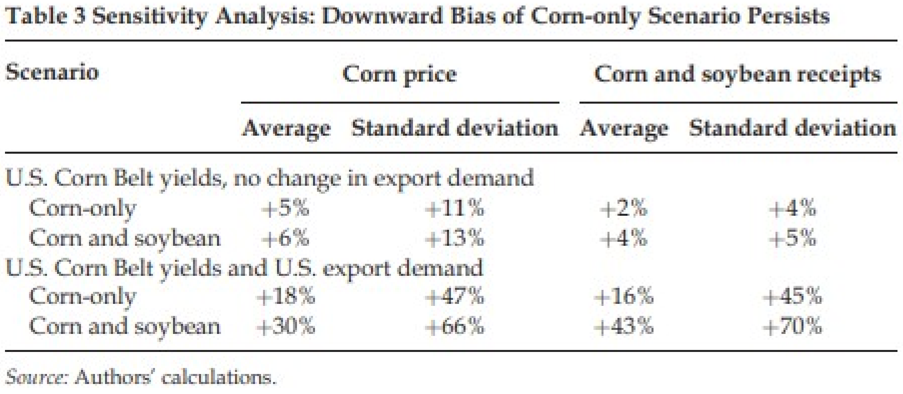


Table 3 Sensitivity Analysis: Downward Bias of Corn-only Scenario Persists

Scenario	Corn price		Corn and soybean receipts	
	Average	Standard deviation	Average	Standard deviation
U.S. Corn Belt yields, no change in export demand				
Corn-only	+5%	+11%	+2%	+4%
Corn and soybean	+6%	+13%	+4%	+5%
U.S. Corn Belt yields and U.S. export demand				
Corn-only	+18%	+47%	+16%	+45%
Corn and soybean	+30%	+66%	+43%	+70%

Source: Authors' calculations.

Sensitivity Analysis

Our focus is on Corn Belt yield impacts of climate change. We test if the finding that focusing on one of the two main crops that compete for land in this area might lead to bias is sensitive to the narrow regional scope of our exercise. To do so, we simulate the impacts of Corn Belt yield shocks again, but we also shock export demand for corn or for corn and soybeans. This alternative case explores the potential that global climate change increases the demand and variation in demand for U.S. corn, soybeans, soybean meal, and soybean oil. Because our goal is to assess the robustness of our key finding, we test if the finding persists even if export demand changes are pronounced. We increase export quantity standard deviations by 30% to 50% for corn, soybeans, and soybean products and shock export demand for corn and soybean products out by 25% relative to the initial levels.

The key finding is not sensitive to these shocks to exports. The estimated corn price impact of a corn-only scenario remains smaller than the estimated corn price change if corn and soybeans are affected (table 3). This comparison is true of corn variation as well, as measured by the standard deviation. Results for corn and soybean receipts follow the same pattern as well, with corn-only effects biased downward relative to a broader scenario with corn and soybean impacts.

Sensitivity analysis confirms that broadening the geographic scope does not undo our key finding. Rather, it remains the case that a narrow focus on one commodity tends to generate a biased impact of price and other market impacts compared to a broader analysis that includes an additional commodity that competes for land in the target region.

Summary

Scientists who study climate change estimate that future crop yields in the U.S. Corn Belt could be reduced overall and vary more widely. This finding raises immediate questions about the prices of commodities grown in this region: how much will these prices rise and how much more will they vary? Answers to these questions are important for decision makers who want to know the risks associated with any yield effects of climate change for consumers and producers.

We use a structural model of commodity market supplies and demands that is simulated stochastically over ranges of exogenous variables, including yields, drawn from historical observations. In our experiments, we exploit new estimates of the impacts of climate change on corn and soybean yields in five states of the U.S. Corn Belt to estimate how corn and soybean markets respond. Whereas many studies might consider average impacts, our research also incorporates yield distribution (standard deviation) impacts. A new element introduced here relative to other work that focuses on market impacts in terms of distributions, rather than only average impacts, is the use of a model that has automatic responses, including endogenous crop stocks, explicitly represented. Also, in contrast to initial research in this direction, we allow climate change to affect two main crops in the growing region, rather than one.

We find that the estimated yield impacts associated with mid-twenty-first century climate change for these five states do not amount to very large shocks relative to the total market. Impacts on price levels and price distributions are consequently not very large, either. The directional impact on aggregate revenues runs opposite to the yield impacts because of inelastic demand, setting aside distributional impacts among producers. The scale of impacts is not extremely surprising given that the yield impacts over this interval are not large, the focus is exclusively on one growing region – albeit an important one – that accounts for only a share of global production, and some of the impacts are reduced by the reallocation of inputs, stocks, and other demand and supply responses.

Our key finding is that focusing on one commodity risks understating the impacts. At least for this region, which is characterized by the presence of two primary crops, focusing on the climate change impacts on only one of the crops generates estimates of price, area, and producer receipts that are lower than the results if impacts on both crop yields are included. If only corn yields are decreased, then cross-commodity effects will tend to soften and spread out the market impacts as some land is shifted from soybeans to corn, for example. Some of the corn market impacts will be shifted into the soybean market. In contrast, if soybean yield decreases due to climate change are introduced at the same time as the corn yield impacts, then cross-effects compound the impacts rather than soften them. The impacts on corn prices, area, and receipts are larger if the climate change assessment includes both corn and soybean yield decreases.

The downward bias of a narrow experiment is present for measures of the distribution, as well as the averages. The ranges of prices, area, and receipts widen more if climate change impacts on both crop yields are included, rather than only one. The high values are increased more in the broader analysis compared to the narrow analysis. Estimated crop price spikes can be higher if climate change impacts on corn and soybean yields are included in the analysis together, rather than focusing narrowly on a single crop.

This result partly reflects the model structure, we believe. If a model were built explicitly to represent a single commodity market for this exact experiment, then perhaps the response to changes in yields and prices would implicitly include cross effects from other crops. Opting for a narrower model raises new problems, however, rather than serving as a panacea. Key questions surrounding climate change are broad in nature, and might require an examination of many commodity markets. Also, choosing a one-crop model begs the question of identifying what cross-effects are implicit in the model, and whether or not they are exogenous in the presence of climate change.

Our findings are relevant for decision makers, as well as for applied economists involved in climate change analysis. When looking at case studies of the impacts of climate change, particularly studies that focus on a single commodity or a small set of activities relative to what is practiced in a region, there is a risk of downward bias if cross-effects would exacerbate the size and distribution of market impacts. We do not argue that any one method is the best approach. For example, our use of stochastic simulations for a two-crop case that includes automatic policy and yield response represents an improvement over previous methods of assessing the impacts of climate change on individual crop markets. However, our focus on the impacts of climate change on crop yields in one key growing region remains incomplete relative to the full scope of potential global impacts. Setting aside the potential for an all-inclusive study that includes all conceivable impacts, however, policy makers are often left to draw conclusions from many partial assessments in the form of individual studies or combined in a literature review or formal meta-analysis. Our finding warns policy makers that, at least under certain conditions, a partial assessment will provide results that are biased downward.

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