The Impact of the Renewable Fuels Standard on Cropland Transitions

This document is for material to be included in the supplementary appendix of the journal submission.

Data

Land use transition data are from the National Resources Inventory (NRI) collected by Natural Resources Conservation Service (NRCS). The NRI provides annual land use data at a sample of points across the United States from 2000 to 2012. Our analysis focuses on cropland (cultivated and noncultivated) transitions with pasture or Conservation Reserve Program (CRP). We also use the information in the NRI about the land capability classification of the point and the soil texture. If the point is enrolled in CRP, the NRI indicates the year of the general signup number associated with its enrollment. The point level data from the NRI indicates the county that the point is located in, but not the GIS location, so variables constructed from other data sources are merged to the NRI by county.

We construct cropland returns as a 10-year discounted stream of expected returns averaged across the relevant crops of the county assuming a discount rate of 5%. Crops included in the calculations include corn, soybeans, winter wheat, spring wheat, rice, cotton, and sorghum. Projected prices for the next 10 years are obtained from the Agricultural Baseline Database from Economic Research Service. These prices are created as part of USDA's long-term projections report. For the yields, we estimate county-specific trend yields. Costs of production are from Economic Research Service Commodity Costs and Returns. Cost of production are at the Farm Resource Region level or groups of states—ERS has changed their definition of regions over time. We include costs for seed, fertilizer, chemicals, and custom operations. Other cost categories were not included because the definition of other cost categories changed over time and we want consistent costs over time. The cost categories that we include represent the primary cost differences across commodities. We assume constant costs over the 10-year period. Returns are then averaged across crops for each county where the weight given to each crop is the 5-year moving average acres planted to that crop.

Pasture returns are calculated as an estimate of pasture rental rates from information about the animal unit months from the pasture and the price of hay (Hofstrand and Edwards, 2015). Animal unit months at the county level are obtained from work by Atwood et al. (2005) who extracted the values from the STATSGO soils data and cleaned the data.[1] Hay prices are a 5-year moving average of hay prices from NASS (National Agricultural Statistics Service). Translating animal unit months into rental rates requires several other parameter assumptions that can vary across states. Instead of making assumptions about these parameters, we calibrate

[1] The county-level animal unit month data were obtained through personal correspondence with Jude Kastens.

our rent estimates by state so that our rent estimate is similar in magnitude to 2009-2016 pasture rental rates reported by NASS.

Several important variables for CRP were obtained at the county level through a Freedom of Information Act request. The returns from enrolling in CRP are the rental rate of newly enrolled contracts. CRP rental rate data available online are the average rent for all enrolled acres, but we use only the rental rate of newly enrolled contracts which represents the decision variable for famers. Data are also utilized on the average Environmental Benefits Index of land offered—land both accepted and rejected—for CRP enrollment. We also obtain data on how many acres had expiring contracts in each year based on the original contract and how many acres were eligible for early contract release in 2015 (see Stubbs, 2014).

Climate data at the county level are from Hendricks (2018). We assume that farmers make land use decisions based on expected climate conditions and that these climate conditions are approximated with a 30-year average of weather variables. Weather variables included are the water deficit, water surplus, growing degree days between 10°C and 30°C, and extreme degree days (degree days above 30°C). Water deficit and surplus are calculated from a daily water balance model. Water deficit represents the amount of reference evapotranspiration demand that cannot be met by available water. Water surplus represents precipitation in excess of evapotranspiration demand. Hendricks (2018) provides greater detail on the calculation of these variables.

For our sample to estimate models, we select Major Land Resource Regions (MLRAs) where (i) greater than 20% of total land area is crop production; (ii) greater than 10% of cropland is planted to corn, soybeans, or wheat; and (iii) greater than 50% of total crop acres were planted to crops included in our estimate of cropland returns. Figure 1 shows the regions included in our analysis—separate models were estimated for each region. The label of the region in figure 1 indicates the letter of the Land Resource Region (LRR) and multiple letters indicate that LRRs were combined. LRR M had many more NRI points than other LRRs and included some areas that were very densely cropped while other areas had a substantial portion of grassland. Therefore, we divided this LRR based on whether the Major Land Resource Region (a subregion within am LRR) had grassland area less than or greater than 15% of the area of cropland.

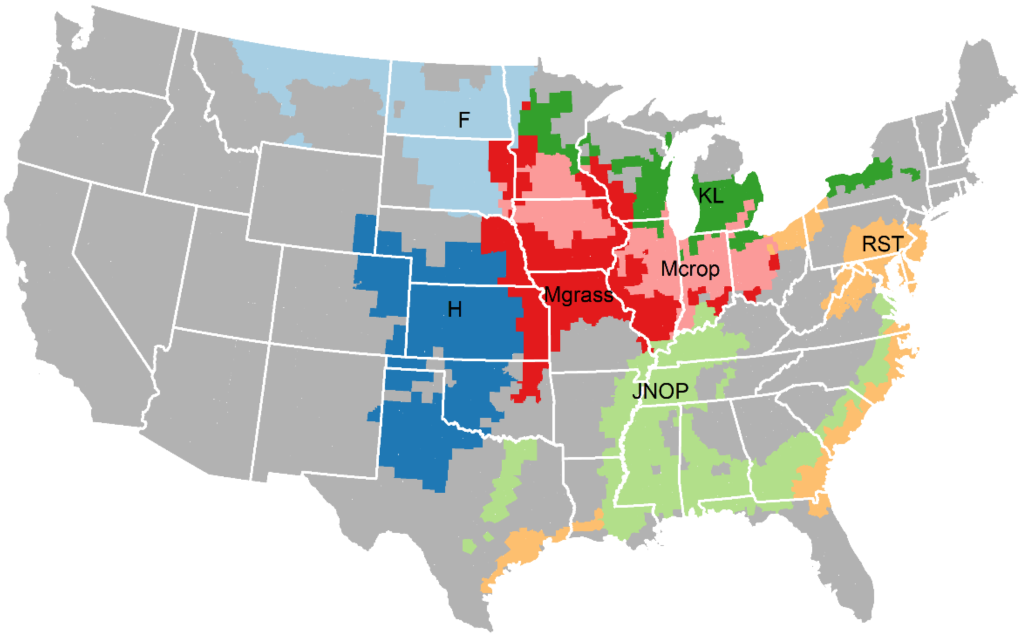

Figure 1. Map of Regions for the Analysis

Methods

Econometric Model

We utilize the NRI data to estimate how land use returns impact the probability of a landowner selecting a particular land use (Lubowski, Plantinga, and Stavins 2008; Rashford, Walker, and Bastian 2011; Lawler et al. 2014; Langpap and Wu 2011; Claassen, Langpap, and Wu 2016). In particular, we utilize information on land use transitions over time to estimate transition probabilities (Lubowski, Plantinga, and Stavins 2008; Lawler et al. 2014). We estimate the effect of changes in crop returns on transitions between cropland and pasture and between cropland and CRP because there are very little transitions with between cropland and other types of land use in our study region.[2]

The probability of expansion of cropland from pasture is estimated as

$$Prob(lu_{nt} = crop | lu_{n,t-1} = pas)$$
$$= \Phi(\theta_0^{crop} R_{mt}^{crop} + \theta_0^{pas} R_{mt}^{pas} + \varphi_0^{crop} \bar{R}_m^{crop} + \varphi_0^{pas} \bar{R}_m^{pas} + \boldsymbol{\delta}_0' \boldsymbol{X}_n)$$

where $Prob(lu_{nt} = crop | lu_{n,t-1} = pas)$ denotes the probability that NRI point n has a land use of cropland in year t and pasture in year $t - 1$ and this probability is a function of the returns to

[2] Between 2000 and 2012 in our region, only 0.01% of cropland transitioned to rangeland, 0.02% of cropland transitioned to forestland, 0.01% of rangeland transitioned to cropland, and 0.01% of forestland transitioned to cropland. These represent too small of a sample of transitions in the NRI data to try and estimate how returns impacted the likelihood of a transition.

cropland (R_{mt}^{crop}) in county m, returns to pasture (R_{mt}^{pas}), and a vector of other characteristics of the NRI point ($\boldsymbol{X}_n$). The notation $\Phi(\cdot)$ denotes the cumulative normal distribution to indicate that the probability is estimated with a probit model. The probability of abandonment of cropland to pasture is estimated similarly as

$$Prob\big(lu_{nt} = pas | lu_{n,t-1} = crop\big)$$
$$= \Phi\big(\theta_1^{crop} R_{mt}^{crop} + \theta_1^{pas} R_{mt}^{pas} + \varphi_1^{crop} \bar{R}_m^{crop} + \varphi_1^{pas} \bar{R}_m^{pas} + \boldsymbol{\delta}_1' \boldsymbol{X}_n\big).$$

The controls included in the regression to account for soil productivity include a set of binary variables to indicate if the land capability classification is 1 or 2, if the land capability classification is 3 or 4, and indicators for five different soil texture classifications. Controls to account for the climate of each county include water deficit, water surplus, growing degree days, and extreme degree days. The models are estimated separately for each region in figure 1 because we expect that crop returns have a different impact on transitions in different regions.

A key difference in our specification from the previous literature is that we control for average returns ($\bar{R}_m^j = \frac{1}{T}\sum_t R_{mt}^j$) to account for unobservables that may be correlated with returns. This specification is known as the correlated random effects probit model and assumes that conditional on average returns and observables $\boldsymbol{X}_n$, any remaining unobserved heterogeneity is uncorrelated with returns (Wooldridge, 2010). Intuitively, adding $\bar{R}_m^{crop}$ and $\bar{R}_m^{pas}$ as controls means that we are exploiting changes in returns over time rather than the pure cross-sectional variation in returns. The parameters φ_0^{crop} and φ_0^{pas} are nuisance parameters to account for unobserved heterogeneity and should not be interpreted as causal parameters. The cross-sectional variation in returns is subject to concerns about omitted variable bias because NRI points in counties with higher returns may be more likely to convert to cropland but for reasons not fully accounted for in our controls $\boldsymbol{X}_n$. The correlated random effects specification exploits changes in crop returns over time that occurred due to changes in the demand for crops. The correlated random effects model is similar to a fixed effects model but does not have bias due to the incidental parameters problem (Wooldridge, 2010).

The probability of expansion of cropland from CRP (i.e., exiting CRP) is estimated as

$$Prob\big(lu_{nt} = crop | lu_{n,t-1} = CRPexpiring\big)$$
$$= \Phi\big(\theta_0^{crop} R_{mt}^{crop} + \theta_0^{CRP} R_{mt}^{CRP} + \varphi_0^{crop} \bar{R}_m^{crop} + \varphi_0^{CRP} \bar{R}_m^{CRP} + \boldsymbol{\delta}_0' \boldsymbol{X}_n\big).$$

One important point about expansion of cropland from CRP is that we only estimate the model for NRI points that were in CRP the previous year and the contract may be expiring. Farmers enrolling in CRP agree to a multi-year contract—typically 10 years. Therefore, farmers only make a decision about changing land use when the CRP contract is expiring. We cannot know the exact date an individual point expires but can get close because the NRI data indicate the CRP signup year for each NRI point. We then tabulate how often land exited CRP for each signup year, determine the most common exit years, and only estimate the model for points in the respective years of potentially exiting. One reason that it is difficult to determine the exact expiration year is that USDA offered 2 to 5-year contract extensions for contracts expiring between 2007 and 2010 in order to stagger the expiration of CRP contracts (Stubbs, 2014).

The probability of abandonment of cropland to CRP (i.e., enrolling in CRP) is estimated as

$$Prob\left(lu_{nt} = CRP | lu_{n,t-1} = crop, t = signup\ year\right)$$
$$= \Phi\left(\theta_1^{crop} R_{mt}^{crop} + \theta_1^{CRP} R_{mt}^{CRP} + \varphi_1^{crop} \bar{R}_m^{crop} + \varphi_1^{CRP} \bar{R}_m^{CRP} + \boldsymbol{\delta}_1' \boldsymbol{X}_n\right).$$

The model of CRP enrollment is only estimated in years where there was a signup for general CRP. There were signups for CRP in 2000, 2003, 2004, 2006, 2010, and 2011. However, the actual land use change usually occurs in the year after the signup, so we estimate the model of CRP enrollment in years 2001, 2004-2007, and 2011-2012. We include 2006 because there were two signups in 2006 and one signup was in the spring and we observe a significant number of land use transitions to CRP in 2006. Our models of CRP transitions are unique compared to previous literature in that we account for the effect of the CRP contract on land use transitions.

The controls in the CRP transition equations are the same as for pasture but also include the average Environmental Benefits Index (EBI) of land offered for CRP in the county. We do not use the EBI of the respective year due to endogeneity concerns—the EBI of acres offered for CRP increases when crop prices are high because less land is offered for enrollment. Instead, we use the average EBI of offered acres over time as the control to account for the fact that CRP enrollment is more likely in some counties because of a higher EBI.

Simulation

For the simulations, we estimate the acres of land use that transition to and from cropland between 2009 and 2016 for each region due to the RFS. For transitions with pasture, we first predict the probability of transitions at each point with observed crop returns between 2009 and 2012. The probability of transitioning is multiplied by the number of acres the point represents—this is included in the NRI data—and aggregated to the region level. We then calculate new cropland returns if the price of corn is decreased by 30% and the price of soybeans and wheat decreased by 20% and calculate the predicted acres of transitions to represent the counterfactual scenario without RFS. The average annual change in acres of transitions is multiplied by 8 to predict the total changes in transitions due to the RFS between 2009 and 2016.

The same basic simulation approach was used to estimate the change in transitions with CRP except that we account for expiring CRP acres and signups. To predict how many acres exit CRP we calculate the change in the probability of exiting CRP if the contract is expiring and multiply this times the total number of acres expiring in a given year. For years 2013-2016 that are outside the NRI sample period, we scale our estimate of exiting CRP by the relative change in the number of CRP contracts with expiring acres. The relative change in the number of expiring contracts is calculated from county-level data from the Farm Service Agency. To simulate CRP enrollment, we estimate how predicted enrollment changes in signup years between 2009 and 2016. The only general CRP signups in this period were in 2010, 2011, and 2013. We assume that all points in cropland in 2012 were eligible for CRP enrollment in fiscal year 2013.

Results

Table 1 shows the results of the simulations for transitions with pasture. In general, we find no statistically significant evidence that the increase in cropland returns increased the amount of expansions of pasture to cropland. However, in region Mgrass we estimate an increase in conversions by about 308,827 acres, which is about an 18% increase in the average number of conversions. Some of the estimates of cropland expansion have an unexpected negative sign but only one is significant at the 10% level.

Table 1. Predicted Changes in Transitions of Cropland with Pasture due to RFS

Expand Cropland from Pasture		Abandon Cropland to Pasture		
Region	Change in Acres	Region	Change in Acres	Net Change
F	82,859	F	243,136 **	-160,277
	(67,962)		(95,274)	(116,759)
H	-23,096	H	87,643	-110,738
	(76,655)		(80,060)	(109,767)
JNOP	-287,849 *	JNOP	112,656	-400,505 **
	(157,561)		(75,842)	(176,243)
KL	-168,079	KL	-184,092 *	16,012
	(137,161)		(110,316)	(175,059)
Mcrop	38,213	Mcrop	73,363	-35,151
	(95,112)		(103,074)	(138,194)
Mgrass	308,827	Mgrass	-509,856 **	818,683 **
	(232,020)		(183,576)	(297,747)
RST	743	RST	-13,105	13,848
	(50,933)		(46,311)	(68,734)
Total	-48,383		-190,254	141,871
	(341,171)		(282,042)	(441,841)

Note: Bootstrap standard errors are in parentheses. * and ** denote significance at the 10% and 5% levels.

We find stronger evidence that the increase in cropland returns decreased the amount of cropland abandonment. In region Mgrass, we estimate that 509,856 acres were not abandoned that otherwise would have in the absence of the RFS. This effect is statistically significant at the 5% level. We also find significant evidence of reduced abandonment in the KL region. On net, we estimate that cropland area only increased by 141,871 acres from transitions with pasture due to the RFS. But the impact differs by region and there was an 818,683 acre increase in cropland in the Mgrass region from transitions with pasture due to the RFS that is significant at the 5% level.

Table 2 shows the results of transitions with CRP. Here we find large and statistically significant impacts of the RFS on cropland conversions. The largest increases in cropland expansions occurred in regions F and Mgrass where conversions of CRP to cropland increased by nearly 1.6 million acres in each region due to the RFS. Region H also saw an increase in conversions of nearly 0.8 million acres.

The increase in crop prices not only increased cropland expansions but also decreased the amount of abandonment (i.e., enrollment in CRP). Enrollment of cropland into CRP decreased by about 125,000 acres in regions F and Mgrass and about 240,000 acres in region H. Overall, cropland increased by 5.2 million acres due to the RFS from changes in transitions of cropland with CRP.

Table 2. Predicted Changes in Transitions of Cropland with CRP due to RFS

Expand Cropland from CRP		Abandon Cropland to CRP		
Region	Change in Acres	Region	Change in Acres	Net Change
F	1,580,282 **	F	-125,320 **	1,705,602 **
	(113,054)		(36,252)	(118,155)
H	799,115 **	H	-242,433 **	1,041,548 **
	(64,455)		(22,877)	(68,543)
JNOP	186,480 **	JNOP	-64,612 **	251,092 **
	(23,623)		(15,996)	(27,922)
KL	126,483 **	KL	-20,562 **	147,045 **
	(24,283)		(9,159)	(26,267)
Mcrop	197,447 **	Mcrop	-95,397 **	292,844 **
	(24,871)		(40,693)	(47,978)
Mgrass	1,566,931 **	Mgrass	-125,744 **	1,692,676 **
	(71,213)		(34,908)	(79,056)
RST	28,834 **	RST	-10,882 **	39,716 **
	(10,170)		(5,767)	(11,540)
Total	4,485,571 **		-684,951 **	5,170,522 **
	(152,769)		(72,093)	(168,676)

Note: Bootstrap standard errors are in parentheses. * and ** denote significance at the 10% and 5% levels.

Table 3 combines the results in tables 1 and 2 to show the total change in cropland transitions. Overall, we find that cropland expansion increased by 4.4 million acres due to the RFS and cropland abandonment decreased by 0.9 million acres. Together this resulted in an increase of 5.3 million acres of cropland that can be attributed to the RFS policy. The aggregate changes in cropland area due to the RFS are significant at the 5% level. The largest increase in cropland area due to the RFS was in the region Mgrass where expansion increased by over 1.9 million acres and abandonment decreased by 0.6 million acres for an overall increase in cropland by 2.5 million acres. Region F also saw an increase of 1.5 million acres and regions H had and increase of more than 0.9 million acres due to the RFS.

Table 3. Predicted Changes in Transitions of Cropland with Pasture or CRP due to RFS

Expand Cropland from Pasture or CRP		Abandon Cropland to Pasture or CRP		
Region	Change in Acres	Region	Change in Acres	Net Change
F	1,663,140 **	F	117,815	1,545,325 **
	(130,222)		(102,433)	(165,710)
H	776,019 **	H	-154,790 *	930,809 **
	(99,161)		(83,463)	(129,461)
JNOP	-101,369	JNOP	48,044	-149,413
	(158,725)		(77,565)	(178,690)
KL	-41,597	KL	-204,653 *	163,057
	(139,181)		(110,457)	(177,527)
Mcrop	235,659 **	Mcrop	-22,034	257,693 *
	(98,410)		(111,376)	(147,492)
Mgrass	1,875,758 **	Mgrass	-635,600 **	2,511,358 **
	(241,301)		(187,804)	(309,106)
RST	29,577	RST	-23,987	53,564
	(51,191)		(46,700)	(69,669)
Total	4,437,188 **		-875,205 **	5,312,393 **
	(373,858)		(294,353)	(477,650)

Note: Bootstrap standard errors are in parentheses. * and ** denote significance at the 10% and 5% levels.

Comparison to National Data

Figure 2 shows that our estimate of the net change in cropland area due to the RFS is reasonable when compared to aggregate trends in cropland area. The blue line shows total cropland area across the United States according to the NRI. We include an estimate for 2015 national-level cropland area because this estimate is available online even though the 2015 point-level data were not available for our analysis. Cropland area was clearly been trending downward from 1982 to 2007, at the start of the RFS impacts. The red line shows the trend in cropland acres fit to the 1992-2007 data. Cropland area increased nationally by 7.52 million acres from 2007 to 2015. However, figure 2 shows that cropland area in 2015 was actually 19.2 million acres larger than it would have been if the pre-2007 trend had continued. Our estimate of cropland area without the RFS is shown as the point in figure 2 and is calculated as the 2015 cropland area minus the impact of the RFS—simulated between 2008 and 2015 for consistency with these data. This indicates that about 24% of the difference between trendline cropland area and actual 2015 cropland area is due to the RFS.

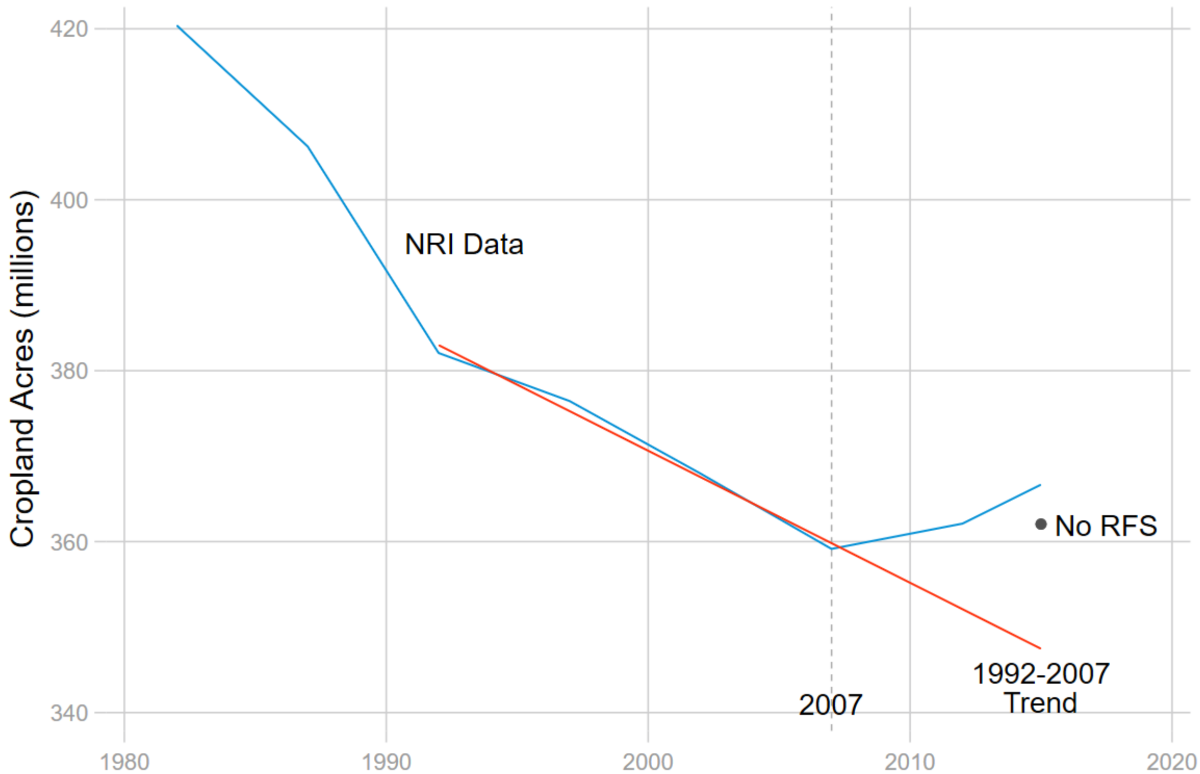

Figure 2. National Cropland Area over Time Compared to Our Estimate of the Impact of the RFS

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