# Do Farm Subsidies Affect Crop Diversification?

Author: Chadwick O'Neal
Chadwick.oneal@bobcats.gcsu.edu
(404) 323-6118
Affiliation: Georgia College & State University
February 8, 2017

Abstract: The United States spends $20 billion each year on farm subsidies. Farmers face increased risk and income variation when their crop portfolio is less diversified. It's possible for farm subsidies to decrease diversification if they are focused on specific crops. Utilizing state level subsidy and agricultural data from the Environmental Working Group, I estimate the effect of farm subsidies on crop diversification. I expect to find that crop specific subsidies decrease crop diversification, which prior research suggests may have negative consequences for farmers and society, in general.

# Do Farm Subsidies Affect Crop Diversification?

## I. Introduction

The United States spends $20 billion each year on farm subsidies (Top Crops in the States We Serve). Farmers face increased risk and income variation when their crop portfolio is less diversified. Utilizing state level subsidy and agricultural data from the Environmental Working Group, I estimated the effect of farm subsidies on crop diversification. I found that crop specific subsidies have an impact on diversification. Some crop subsidies increase overall crop diversification while others lead to less diversification. Research suggests that decreases in crop diversification has negative consequences for farmers and society in general.

Crop diversification in this paper is defined as a variety of crops grown in one region or on one farm. I look at diversity across species not within. This rarely discussed topic has a sizeable impact on both farmers and agriculture policy makers. This paper contributes to literature attempting to understand the effects of government subsidies on long-term agricultural outcomes. There is little research done on this topic within the field of agriculture, and considering its substantial effects, it is it is important to explore the relationship between subsidies and crop diversification.

In 1845, Ireland faced a widespread hardship known as the Irish Potato Famine. The country had a large monocultural potato crop (Monoculture and the Irish Potato Famine: Cases of Missing Genetic Variation). Within one year, a simple blight wiped out 40% of the potato crop across the nation, leaving the citizens with few agricultural alternatives leading to cases of starvation and financial ruin (Irish Potato).

This paper begins with a literature review examining past crop diversity research, and the consequences of having less crop diversity. Section III looks at the economics theory behind the question. Section IV explains the sources of the data, the basic model, and an explanation of each variable. Section V details the results and the interpretation of the significant variables. Section VI describes limitations with my model and the various techniques used to address each issue. Finally, Section VII reviews the findings and application of this study.

## II. Literature Review

There are many studies that examine the impact of subsidies on crop output, acreage, and price changes. Wu and Adams found that insurance premiums affect the acreage planted and alter cropping patterns ( 2001). Ye, Yokomatsu, and Okada found that farm output changes in response to subsidized insurance premiums (2012). Babcock, Fabiosa, and Jacinto explore the impact of ethanol subsides on corn prices (2011). However, none of these studies consider subsidies' impact on crop diversity.

Crop diversity in agriculture is essential, as D. M. Spratt emphasizes in his esteemed research on biodiversity. Specifically he states, "Some undetermined level of biological diversity is necessary to maintain ecological function and resilience" (1997). Crop diversification is a buffer against blights, pest outbreaks, and natural events such as drought, oversaturation, and frost (Lin 2011). A decrease in crop diversity means an increase in the likelihood that crops will suffer from blights similar to the one in Ireland. The difference between 1845 and today is that we have modern insecticides to help overcome this weakness. Meehan and Gratton find a statistically significant relationship between landscape simplification and the use of insecticide (2015). As crop diversity decreases, the farmers increase their use of insecticides or vise versa. Without the buffer of crop diversity, farmers are forced to use the controversial method of insecticides to protect their crops.

Aguilar *et al* say, "Diverse cropping systems tend to increase farmers' chances of encountering favorable conditions while decreasing the probability of widespread crop failures" (2015). He means that the risk is spread out across several different crops, which is beneficial because each crop has its own unique tolerance level for inclement weather (2015). Aguilar *et al* found in their recent research based on long-term data collected in Ontario, Canada, that "compared to simple corn/corn and corn/soybean cropping systems, more diverse systems that included a small grain such as wheat, or under-seeding with a cover crop such as red clover, produced more stable yields over a 31 year period" (2015). This research exemplifies the pattern that crop diversity leads to a more consistent harvest. Despite the benefits of more diverse cropping systems there is still a decline in crop species diversity (Gaudin 2015). More strikingly, Aguilar *et al* found that crop species diversity in the United States was lower in 2012 than in 1978 (2015).

Bianchi, Booij, and Scharntke find that a decrease in crop biodiversity is from agricultural intensification, which is the act of trying to produce more units per acres of land (2006). In addition to agricultural intensification I found that federal crop subsidies also contribute to decreases in diversification. Crop specific subsidies lower the growing cost of that crop, create attractive profits, and incentivize farmers to convert more acreage into the production of that crop. Price support subsidies guarantee farmer's revenue allowing them to keep their prices high regardless of market conditions, creating even better profit margins (Spratt 1997). Therefore, it follows that crops with higher expected profit yields are planted more abundantly. In a market with no price controls, the market would adjust to the equilibrium price and quantity. The quantity demanded would be supplied at an equilibrium price. Instead, in the agricultural market price support subsidies act as price controls, preventing the price from changing. This creates a price floor and means quantity will rise until the USDA lowers the price level by reducing subsidies (Thompson 1993).

Crops that receive subsidies are grown more abundantly than those that do not (USDA). Crops with higher profit margins will replace those with lower profit yields. Wright and

Wimberley (2013) found that the steep price of corn caused by ethanol subsidies led to more grassland being converted into corn (Alan, Doraiswamy, and Hunt 2013). "The area planted in corn increased from 4.7 million hectares in 2001 to 5.7 million hectares in 2007, which was correlated with the market price for corn" (Alan, Doraiswamy, and Hunt 2013).

Stern, Doraiswamy, and Hunt find that crop prices are correlated with acres planted (2013). It is not directly the price that causes corn be more widely planted but rather larger profit margins created by subsidizing the crop.

## III. Economic Theory

Crop insurance subsidies create unintended consequences. They create a moral hazard because taxpayers pay about 60% of the premium, meaning, "Over time most farmers can expect to collect far more in payouts than they pay in premiums" (EWG). Farmers respond to these incentives by behaving rationally in "planting crops on poor-quality land, cutting back on things like pesticides and fertilizer that reduce the risk of crop losses and reducing the extent to which they diversify their enterprises" (Smith, 2015). Smith points out that subsidies cause farmers to practice riskier behavior by not diversifying their crops and not using as many protective measures such as insecticides (2015).

The Peltzman effect is a behavioral economic theory that states, as safety measures increase people tend to take more risks. This can be seen with the subsidized insurance premiums. As the insurance safety net is increased, farmers react with riskier behavior by not diversifying their crops since they know they will be covered and not suffer a large loss if a blight or other event wipes out their entire crop.

## IV. Data and Methodology

The data used for this research was collected from a State level panel of four primary sources. The first source is the USDA's National Agricultural Statistics Service. The data set provides detailed agriculture statistics from the county to the national level. Specifically from this data, I used statewide panel data of individual crop prices and acres planted per year. My second source was the Environmental Working Group's (EWG) Farm Subsidy Database. This source provided me with statewide panel data of the dollar value for subsidies paid toward the production of 16 different crops from 1995 to 2014. The data is organized by crop per year. I used the National Oceanic and Atmospheric Administration's (NOAA) database for the climate variables in my model. These variables, $AVERAGE\_TEMPERATURE$ and $DROUGHT\_SEVERITY$, vary across states and over time. My last primary data source was the Bureau of Labor Statistics' Producer Price Index (PPI). I used the PPI data to adjust crop prices for inflation over time.

My data spans 20 years, 1995 to 2014. It includes 49 states (Hawaii was dropped because it did not grow any of the 16 crops chosen for this paper). The 16 crops were chosen based on the top subsidized and top produced field crops grown in the United States (Farm Bureau Financial). Tobacco was dropped because no data was available for acres planted. Dropping tobacco reduced the number of crops to 15. Following these drops, the number of observations in my sample fell from 1,000 to 980. Instead of using the statewide crop price, I used average national price to prevent problems occurring with states that did not grown any of that crop. The states that did not grow the specific crop would have a price of zero which would cause an error in the relationship between crop price and subsidies.

Using number of acres planted, I derived my dependent variable, Herfindahl-Hirschman Index (HHI).

$HHI = \sum_{i=1}^{n} S_i^2$ Where n = number of crops grown in $year_t$ and $S_i$ = crop's market share (1)

The Herfindahl- Hirschman is a measurement used by the Department of Justice, Federal Trade Commission, and state attorneys general to measure market concentration when evaluating company mergers. HHI is not about the number of crops grown in the state but rather the distribution of market share or in this case crop concentration. 10,000 is the maximum value. This would mean that a state is monoculture and grows only one crop in that one state. The minimum value is zero. This would mean that a state grows a little of almost every type of crop in the state. “A merger potentially raises ‘significant competitive concerns’ if it produces an increase in the HHI of more than 100 points in a moderately concentrated market.” An HHI of less than 1,500 is considered unconcentrated (Chin 2016).

I choose to use acres planted instead of acres harvested to capture the true intention of the farmer’s planting decision. This helps to control for variation from external factors that might cause a difference between acres planted and acres harvested. The variation would most likely cause a downward bias on the true effect of subsidies on amount of crops grown.

To estimate the effect of crop specific subsidies on crop portfolio diversity, I use the following empirical model that contains state fixed effects to control for invariant characteristics between states and across time.

$$HHI_{it} = \beta_0 + \beta_1 SUBSIDY_{it} + \beta_2 CROP\_PRICE_{it} + \beta_3\, AVERAGE\_TEMPERATURE_{it} + \beta_4\, DROUGHT\_SEVERITY_{it} + \beta_5 STATE\_FE_i + \varepsilon_{it}$$

*HHI* is the measure of crop market concentration, which comes from equation (1). *SUBSIDY* is the dollar value of a subsidy paid toward a specific crop in year t. *CROP_PRICE* is the real price received for a crop measured in dollars per lb., bushel, or cwt. *AVERAGE_TEMPERATURE* is the absolute value of the temperature’s deviation from the mean. This measurement is important because it measures the difference between the expected and actual temperature in degrees Fahrenheit. The absolute value equally weights the deviation since temperatures colder or warmer than expected both have an impact on crop growth. *DROUGHT_SEVERITY* is the Palmer Drought Severity Index (PDSI) value. This index reports moisture level of the earth's soil where zero is normal and -4 is extreme drought. Positive values mean higher than normal levels of moisture in the soil. Too much moisture in the soil can have equally adverse consequences on crop growth as drought does (Kanwar, Baker, Mukhtar 1998). Therefore, I use the absolute value of the PDSI value to give equal weight to both drought and over-saturation. *STATE_FE* are state fixed effects, and $\varepsilon_{it}$ is the normally distributed error term.

Looking at the summary statistics, the largest crop subsidy was corn, with a mean of $107 million. Wheat, cotton, soybean, and rice were also very large with average subsidies of $40, $ 36, $32, and $14 million. The smallest subsidies were Dry Peas, Oats, and Canola with averages of $34, $50, and $494 thousand. Two negative subsidies are found in the summary statistics. These two negative subsidy values come from 2003 South Dakota barley subsidies, and 2003 Delaware sorghum subsidies. The subsidies are negative because premiums paid by the farmers to the USDA risk management department were greater than the payout by the USDA for those specific crops, in SD. and DE. in that year. Potatoes and Hay did not receive any subsidies. The mean HHI, market share concentration measure, was 4,058.

**Summary Statistics**

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| State | 0 | 0 | 0 | 0 |
| Year | 2004.5 | 5.769226 | 1995 | 2014 |
| PDSI. Index | 1.6556 | 1.3724 | 0 | 7.38 |
| Temp Dev from mean°F | 0.9833 | 0.7614 | 0 | 4.4 |
| HHI | 4058.837 | 1812.524 | 1276.81 | 10000 |
| Barley_subsidy | 2,865,035 | 8,965,507 | -1,560,047 | 89,700,000 |
| Canola_subsidy | 494,105 | 4,099,084 | 0 | 64,000,000 |
| Corn_subsidy | 107,000,000 | 213,000,000 | 0 | 1,940,000,000 |
| Cotton_subsidy | 36,500,000 | 109,000,000 | 0 | 1,190,000,000 |
| Hay_subsidy | 0 | 0 | 0 | 0 |

| | | | | |
|---|---|---|---|---|
| Dry Peas_subsidy | 34,401 | 378,665 | 0 | 6,249,410 |
| Oats_subsidy | 50,370 | 3,59,565 | 0 | 6,666,593 |
| Peanut_subsidy | 3,971,452 | 21,700,000 | 0 | 491,000,000 |
| Potato_subsidy | 0 | 0 | 0 | 0 |
| Rice_subsidy | 14,600,000 | 58,700,000 | 0 | 677,000,000 |
| Sorghum_subsidy | 7,323,856 | 26,300,000 | -6,928 | 252,000,000 |
| Soybean_subsidy | 32,300,000 | 73,000,000 | 0 | 756,000,000 |
| Sugar beet_Subsidy | 143,574 | 1,725,581 | 0 | 34,400,000 |
| Sunflower_ Subsidy | 1,055,431 | 5,778,095 | | 79,600,000 |
| Wheat_subsidy | 40,800,000 | 77,100,000 | 0 | 683,000,000 |
| Barley_price | 3.50 | 1.52 | 1.95 | 6.69 |
| Canola_price | 15.96 | 7.24 | 0.00 | 30.87 |
| Corn_price | 4.07 | 1.91 | 2.13 | 8.74 |
| Cotton_price | 67.60 | 19.35 | 33.82 | 107.82 |
| Hay_price | 134.48 | 13.58 | 81.51 | 143.34 |
| Dry peas_price | 11.56 | 5.10 | 0.00 | 20.26 |
| Oats_price | 2.72 | 1.03 | 1.42 | 4.66 |
| Peanut_price | 0.28 | 0.06 | 0.20 | 0.43 |
| Potato_price | 8.45 | 2.70 | 5.07 | 13.24 |
| Rice_price | 12.00 | 5.14 | 4.78 | 20.82 |
| Sorghum_price | 6.61 | 3.27 | 3.14 | 14.80 |
| Soybean_price | 9.19 | 4.01 | 4.75 | 17.61 |
| Sugar beet_price | 50.80 | 14.69 | 33.67 | 85.44 |
| Sunflower-price | 18.78 | 8.61 | 7.99 | 36.03 |
| Wheat-price | 5.09 | 2.17 | 2.46 | 9.32 |

## V. Results

In this section, I report two sets of OLS crop diversification results: one with state level fixed effects and one without. To address concerns of heteroscedasticity, I use robust standard errors in both variations. The two results both have significant coefficients at the .05 type I error level for subsidy and price variables. The largest difference is in the adjusted R-squared. OLS with state level fixed effects has an adjusted R-squared of .965. Running the same model without state fixed effects returns an R-squared value of .167. This shows that state level fixed effects explains a large amount of variation in the model.

**Linear regression with state fixed effects**

Number of obs = 980
F( 30, 901) = 4.27
Prob > F = 0.0000
Adj R-squared = 0.9653
Root MSE = 337.4000

| Variable | Coefficient | Std. Error | t-Statistic | p-value | 95% Confident intervals | |
|---|---|---|---|---|---|---|
| Year | -2.007714 | 17.29983 | -0.12 | 0.908 | -35.96036 | 31.94493 |
| PDS Index | 7.263384 | 9.333012 | 0.78 | 0.437 | -11.05359 | 25.58036 |
| °F dev. From mean | -3.39993 | 20.82481 | -0.16 | 0.870 | -44.27071 | 37.47085 |
| Barley_subsidy | 0.00000145 | 3.60E-06 | 0.4 | 0.687 | -5.61e-06 | 8.51e-06 |
| Canola_subsidy | -0.0000223** | 0.0000109 | -2.05 | 0.040 | -.0000436 | -9.85e-07 |
| Corn_subsidy | 0.000000102 | 9.07E-08 | -1.13 | 0.261 | -2.80e-07 | 7.59e-08 |
| Cotton_subsidy | 0.000000289 | 1.80E-07 | 1.61 | 0.107 | -6.29e-08 | 6.42e-07 |
| Hay_subsidy | - | - | - | - | - | - |
| Dry Peas_subsidy | 0.0000354* | 0.0000191 | 1.86 | 0.064 | -2.00e-06 | .0000728 |
| Oats_subsidy | -0.0000748** | 0.0000239 | -3.13 | 0.002 | -.0001217 | -.0000279 |
| Peanut_subsidy | 0.00000146** | 5.08E-07 | 2.88 | 0.004 | 4.66e-07 | 2.46e-06 |
| Potato_subsidy | - | - | - | - | - | - |
| Rice_subsidy | -.000000919*** | 2.38E-07 | -3.87 | 0.000 | -1.38e-06 | -4.53e-07 |
| Sorghum_subsidy | 0.00000105 | 8.80E-07 | -0.23 | 0.822 | -1.93e-06 | 1.53e-06 |
| Soybean_subsidy | 0.00000105*** | 2.68E-07 | 3.92 | 0.000 | 5.26e-07 | 1.58e-06 |
| Sugar beet_Subsidy | -0.00000373 | 3.27E-06 | -1.14 | 0.255 | -.0000102 | 2.69e-06 |
| Sunflower_ Subsidy | 0.0000134** | 6.26E-06 | 2.13 | 0.033 | 1.07e-06 | .0000256 |
| Wheat_subsidy | -0.00000125** | 5.17E-07 | -2.41 | 0.016 | -2.26e-06 | -2.33e-07 |
| Barley_price | -34.95109 | 81.0801 | -0.43 | 0.667 | -194.0789 | 124.1767 |
| Canola_price | -16.9263** | 6.254845 | -2.71 | 0.007 | -29.20206 | -4.650538 |
| Corn_price | 83.28706 | 200.8556 | 0.41 | 0.678 | -310.9122 | 477.4864 |
| Cotton_price | 3.506568 | 2.811706 | 1.25 | 0.213 | -2.011688 | 9.024824 |
| Hay_price | -2.892213 | 2.543935 | -1.14 | 0.256 | -7.884941 | 2.100514 |
| Dry peas_price | 8.099798 | 14.67588 | 0.55 | 0.581 | -20.7031 | 36.9027 |
| Oats_price | -58.91206** | 20.95636 | -2.81 | 0.005 | 100.041 | -17.78309 |
| Peanut_price | -793.4014 | 751.9775 | -1.06 | 0.292 | -2269.233 | 682.43 |
| Potato_price | -36.22911* | 20.12677 | -1.8 | 0.072 | -75.72992 | 3.271696 |
| Rice_price | 22.88003** | 9.53074 | 2.4 | 0.017 | 4.174996 | 41.58507 |
| Sorghum_price | -19.44942 | 67.7826 | -0.29 | 0.774 | -152.4796 | 113.5807 |
| Soybean_price | -24.61833 | 6.160654 | 0.47 | 0.639 | -96.00346 | 46.7668 |
| Sugar beet_price | 2.887553 | 6.160654 | 0.47 | 0.639 | -9.20335 | 14.97846 |
| Sunflower_price | -33.20325 | 20.64353 | -1.61 | 0.108 | -73.71831 | 7.311821 |
| Wheat_price | 40.10713 | 88.00783 | 0.46 | 0.649 | -132.6171 | 212.8313 |

*** significant at .01

**Linear regression without State Fixed Effects**

Number of obs = 980
F( 31, 948) = 10.21

Prob > F = 0.0000
R-squared = 0.1669
Root MSE = 1681.2

| Variable | Coefficient | Standard Error | t-Statistic | P value | 95% Confidence interval | |
|---|---|---|---|---|---|---|
| Year | 32.1611 | 90.74127 | 0.35 | 0.723 | -145.9159 | 210.2381 |
| PDS Index | 180.0447*** | 28.89858 | 6.23 | 0.000 | 123.3321 | 236.7573 |
| °F Dev. from mean | 96.12742** | 56.63974 | 1.7 | 0.005 | -15.02634 | 207.2812 |
| Barley_subsidy | -0.0000101 | 8.87E-06 | -1.14 | 0.256 | -.0000275 | 7.33e-06 |
| Canola_subsidy | 0.0000272* | 0.0000162 | 1.68 | 0.094 | -4.59e-06 | .0000589 |
| Corn_subsidy | 2.69E-07 | 2.48E-07 | 1.08 | 0.279 | -2.19e-07 | 7.57e-07 |
| Cotton_subsidy | -2.31E-06*** | 5.70E-07 | -4.04 | 0.000 | 0.00000342 | -0.00000119 |
| Hay_subsidy | - | - | - | - | - | - |
| Dry Peas_subsidy | 0.0004676* | 0.0000773 | 6.05 | 0.000 | .0003159 | .0006194 |
| Oats_subsidy | -8.72E-06** | 0.0000799 | -0.11 | 0.913 | -.0001655 | .0001481 |
| Peanut_subsidy | -5.66E-06** | 2.41E-06 | -2.35 | 0.019 | -.0000104 | -9.35e-07 |
| Potato_subsidy | - | - | - | - | - | - |
| Rice_subsidy | -5.29E-06*** | 9.13E-07 | -5.79 | 0.000 | -7.08e-06 | -3.50e-06 |
| Sorghum_subsidy | -9.81E-06*** | 2.70E-06 | -3.64 | 0.000 | -.0000151 | -4.51e-06 |
| Soybean_subsidy | -2.36E-06** | 8.24E-07 | -2.87 | 0.004 | -3.98e-06 | -7.45e-07 |
| Sugar beet_Subsidy | -0.0000688*** | 0.0000156 | -4.41 | 0.000 | -.0000995 | -.0000382 |
| Sunflower_ Subsidy | -0.000083*** | 0.0000156 | -7.25 | 0.000 | -.0001055 | -.0000605 |
| Wheat_subsidy | 4.44E-06** | 1.41E-06 | 3.16 | 0.002 | 1.68e-06 | 7.20e-06 |
| Barley_price | -206.7345 | 439.9257 | -0.47 | 0.639 | -1070.075 | 656.6061 |
| Canola_price | -72.50976*** | 20.10843 | -3.61 | 0.000 | -2813.377 | 2301.908 |
| Corn_price | -255.7346 | 1303.278 | -0.2 | 0.844 | -2813.377 | 2301.908 |
| Cotton_price | -3.04271 | 14.84754 | -0.2 | 0.838 | -32.18055 | 26.09513 |
| Hay_price | 4.48319 | 16.25074 | 0.28 | 0.783 | -27.40839 | 36.37477 |
| Dry peas_price | 97.69435 | 80.74782 | 1.21 | 0.227 | -60.77079 | 256.1595 |
| Oats_price | 32.66686 | 118.3994 | 0.28 | 0.783 | -199.6884 | 265.0221 |
| Peanut_price | 3237.101 | 4013.233 | 0.81 | 0.42 | -4638.747 | 11112.95 |
| Potato_price | 9.871267* | 167.8436 | 0.06 | 0.953 | -319.5167 | 339.2593 |
| Rice_price | -90.47202* | 49.31765 | -1.83 | 0.067 | -187.2564 | 6.312364 |
| Sorghum_price | 58.84689 | 396.5533 | 0.15 | 0.882 | -719.3769 | 837.0706 |
| Soybean_price | 25.40146 | 198.7345 | 0.13 | 0.898 | -364.6089 | 415.4118 |
| Sugar beet_price | 18.96123 | 51.03113 | 0.37 | 0.71 | -81.18581 | 119.1083 |
| Sunflower_price | -83.07931 | 88.97438 | -0.93 | 0.351 | -257.6888 | 91.5302 |
| Wheat_price | 506.5073 | 765.2419 | 6.23 | 0.508 | -995.2566 | 2008.271 |
| _cons | -61420.62 | 179086 | -0.34 | 0.732 | -412871.4 | 290030.2 |

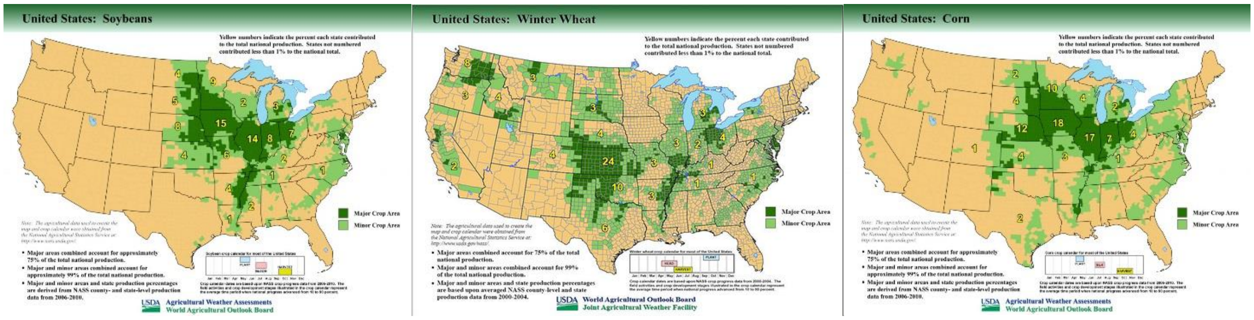
*** significant at .01 level

The rice and soybean subsidies were the most significant of my key variables. They are both significant at the .01 type I error level. The coefficient for rice is -9.19e-07. This means that for every dollar spent on rice specific subsidies HHI will decrease by –9.19e-07 which is an increase in the diversification of crops. The magnitude of this decrease is seen by multiplying the coefficient by the average rice subsidy. The average rice subsidy is $14.6 million. Therefore rice subsidies increases diversification by 13.4 HHI. This is a .3 percentage point increase in crop diversification. Canola, oats, and wheat subsidies also have negative coefficients and are all significant at the .o5 level.

Soybeans, peanuts and, sunflowers are significant at the .o5 level and have positive coefficients meaning, that an increase in those subsidies decrease crop diversification. Soybean was the most significant and had the largest magnitude with a coefficient of 1.05e-6, and a mean subsidy of $32 million. The impact of soybean subsidies is an increase of 33.9 HHI which is a .84 percentage point increase in crop diversification.

The real price variables for canola, oats, potatoes, and rice are statistically significant. These first three have negative coefficients, meaning that a $1 increase in the price of these crops decreases HHI. The decrease in HHI means an increase in crop diversification. For example, a $1 increase in canola per cwt. will decrease HHI by 16.9points. In contrast to the first three crops the coefficient of rice is positive; therefore, an increase in price of rice leads to an increase in HHI, decreasing the diversification of crops planted.

Not all crop subsidies have the same result. An increase in a subsidy for one crop may increase variety while an increase in another will reduce variety. In order to understand why subsidies either increase or decrease crop diversification, consider the impact soybeans, wheat, and corn have on crop diversification in the Corn Belt. Because these three crops are grown in the same region and the same type of soil, they provide a simplified context to understand this concept.




As one of the top two abundant crops, soybean subsidies will decrease diversification. Increasing soybean subsidies means less wheat and more soybean acres planted. *Soybean_subsidy* has a positive coefficient signaling a decrease in crop diversification. Although wheat is the third most grown crop in the United States, increasing wheat subsidies actually increases diversification because farmers replace the most abundantly grown crops, corn and soybean, with wheat (USDA 2016). The decrease is shown in the negative coefficient of *wheat_subsidy.* While both soybean and wheat are widely grown in the Corn Belt, when subsidized, the two crops have opposite effects on diversification.

## VI. Limitations

Corn was not significant in this model, most likely due to other forms of subsidies indirectly paid to farmers through energy mandates and tax breaks. These imitation subsidies are not captured in my model. The Renewable Fuel Standard mandate is a government-funded program that incentivizes the production of corn by providing tax credits to petroleum companies that blend ethanol with their fuel (Renewable Fuels Association 2016). These tax incentives, adopted in 2007, provide farmers approximately $10 million per year (Bryce 2016). Lark, Salamon, and Gibbs (2015) found that The Renewable Fuel Standard has a significant impact on the displacement of existing crop for corn production. In a later draft of this paper, I will include the annual $10 million in my model, which I believe will strengthen the correlation between corn subsidy and HHI, causing the coefficient of *corn-subsidy* to be significant.

I was unable to find data on farm productivity. One concern is that the omission of productivity as a variable in my model causes bias. In an effort to minimize this possible bias along with the bias caused by other immeasurable and invariable characteristics between states, I included state fixed effects in my model. This inclusion pushed the climate variable coefficients down. Drought severity index, which is not statistically significant with state fixed effects, is significant at the .01 type I error level in the model without state level fixed effects.

Measurement error of subsidies is another concern. My measure of crop subsidies includes both specific (direct) and non-specific (indirect) subsidies. A specific subsidy is a payment to a farmer to grow a certain crop. A non-specific subsidy is a payment to farmers regardless of what type of crop they plant. The problem is that while the inclusion of non-specific subsidies causes measurement error, the data I used made it is impossible to separate them from specific subsidies. For example, subsidized insurance premiums are non-specific and, therefore, do not depend on the type of crop planted. The independent relationship between the type of crop planted and the subsidized insurance premiums causes a noisy measurement and a downward bias on the coefficient for subsidies. Available aggregate data shows that subsidized insurance premiums can range from 3.5% (sorghum) to 73% (soybean) of subsidy payments depending on the crop. Knowing that this measurement error exists, subsidy effects found to be significant are likely more significant than they actually appear to be.

My model does not include a variable for the distribution of subsidies. Approximately 10-15% of farmers receive 85% of all farm subsidies (Smith and Goodman 2015). With this information comes the concern that the impact of subsidies on crop diversification would be immeasurably small. However, large farms account for 66% of output, due mostly to economies of scale. Using this knowledge and the knowledge that large farms receive 74% of all subsidies, it is safe to assume that the effect of subsidies on crop diversification will be measurable (Koba 2014).

Having an independent price variable and a quantity measure as a dependent variable causes simultaneity. To address this issue, I used a market concentration measure for my dependent variable instead of a direct measure of quantity. Some simultaneity still exists, but it is not as significant as if I used a direct quantity measure.

One final concern is the existence of negative multicollinearity between subsidy and crop price. An increase in subsidies for a particular crop will decrease the price of that crop and vise-versa. Many subsidies are triggered when a crop price falls below a certain threshold (Edwards 2016). I compared the correlation between the two variables for each crop. I found only slight correlation between each pair with the highest being .0992 between *cotton subsidy* and *cotton price*. Subsidy is my key variable, so I am unable drop it. If the correlation was strong enough, I would drop the price variable.

## VI. Conclusion

Crop specific subsidies significantly affect crop diversification. Farmers respond to the incentive of lower growing costs by replacing existing crops with the subsidized crops. Less diverse cropping systems and farm portfolios increase the probability of suffering from adverse consequences such as crop failure, blights, pests, frost, drought, and oversaturation.

An increase in the HHI of more than 100 points in a moderately concentrated market raises significant concerns about market concentration (Chin 2016). Over the 20 year span of my data, crop specific subsidies have increased HHI an average of 16.79 points. Wheat had the largest impact, decreasing HHI by 51points. Even with the limitations of noisy measurement error and the distribution of subsidies, the results are large in magnitude. With the ability to tease out this bias, the results recorded would carry even greater significance. When considering introducing, increasing, or decreasing subsidies, agriculture policy makers need to first consider the impact on diversification.

Bibliography

Aguilar J, Gramig GG, Hendrickson JR, Archer DW, Forcella F, et al. 2015 Crop Species Diversity Changes in the United States: 1978–2012. *PubMed Central* 10(8): e0136580.

Alan, Stern J., Paul C. Doraiswamy, and E. Raymond Hunt, Jr. (2013) *Journal of Applied Remote Sensing.*6:1-17

Babcock, Bruce A. and Fabiosa, Jacinto F. 2011. The Impact of Ethanol and Ethanol Subsidies on Corn Prices: Revisiting History. *CARD Policy Briefs.* Paper 1.

Bianchi, F.J.J.A, C.J.H Booij, and T Tscharntke. 2006. Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity and natural pest control. *Proceedings of the Royal Society B: Biological Sciences Journal.* 273(1595): 1715–1727.

Bryce, Robert. 2016 The Hidden Corn Ethanol Tax: How Much Does the Renewable Fuel Standard Cost Motorists? *Manhattan Institute*. (Accessed Nivember 18, 2017).

Bureau of Labor Statistics. 2016. Producer price indexes. https://www.bls.gov/ppi/ (Accessed November 18 2016).

Chin, Andrew. "Herfindahl-Hirschman Index (HHI) Calculator." Herfindahl-Hirschman Index (HHI) Calculator. University of North Carolina Law, Dec. 2010. Web. 20 Jan. 2017.

EWG. 2017. EWG's Farm Subsidy Database. https://farm.ewg.org/index.php (Accessed November 16, 2016)

Edwards, Chris. "Agricultural Subsidies." Downsizing the Federal Government. Cato Institute, 7 Oct. 2016. (Accessed November 19, 2016).

Irish Potato Famine And Trade (History). Published May 10, 1996 http://www1.american.edu/TED/POTATO.HTM. (Accessed January 6, 2017).

Kanwar, J. L. Baker, S. Mukhtar. 1998. Excessive Soil Water Effects at Various Stages of Development on the Growth and Yield of Corn. *Institute of Agriculture and Natural Resources.*

Koba, Mark. Meet the '4%': Small Number of Farms Dominates US. CNBC. CNBC, 06 May 2014. (Accessed November 18, 2016).

Lark, Tyler, J Meghan Salmon and Holly K Gibbs

2015. Cropland expansion outpaces agricultural and biofuel policies in the United States. *Environmental Research Letters*. 10(4)

Lin, Brenda B. 2011. Resilience in Agriculture through Crop Diversification: Adaptive Management for Environmental Change. *BioScience* 61.3 183-93.

grasslands and wetlands.

Meehan, Timothy D, and Claudio Gratton. 2015. A consistent positive association between landscape simplification and insecticide use across the Midwestern US from 1997 through 2012. *Environmental Research Letters.*(10)11

Monoculture and the Irish Potato Famine: Cases of Missing Genetic Variation. http://evolution.berkeley.edu/evolibrary/article/agriculture_02. N.d.(Accessed January 10, 2017).

NOAA National Centers for Environmental information, Climate at a Glance: U.S. Time Series, published November 2016. (Accessed on November 18, 2016)

Renewable Fuels Association. 2016. Tax Incentives. *Renewable Fuels Association*. (Accessed January 27, 2017).

Smith, Vincent H, and Robert W. Goodman. "Should Washington End Agriculture Subsidies?" WSJ. Wsj.com, 12 July 2015. (Accessed November 18, 2016).

Spratt, D.M. 1997. Endoparasite control strategies: Implications for biodiversity of native fauna. *International Journal for Parasitology*. (2):173-80.

Thompson, Robert. 1993. Agricultural Price Supports. Library of Economics and Liberty. http://www.econlib.org/library/Enc1/AgriculturalPriceSupports.html>. (Accessed January 19, 2017.

Top Crops in the States We Serve (Infographic). Www.beafarmbureauagent.com. Farm Bureau Financial Services, 15 Mar. 2016. (Accessed November 18, 2016).

USDA. United States Department of Agriculture National Agricultural Statistics Service, n.d. (Accessed November 12, 2016).

Wright CK, Wimberly MC. 2013 Recent land use change in the Western Corn Belt threatens Grasslands and Wetlands. *Proceedings of the National Academy of Sciences.* 110(10):1

Wu, J. and Adams, R. M. 2001. Production Risk, Acreage Decisions and Implications for Revenue Insurance Programs. *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie,* 49: 19–35.

Ye,Tao, Muneta Yokomatsu, Norio Okada.2012 Agricultural production behavior under premium subsidy: Incorporating crop price when subsistence constraint holds *International Journal of Disaster Risk Science*.3(3):131