Climate Impact on Agricultural Productivity

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Selected Poster prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August, 2012.

Climate Impact on Agricultural Productivity

Analysis on counties in Nebraska along the 41st parallel.

Abstract

Using linear programming data envelope analysis (DEA) I studied the impact that high temperatures have over the agricultural performance of counties in Nebraska. I have found that the incidence of high temperatures is no uniform for all the counties. There is an important negative incidence of temperatures over 32° Celsius during the growing season over agricultural performance on most counties, but for some counties this incidence is not significant.

Introduction

Since it has been a widespread accepted idea during the last decade that climate change is happening, and that some areas will have critical changes in temperatures, several authors have studied the impact that high temperatures may have over agriculture, one of the sectors that are more likely to be affected. Some of these studies have shown that the impact over crop yields will most likely be negative. This finding creates uncertainty about how an increasing world population is going to be fed during the next 50 years.

To shed some light over this issue, I analyze the impact of high temperatures on the performance of the agricultural sector for a set of counties in Nebraska. This, by using linear programming models to study the technical efficiency of counties in the selected area and how this efficiency may be affected and explained if we consider the effects that high temperatures may have over crop yields.

The method of analysis is Data Envelopment Analysis (DEA), which I use to infer the boundaries of a possible feasible technology set from the observed points in the data. With this, I estimate a (C,S) Graph Measure of Technical Efficiency (GMTE) for each county with and without considering the effects of high temperatures.

Results show that there is a negative impact of degree days (DDs) on agricultural technical efficiency for some of the counties but not for all of them. Average annual precipitations, irrigation and levels of DDs were analyzed to try to explain why some counties have a greater impact than others, but results are not conclusive. Other differences among counties like different types of soil or groundwater usages may the reason for the no uniform impact of degree days, but it is left for a future possible extension of this article.

Data

Area of study

The area of study corresponds to selected counties in the state of Nebraska along the 41st parallel. The period of analysis is between 1988 and 2008. The data for the study is county-level agricultural biomass output, fertilizers and chemicals used, nonirrigated and irrigated harvested area and weather variables. Agricultural data was reported by the U.S. Department of Agriculture's National Agricultural Statistical Service (USDA-NASS) and the climatology data was reported by the United States Historical Climatology Network.

Figure 1 – Selected counties in Nebraska

Dependent Variable

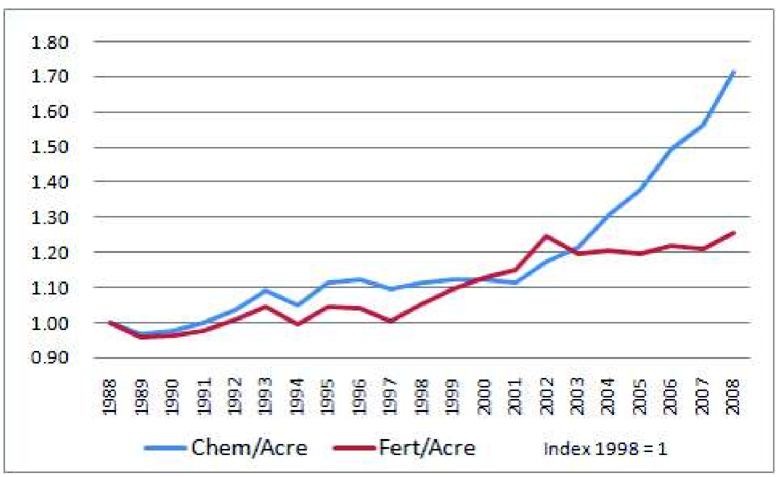
As a dependent variable it was used total county-level agricultural biomass output. Biomass consists in the total weight of agricultural crop production measured in tons for each year from 1988 to 2008. The data is reported by the U.S. Department of Agriculture's National Agricultural Statistical Service (USDA-NASS). The most important commodities produced in the selected counties were, in order of importance, Corn, Soybean, Wheat and Hay, with greater concentration on these in the last decades. To convert to tons from bushels it was used a coefficient of 0.0254 for Corn, Sorghum and Rye and 0.027216 for Wheat and Soybeans.

Fertilizers

Fertilizers include commercial fertilizers, lime, and soil conditioners including rock phosphate and gypsum. Data was obtained from the CENSUS OF AGRICULTURE reported by USDA, National Agricultural Statistics Service. Since the data are expenses in monetary value, to obtain real quantities the values were converted using the price index of fertilizers published by USDA-NASS[1] and since the census is made every five years, the missing years where estimated using a linear interpolation method. Price indexes were applied to the census year's data to convert these into real quantity values, then these values for the census years were linearly interpolated to obtain the missing years, thus, an inelastic demand for Fertilizers is assumed during the years with no census.

Chemicals

Chemicals includes insecticides, herbicides, fungicides, and other pesticides. Data was obtained from the CENSUS OF AGRICULTURE reported by USDA, National Agricultural Statistics Service. As these values were also reported as expenses in monetary value and every five years, it was done a treatment similar to that of fertilizers to obtain yearly real quantities, an inelastic demand for fertilizers is also assumed.



Graph 1 – Chemicals and Fertilizers use

Non Irrigated Harvested Acres

This item was reported by the U.S. Department of Agriculture's National Agricultural Statistical Service (USDA-NASS). Consists in total harvested area that is not irrigated by county by year for every crop.

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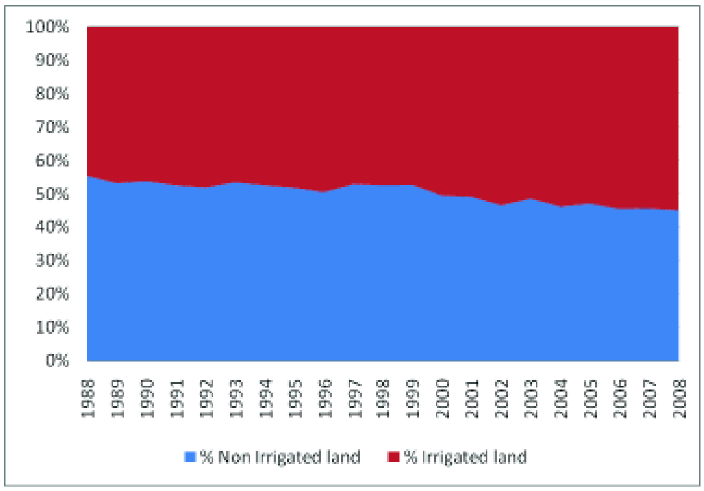
1 http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1002

Irrigated Harvested Acres

This item was reported by the U.S. Department of Agriculture's National Agricultural Statistical Service (USDA-NASS). Consists in total harvested area that is irrigated by county by year for every crop.

Graph 2 shows the evolution of the percentages of irrigated and non irrigated land in Nebraska for the selected counties from 1988 to 2008. Irrigated harvested land went from an average of 45% in 1988 to 55% in 2008.

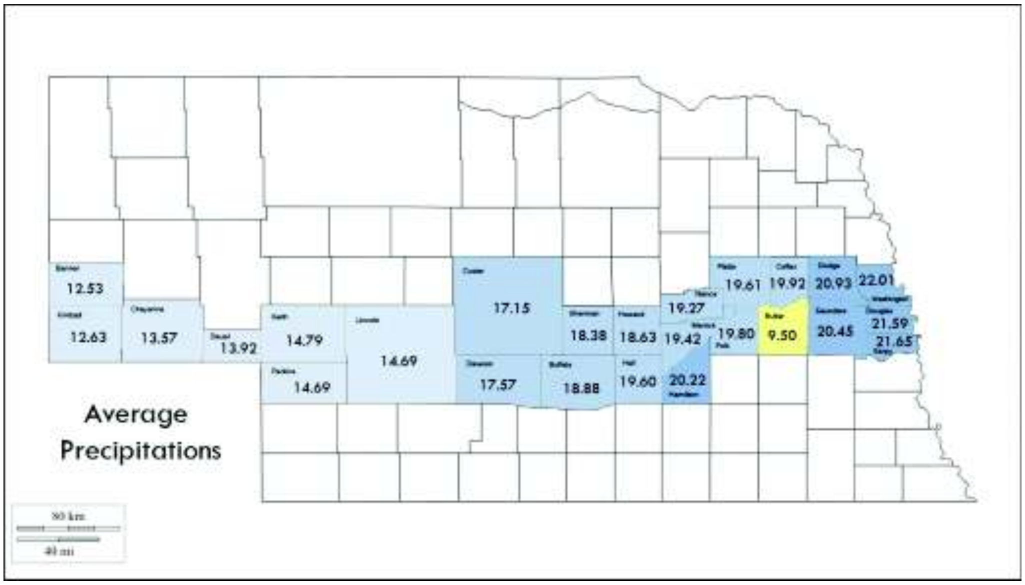


Graph 2

Weather data

Weather data includes two items, precipitations and a variable that accounts for high temperatures affecting the crops: "degree days" (DDs). DDs are a measure of how much (in degrees), and for how long (in days), the outside air temperature was above a certain level.

With respect to precipitations, initial regressions showed a relative significant (10%) negative effect of precipitations on Crop Yields along the period analyzed, using or not counties as dummy variables (Regression 1b in the appendix). This result may be misleading, since counties in the data set have been affected by an important flooding that occurred in most of the corn belt during 1993. If we ignore this year in the estimation, regressions show that the effect of precipitations on Crop Yields is positive and significant (5%) if we include the County dummy variables and positive but not significant if we do not include the County dummy variables. Results for this regression may be seen in table 1 in the appendix.



For degree days, to implement this item I followed Schlenker and Roberts (2009). They found that there is a nonlinear relationship between temperatures and yields, where yield growth is benefited from warm temperatures up to 29-32° Celsius, but decreases sharply for temperatures higher than 32°C. To measure this effect I estimated the degree days (DDs) variable in a similar way Schlenker and Roberts did. One DD is defined as one degree above 32° Celsius temperature during a 24 hours period (1 DD = 24 Degree Hours). If during 36hs the temperature was 34°C, for that period the total quantity of DDs is going to be equal to three ((34-32)x36/24=3). I also tried dividing the DDs in two variables, one to account for temperatures above 32°C but below 34°C and other for temperatures of 34°C and above, where the sum of these two variables equals the original single DDs. Results in this case are similar to the ones using only one DDs variable, thus only the single DDs variable estimation is followed in this study.

From the maximum and the minimum temperatures for each day I used a single sine wave method to estimate how many hours during each day the temperatures were at each value above 32° Celsius. This technique uses a day's minimum and maximum temperatures to produce a single sine curve over a 24-hour period, and then estimates DDs for that day by calculating the area above the threshold and below the curve. This method assumes the temperature curve is symmetrical around the maximum temperature[2]. When the minimum temperature is over 32°C, the degree-days are simply calculated as the mean of the maximum and the minimum minus 32. If the maximum temperature is less than 32°C, then there are zero degree-days. When the 32°C is between the minimum and the maximum the single sine wave method was used following R.L. Snyder[3] (2001). This method was applied to each day during the relevant months of the growing season. Schlenker et al (2009) method is more complex, it includes predictions of temperatures on a 2.5 x 2.5 mile grid along US up to the 100° west meridian. Even though the variable I am using is less complex, my regressions of this variable against yield per acre showed that this variable is significant at a 1% level, with the sign of the coefficient negative. For the relevant months of the growing season, after regressing different range combinations, the most significant range was found to be April to August.

All the daily weather variables, precipitations and temperatures, were collected from the United States Historical Climatology Network[4]. They report daily data on maximum/minimum temperatures and precipitations, obtained from different weather stations along US. The value for each county was constructed from the five closest stations to each county using a Sheppard's inverse distance weighting function with a power weighting parameter equal to two (p = 2).

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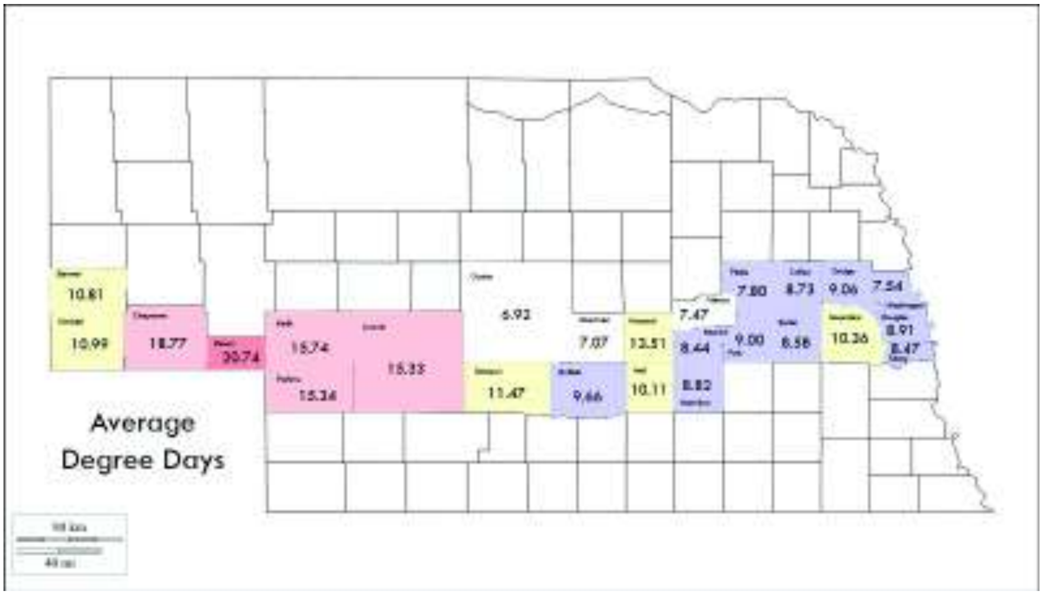
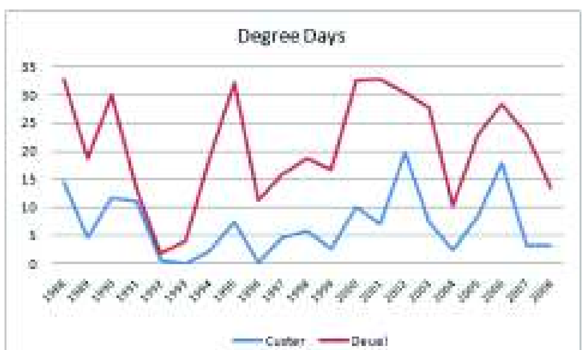
[2] http://www.ipm.ucdavis.edu/WEATHER/ddconcepts.html#note

[3] http://biomet.ucdavis.edu/DegreeDays/DDhand.htm

[4] http://cdiac.ornl.gov/epubs/ndp/ushcn/access.html



Graph 2 shows the values for the Degree Days (DDs) variable for two of the selected counties. Deuel has the highest average of degree days in the sample with 20.74 days in average every year. In the other extreme, Custer has the lowest average of heating days, accounting for 6.92 days in average every year. Counties in the West have generally the highest temperatures but also the highest daily temperature range between the maximum and the minimum.



Graph 2 – DDs for Deuel and Custer counties

Regression 1 in the appendix shows the significance of the chosen dependent variables over production per acre. Fertilizers and Chemicals are significant with the expected sign at a 1% and 10% significance level respectively, degree days variable (DDs32) is also significant at 1% with a negative coefficient, precipitations is significant at 5% confidence level with a positive sign in the coefficient and County dummy variables are also significant for most of the counties. County dummies significance reflects not accounted variables that are different for each county, like soil type or humidity. Since creating dummy variables for each county decreases the amount of degrees of freedom, I did another regression with a mixed model using random effects to account for the different characteristics that each county may have. Results are in Regression 2 in the appendix and show not significant difference between the two estimations.

Table 1 in the appendix has summary statics about the variables used.

Method

Following Färe, Grosskopf and Lovell (1994) I used data envelopment analysis (DEA) to infer the boundaries of a feasible technology set from the observed points. This method allows us to infer efficient combinations of inputs and outputs without knowing the technology of production but doing two assumptions, one about the returns of scale and other about the disposability of inputs and outputs. In this case, the technology of production is assumed to be of constant returns to scale and the disposability is assume to be strong for Biomass and for Chemicals, Fertilizers, Non Irrigated and Irrigated Area and Precipitations, and weak for the Degree Days variable. Strong disposability means that the inputs can be increased without decreasing the output and weak disposability means that increases in the input decrease the output.

For the estimations without considering heating days, the graph reference set is defined satisfying constant returns to scale and strong disposability of outputs. This is,

$$(GR|C,S) = \{(x,u): u \leqq zM, zN \leqq x, z \in \Re_{+}^{N}\}, u \in \Re_{+}^{M}, x \in \Re_{+}^{N} \qquad (1)$$

Where u denotes the vector of desirable outputs, x the vector desirable inputs, z the vector of intensity variables, N is the matrix of observed inputs (Fertilizers, Chemicals, Precipitation and Non irrigated and

Irrigated Area) and M is a vector of the observed outputs (Biomass). The Graph of the technology is the collection of all feasible input output vectors.

From the Graph can be defined the function (C,S) Graph Measure of Technical Efficiency (GMTE) as

$$F_g\left(x^j, u^j \middle| C, S\right) = min\left\{\lambda: \left(\lambda x^j, \lambda^{-1} u^j\right) \in (GR|C,S)\right\}, j = 1,2 \dots J \qquad (2)$$

For observation j, this measure computes the ratio of the maximum equiproportionate input reduction and output expansion in (GR | C,S) to itself. A level of 1 indicates that the observation is on the boundary and is efficient, and values less than 1 denote inefficiency. To find this measure I solved the following linear programming problem

$$\left(F_g\left(x^j, u^j \middle| C, S\right)\right)^2 = min_{\Gamma, z'} \Gamma \qquad (3)$$

$$s.t. u^j \leqq z'M$$

$$z'N \leqq \Gamma x^j$$

$$z' \in \Re_+^J$$

where $\Gamma = \lambda^2$ and z'= λz.

When considering degree days, the graph reference set is defined as

$$(GR|C,S,W^H) = \{(x,y,u): u \leqq zM, zN \leqq x, y \leqq zN_h \; z \in \Re_+^N\}, u \in \Re_+^M, x \in \Re_+^N \qquad (4)$$

Where N_h is the vector of observed heating days and y is the vector of undesirable inputs. The linear programming problem solved in this case was

$$\left(F_g\left(x^j, y^j, u^j \middle| C, S\right)\right)^2 = min_{\Gamma, z'} \Gamma \qquad (5)$$

$$s.t. \; u^j \leqq z'M$$

$$z'N \leqq \Gamma x^j$$

$$\Gamma y^j \leqq z'N_h$$

$$z' \in \Re_+^J$$

I first estimated the (C,S) Graph Measure of Technical Efficiency (GMTE) for each county across years without considering observations of other counties, and without considering DDs variable (Equation 3). Then I added DDs as an undesirable input and estimated a new (C,S) GMTE that contemplates the temperatures (Equation 5).

Second I tried a transversal estimation. I estimated the (C,S) GMTE (Equation 3) for the set of selected counties, one estimation across counties for each year in the sample independently of other years, without considering the degree days variable first and then incorporating it into the estimation (Equation 5). This transversal measure helps to study efficiency among counties and how high temperatures affect in a different way to each other.

Results

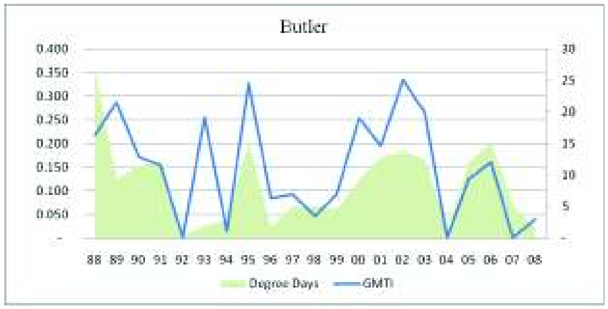
The results from the first estimation of the (C,S) Graph Measure of Technical Efficiency (GMTE) can be seen in Table 2 in the appendix, a subset of it can be seen in Table 2a. This table shows the measure for the counties considered during the period analyzed, 1988 to 2008. It also includes a Measure of Technical Inefficiency (GMTI), defined as one minus the efficiency measure estimated, and the degree days for each year. This last measure tell us the percentage increase in the inputs used during that year that would be required to produce the same amount of output than in the most efficient years (GMTE=1).

Table 2a

County	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Butler	GMTE	0.78	0.71	0.83	0.85	1.00	0.75	0.99	0.67	0.92	0.91	0.95	0.91	0.75	0.81	0.67	0.74	1.00	0.88	0.84	1.00	0.96
	GMTI	0.22	0.29	0.17	0.15	0.00	0.26	0.02	0.33	0.08	0.09	0.05	0.09	0.25	0.20	0.34	0.27	0.00	0.13	0.16	0.00	0.04
	Degree Days	26.88	9.33	11.43	12.34	0.31	1.97	2.66	15.09	1.65	5.07	5.05	4.58	9.25	12.82	13.84	12.45	1.63	12.02	15.24	5.09	1.64
Deuel	GMTE	0.95	0.83	0.96	1.00	0.90	0.96	1.00	1.00	1.00	0.85	1.00	1.00	0.90	0.80	0.95	1.00	0.88	0.80	0.85	1.00	1.00
	GMTI	0.05	0.17	0.04	0.00	0.10	0.04	0.00	0.00	0.00	0.15	0.00	0.00	0.10	0.20	0.05	0.00	0.12	0.20	0.15	0.00	0.00
	Degree Days	32.85	18.69	29.94	13.23	1.81	3.97	18.80	32.30	11.17	15.98	18.68	16.69	32.55	32.75	30.34	27.78	10.17	23.01	28.47	22.86	13.50
Douglas	GMTE	0.94	0.91	0.96	0.94	1.00	0.69	1.00	0.67	0.90	1.00	0.93	0.91	0.86	0.91	0.71	0.74	1.00	0.92	0.86	1.00	1.00
	GMTI	0.06	0.09	0.04	0.06	0.00	0.32	0.00	0.33	0.10	0.00	0.07	0.09	0.14	0.09	0.29	0.26	0.00	0.08	0.14	0.00	0.00
	Degree Days	25.43	9.07	10.70	7.50	0.06	0.91	0.98	16.70	2.12	5.78	6.64	8.60	8.48	10.77	20.69	15.32	1.32	11.47	14.48	7.96	2.17
Merrick	GMTE	1.00	0.99	0.98	1.00	0.89	0.70	0.96	0.81	1.00	0.94	0.95	0.91	0.80	0.94	0.89	0.96	1.00	0.96	0.98	1.00	0.91
	GMTI	0.00	0.01	0.02	0.00	0.11	0.30	0.05	0.19	0.00	0.06	0.05	0.09	0.20	0.06	0.11	0.04	0.00	0.04	0.02	0.00	0.09
	Degree Days	22.51	7.46	9.01	14.46	0.18	0.74	2.31	15.57	2.08	7.68	7.12	5.28	10.65	14.14	17.39	10.81	2.01	7.52	12.85	5.33	2.11
Perkins	GMTE	0.85	0.81	0.89	0.86	0.83	0.82	0.82	0.73	0.85	0.81	1.00	1.00	0.94	0.95	1.00	1.00	1.00	0.89	1.00	0.98	1.00
	GMTI	0.15	0.19	0.11	0.14	0.17	0.18	0.18	0.27	0.15	0.19	0.00	0.00	0.06	0.05	0.00	0.00	0.00	0.11	0.00	0.02	0.00
	Degree Days	24.63	12.75	24.95	13.18	2.02	2.20	11.01	22.80	3.79	10.40	13.27	10.26	23.66	21.37	30.66	19.37	7.36	20.38	24.41	12.15	11.39
Sarpy	GMTE	0.91	0.66	0.99	0.94	1.00	0.78	1.00	0.57	0.93	1.00	0.93	1.00	0.81	0.78	0.50	0.80	1.00	0.93	0.77	0.89	0.86
	GMTI	0.09	0.34	0.01	0.06	0.00	0.22	0.00	0.43	0.07	0.00	0.07	0.00	0.19	0.22	0.50	0.21	0.00	0.07	0.23	0.11	0.14
	Degree Days	23.82	8.52	10.05	7.19	0.01	0.69	0.77	15.84	1.82	4.84	6.72	8.54	8.17	10.03	20.67	15.37	1.46	11.12	13.65	6.86	1.85

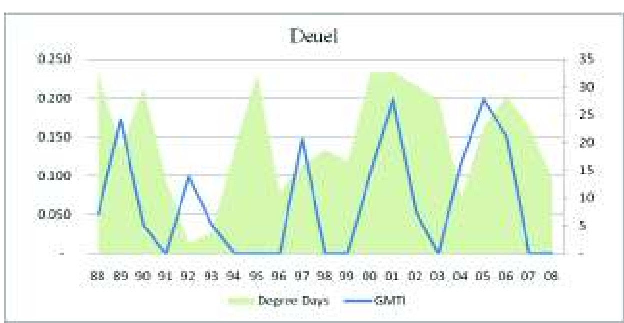
Table 2 shows the evolution of the GMTE and GMTI during the period analyzed. For Butler, years 1992, 2004 and 2007 have a value of 1.000, this tells us that the observations of those years are on the boundary of the Graph Reference Set (GR) and that the use of the inputs was efficient comparing with the other years. All the other "inefficient" years are going to be measured against these years. Observations for 1995 and 2002 with values of GMTE under 0.700 show the most inefficient years. This means that during the most efficient years, production in Butler needed less than 70% of the inputs of the most inefficient years to produce the same amount of output. Or seen it from a productivity perspective and recalling the assumption of constant returns to scale, the most efficient years where at least 43% more productive (1/0.700) than the most inefficient years, this is, with the same amount of input they were able to produce 43% more in the most efficient years than in the less efficient ones.

Looking at the temperatures during the period analyzed, the average value of degree days for the whole period was 8.6. Efficient years 1992, 2004 and 2007 have low values of DDs, 0.3, 1.64 and 5.1 respectively. Inefficient years 1995 and 2002 have values over the average, but with different intensity; 1995 at 15.1 has a DDs value that almost doubles the average and 2002 is a little lower at 13.8 but still much greater than the average. The year with the highest DDs value is 1988 with 26.88DDs and with a GMTE far from the boundary at 0.77.



Graph 2

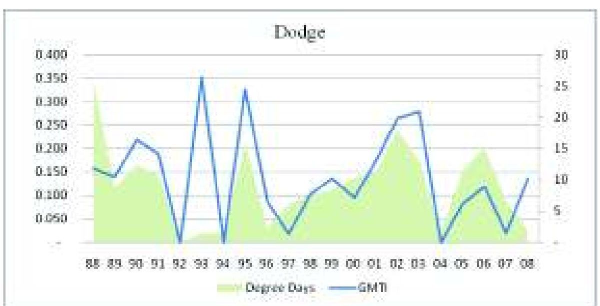
Graph 2 shows the Inefficiency Measure (GMTI) and the corresponding degree days (DDs) for each year for Butler. In the first axis are the GMTI values and in the secondary axis the DDs values. The graph helps us to visualize the relation between both variables. In most years increases in the DDs variable are corresponded with increases in inefficiency, showing that the GMTI is correlated with the DDs values for most of the years but not all. The fact that for some years increases in GMTI are not corresponded with increases in DDs is because inefficiency in those years was motivated by a different cause. The most important case is year 1993, with a very low value of DDs (1.97) but with a high inefficiency measure (0.26), this would imply that inefficiency during this year may be explained by different causes than high temperatures. Indeed, this year corresponds to an important flooding that occurred in most of Nebraska, so inefficiencies are going to be observed for that year in most of the counties. On the other side, there is no year with a GMTI lower than 0.100 with DDs values higher than 5.5DDs. Thus, in Butler county high levels of DDs seem to be a sufficient but not necessary condition for inefficiency.



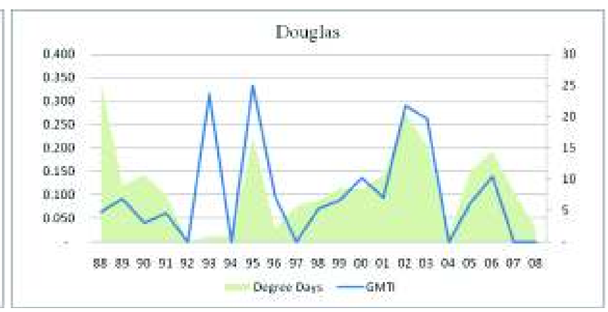
Graph 3

Butler has one of the lowest average DD values in the sample. In the other extreme, Graph 3 shows the evolution of the GMTI and degree days for Deuel. Deuel is the county that consistently has higher DDs values. The years that delimited the boundary for this county were 1991, 1994, 1995, 1996, 1998, 1999, 2003, 2007 and 2008. The most inefficient years were 1989, 2001, and 2005, all with values of GMTI between 0.170 and 0.200. Since the Graph Measure of Technical Efficiency is a relative measure, for the analysis it should be considered the average DDs for Deuel, this measure for the period analyzed was 20.74. Looking at the efficient years, it does not seem to be a relation of DDs and efficiency since efficient years 1995, 2003 and 2007 have higher DDs than the average. For the inefficient years, years 1989 was below the average, but 2001 and 2005 were above the average. Thus, for this county it does not seem that the degree days variable has a negative effect over agricultural technical efficiency.

Graphs 4 and 5 shows the same graphs for other 2 counties included in the study.



Graph 4



Graph 5

Significance of Degree Days explaining Inefficiency

To test for the significance of this relation we first have must remember that the GMTE is a relative measure, so we should not join carelessly results from the different counties. To solve this problem I tried two different approaches. First, I estimated GMTI not as a function of the DDs, but as a function of its deviation from the mean. Variable DDDev in Regression 3 is the deviation of the DDs of each year from the mean of the 21 years period for each county. Results show that DDDev is very significant (1%) explaining changes in GMTI.

```
Call:
glm(formula = GMTI ~ DDDev, data = ineff2)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.14520  -0.06421  -0.02143   0.04724   0.37897

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 0.0783830  0.0038152  20.545  < 2e-16 ***
DDDev       0.0033340  0.0005722   5.826 1.02e-08 ***
```

Regression 3

Another test I made is considering a random effect model to account for the different characteristics of each county and avoiding loosing so many degrees of freedom by using dummy variables. Regression 4 shows that DDs is still significant at 1% level.

```
Linear mixed model fit by REML
Formula: GMTI ~ DDs + (1 | County) + (0 + DDs | County)
   Data: ineff2
   AIC   BIC logLik deviance REMLdev
 -1096 -1075    553    -1127   -1106
Random effects:
 Groups   Name        Variance   Std.Dev.
 County   (Intercept) 0.0000e+00 0.0000000
 County   DDs         1.3466e-05 0.0036696
 Residual             5.5363e-03 0.0744064
Number of obs: 500, groups: County, 25

Fixed effects:
             Estimate Std. Error t value
(Intercept) 0.0412311  0.0063164   6.528
DDs         0.0039240  0.0008947   4.386

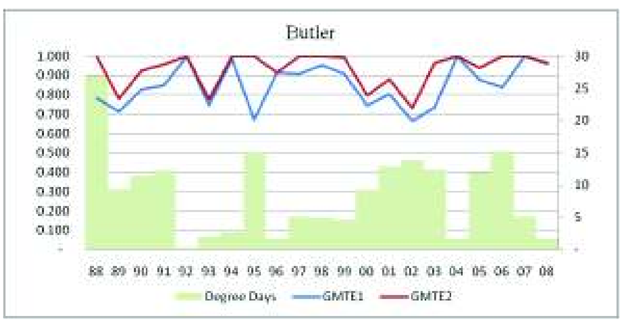
Correlation of Fixed Effects:
    (Intr)
DDs -0.482
```

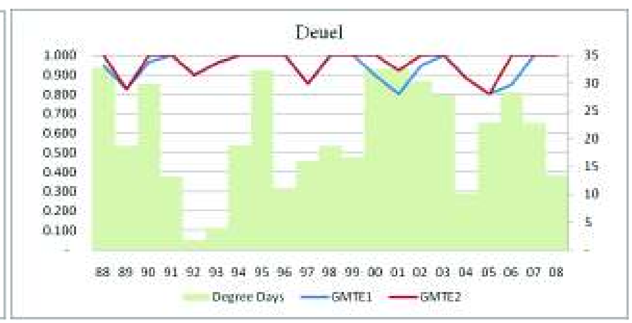
Regression 4

Since the results seem to vary among counties I used a fixed effects model to test for the significance of DDs for each county. The results of this test are in Regression 4 in the appendix. For this test DDs was found significant for some but not all the counties. It was significant (5%) for 10 counties, where 9 of them are the most eastern counties in the sample. For the remaining 15 counties, results were not significant. Following the analysis I have done before, results show that DDs was significant for Butler, but not for Deuel.

Degree Days and GMTE

Since DDs was found significant explaining changes in efficiency. I re estimated the GMTE including DDs as an undesirable weakly disposable input following equation 5. Results are in table 3 in the appendix, GMTE1 is the measure without the DDs variable, and GMTE2 is the measure with DDs. Years that were efficient under measure GMTE1 will be still efficient, but some years with high temperatures that where inefficient now will be on the boundary. The idea of this estimation is to account for a more wide measure of technical efficiency given that degree days is an input that is given and has weak disposability. Graph 6 and 7 show the results for Butler and Deuel respectively.





Changes in the line GMTE2 from the line GMTE1 explain the amount of "inefficiency" that was due DDs. The results that we saw before about the significance of DDs for each the counties are reflected here. Since for Deuel we found that DDs is not significant explaining the observed inefficiency during the period, the GMTE2 line is going to be mostly on the GMTE1 line. For Butler, the GMTE2 generally is more close to one than GMTE1.

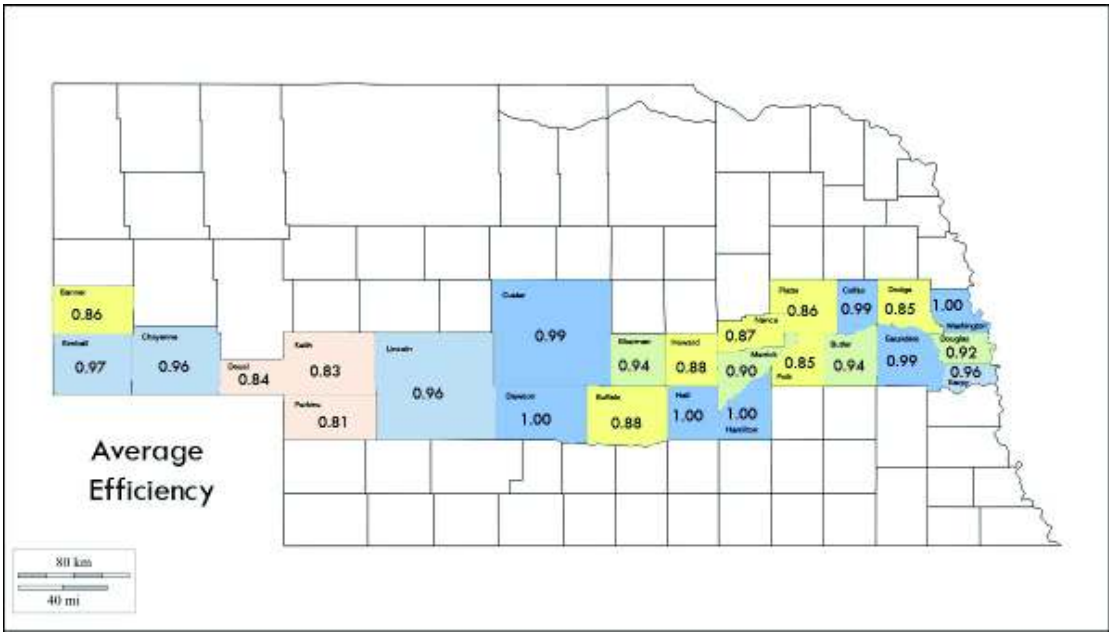
The years were the GMTE2 is still lower than 1, are years where the reason of the inefficiency is not related with high temperatures. Looking at Butler we see many years where now the GMTE2 has a value of 1, this shows us that the reasons of the inefficiencies during those years were related with high temperatures during the growing season. For example, the GMTE1 value for 1995 is equal to 0.672 and the GMTE2 is equal to 1.000. The DDs observed during this year were equal to 15.09, considering that the mean DDs value for this county was 8.58 (2.5 for the efficient years), this extra 6.51 DDs (12.59 DDs from the efficient years) generated a decrease in efficiency of 32.8% or a decrease in productivity of 48.8%. Along the total period analyzed, the average loss of efficiency for Butler county explained by high temperatures was equal to 8.23%, or from the productivity side, DDs generated a loss in production of 11.32%.

Degree Days across counties

To analyze efficiency among counties I did a transversal estimation for each year across counties (usually referred to as contemporaneous technology boundary). The results for this (C,S) Graph Measure of Technical Efficiency (GMTE) with and without considering the DDs variable are in Table 4 in the appendix. The measure creates a different boundary every year by comparing the observations of all the counties.

Table 4 shows that some counties are consistently more efficient than others. Taking an average of the GMTE for the 21 years, the most efficient counties (average GMTE over 0.98) are: Custer, Colfax, Dawson, Hall, Hamilton, Saunders and Washington; all of them are in the East or Center of Nebraska. Another characteristic of this counties, all but Hall, is that they are counties where the DDs variable was found to be highly significant to explain changes in efficiency. This may mean that the most efficient counties are the ones that are more sensitive to changes in temperatures.

Among the most inefficient counties are Perkins, Keith and Deuel with GMTE values of 0.81, 0.83 and 0.84 respectively. A 0.81 GMTE value for Perkins means that a county on the boundary, say Custer, was able, in average, to produce the same amount of output with 19% less inputs than those used by Perkins. Some characteristics of these three inefficient counties are that they are located one next to the other, in the center west of Nebraska, they all have average precipitations below the average of the sample and they are among the counties with higher DDs, they have in average more than 17DDs per year, this is 7DDs more than the average in the sample.



Following a similar procedure than the previous analysis. I included into the DEA analysis the degree days variable following equation 5. Results of the estimation are in Table 5 in the appendix. To the group of most efficient counties mentioned before, now we have to add Cheyenne, Deuel, Kimball and Lincoln counties. Three of this counties have average DDs values 50% higher than the average of the sample, and the remaining county, Lincoln, is on the average. This result tells us that the main reason of the relative inefficiency of these counties with respect to the most efficient ones was related with the higher average temperatures that they had during the period considered. For example, the increase in the GMTE value for Deuel from 0.843 when not considering the DDs to 1.000 tells us that the 15.7% of average inefficiency with respect to the most efficient counties was due to the high average value of DDs observed (it doubles the average) during the period analyzed.

Conclusions

I may highlight two conclusions from this article. First, the negative effect over crop yields of an increasing number of days during the growing season where the maximum temperatures were over 32 degrees Celsius (89.2 °F) can be observed from an efficiency side. The behavior of the (C,S) Graph Measure of Technical Efficiency was affected in a negative way for the counties altogether, but only for 10 of the 25 counties analyzed, the quantity of DDs was found to be very significant to explain inefficiencies. For the remaining counties there may be other different factors that may be affecting the efficiency. In his analysis, Schlenker did not consider counties to the west of the meridian 100° West, because higher level of irrigation may affect incidence, this may be a reason why the significance of the DDs regression on Inefficiency decays when going west.

Second, using the parallel (C,S) Graph Measure of Technical Efficiency (GMTE) that compares between counties, I showed how this method of analysis may be misleading to categorize efficiency among counties if we don't take into account the differences in climate impact that affect each county. Counties that consistently are inefficient when higher temperatures are not considered, generally have greater increases in efficiency than counties that are closer to the boundary when the DDs variable is considered. Nevertheless further analysis is required to have more significant conclusions about the reasons of why some counties do not seem to be affect by high temperatures, other variables that may be affecting the GMTE should be considered.

There are several variables that may explain changes in efficiency that have not been considered and may be considered in a future extension of this article. For example, the Standardized Precipitation Index (SPI) was found highly significant to explain crop yields (Regression 5 appendix), this variable may be included as another weak disposable input to help us to understand how climate impacts on agricultural efficiency.

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Appendix

Regression 1 – Significance of chosen variables over production per acre (year 1993 omitted).

```
Call:
glm(formula = Prod.by.Acre ~ Fert.by.Acre + Chem.by.Acre + DDs32 +
    Prec + County, data = signif2)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.79359  -0.18071   0.01823   0.17902   0.60241

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)       1.190213   0.093179  12.773  < 2e-16 ***
Fert.by.Acre      3.263482   0.639163   5.106 4.79e-07 ***
Chem.by.Acre      1.207822   0.679922   1.776   0.0763 .
DDs32            -0.015863   0.001922  -8.254 1.56e-15 ***
Prec              0.007041   0.003450   2.041   0.0418 *
CountyBuffalo     1.128259   0.114575   9.847  < 2e-16 ***
CountyButler      0.721959   0.087093   8.290 1.20e-15 ***
CountyCheyenne    0.070428   0.085823   0.821   0.4123
CountyColfax      0.810503   0.093703   8.650  < 2e-16 ***
CountyCuster      1.149906   0.100323  11.462  < 2e-16 ***
CountyDawson      1.922429   0.099472  19.326  < 2e-16 ***
CountyDeuel      -0.045766   0.086134  -0.531   0.5954
CountyDodge       0.495104   0.091524   5.410 1.01e-07 ***
CountyDouglas     0.226593   0.098084   2.310   0.0213 *
CountyHall        1.421937   0.126458  11.244  < 2e-16 ***
CountyHamilton    1.463716   0.096372  15.188  < 2e-16 ***
CountyHoward      1.063837   0.121863   8.730  < 2e-16 ***
CountyKeith       0.658847   0.100567   6.551 1.50e-10 ***
CountyKimball    -0.102185   0.085011  -1.202   0.2300
CountyLincoln     1.012217   0.110720   9.142  < 2e-16 ***
CountyMerrick     0.725907   0.150914   4.810 2.03e-06 ***
CountyNance       0.662783   0.101989   6.499 2.07e-10 ***
CountyPerkins     0.411985   0.097199   4.239 2.71e-05 ***
CountyPlatte      0.657293   0.106856   6.151 1.64e-09 ***
CountyPolk        0.958572   0.094687  10.124  < 2e-16 ***
CountySarpy       0.206032   0.092624   2.224   0.0266 *
CountySaunders    0.520374   0.088265   5.896 7.13e-09 ***
CountySherman     1.042821   0.101772  10.247  < 2e-16 ***
CountyWashington  0.410008   0.090261   4.542 7.07e-06 ***
```

Regression 1 b– Significance of chosen variables over production per acre (year 1993 included).

```
Call:
glm(formula = Prod.by.Acre ~ Fert.by.Acre + Chem.by.Acre + DDs32 +
    Prec, data = signif)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-2.71532  -0.30924  -0.01261   0.28795   1.62438

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)   1.181410   0.109891  10.751  < 2e-16 ***
Fert.by.Acre  7.207149   0.391049  18.430  < 2e-16 ***
Chem.by.Acre  2.341015   0.706245   3.315 0.000981 ***
DDs32        -0.021178   0.003083  -6.870 1.84e-11 ***
Prec         -0.007941   0.004315  -1.840 0.066299 .
```

Regression 2 – Significance of chosen variables over production per acre (year 1993 omitted) using mixed models.

```
Linear mixed model fit by REML
Formula: Prod.by.Acre ~ Fert.by.Acre + Chem.by.Acre
+ DDs32 + Prec + (1 |      County) + (0 + Fert.by.Acre | County) +
(0 + Chem.by.Acre |      County) + (0 + DDs32 | County) + (0 + Prec | County)


   Data: signif2
   AIC   BIC logLik deviance REMLdev
 192.7 239.1 -85.37    150.5   170.7
Random effects:
 Groups   Name         Variance   Std.Dev.
 County   (Intercept)  2.2509e-01 0.474436
 County   Fert.by.Acre 9.7144e-02 0.311679
 County   Chem.by.Acre 3.3026e+00 1.817301
 County   DDs32        1.5076e-04 0.012279
 County   Prec         2.4276e-05 0.004927
 Residual              5.8106e-02 0.241051
Number of obs: 500, groups: County, 25

Fixed effects:
              Estimate Std. Error t value
(Intercept)   1.764688   0.147448  11.968
Fert.by.Acre  3.662268   0.598943   6.115
Chem.by.Acre  1.146335   0.751713   1.525
DDs32        -0.017151   0.003091  -5.548
Prec          0.009054   0.003647   2.482

Correlation of Fixed Effects:
            (Intr) Frt..A Chm..A DDs32
Fert.by.Acr -0.502
Chem.by.Acr  0.106 -0.606
DDs32       -0.124 -0.102  0.065
Prec        -0.411  0.141 -0.233  0.200
```

Table 1 – Summary statistics

```
      County         Year        Production       Nonirrig.Harv.Acres
 Banner  : 21   Min.   :1988   Min.   :  93005   Min.   : 23300
 Buffalo : 21   1st Qu.:1993   1st Qu.: 345801   1st Qu.: 61600
 Butler  : 21   Median :1998   Median : 580004   Median : 91000
 Cheyenne: 21   Mean   :1998   Mean   : 624431   Mean   :111540
 Colfax  : 21   3rd Qu.:2003   3rd Qu.: 883515   3rd Qu.:163200
 Custer  : 21   Max.   :2008   Max.   :1555721   Max.   :291800
 (Other) :399
 Irrig.Harv.Acres  Fertilizers       Chemicals         DDs32
 Min.   :  2600   Min.   :  6.98   Min.   : 3.757   Min.   : 0.01392
 1st Qu.: 39300   1st Qu.: 30.11   1st Qu.:15.483   1st Qu.: 4.56140
 Median :100400   Median : 46.94   Median :27.078   Median : 9.98923
 Mean   :110048   Mean   : 49.71   Mean   :29.664   Mean   :10.78705
 3rd Qu.:176800   3rd Qu.: 70.26   3rd Qu.:41.910   3rd Qu.:14.99306
 Max.   :267100   Max.   :140.69   Max.   :98.348   Max.   :33.55322

      Prec
 Min.   : 0.3129
 1st Qu.:14.7493
 Median :17.9214
 Mean   :18.1692
 3rd Qu.:20.8964
 Max.   :45.2381
```

Table 2 – GMTE and GMTI without considering degree days.

Table 2

County	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Banner	GMTE	0.92	0.87	0.91	1.00	1.00	0.96	1.00	0.93	0.87	0.92	0.83	0.98	0.76	0.86	0.77	0.74	0.70	0.98	0.82	0.70	1.00
	GMTI	0.08	0.14	0.09	0.00	0.00	0.04	0.00	0.07	0.13	0.08	0.17	0.02	0.24	0.14	0.23	0.26	0.30	0.02	0.18	0.30	0.00
	Degree Days	12.35	12.55	12.30	8.97	1.34	2.32	10.63	20.05	6.53	7.15	8.29	7.16	14.95	15.75	21.19	19.29	7.01	9.89	12.73	11.09	5.60
Buffalo	GMTE	0.90	0.91	0.99	1.00	1.00	0.76	1.00	0.84	0.99	0.95	1.00	1.00	0.97	0.96	1.00	1.00	1.00	1.00	0.99	1.00	0.90
	GMTI	0.10	0.09	0.01	0.00	0.00	0.25	0.00	0.16	0.01	0.06	0.00	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.01	0.00	0.10
	Degree Days	21.78	7.44	14.33	19.12	0.54	1.01	3.75	16.18	1.50	10.21	8.13	5.98	11.27	13.24	22.44	12.20	2.93	9.87	11.77	6.02	3.17
Butler	GMTE	0.78	0.71	0.83	0.85	1.00	0.75	0.99	0.67	0.92	0.91	0.95	0.91	0.75	0.81	0.67	0.74	1.00	0.88	0.84	1.00	0.96
	GMTI	0.22	0.29	0.17	0.15	0.00	0.26	0.02	0.33	0.08	0.09	0.05	0.09	0.25	0.20	0.34	0.27	0.00	0.13	0.16	0.00	0.04
	Degree Days	26.88	9.33	11.43	12.34	0.31	1.97	2.66	15.09	1.65	5.07	5.05	4.58	9.25	12.82	13.84	12.45	1.63	12.02	15.24	5.09	1.64
Cheyenne	GMTE	0.93	0.76	0.84	0.77	0.89	0.71	1.00	1.00	0.95	0.88	0.99	0.98	0.93	0.84	0.92	0.98	0.94	0.83	0.94	1.00	1.00
	GMTI	0.08	0.24	0.16	0.23	0.11	0.29	0.00	0.00	0.06	0.12	0.01	0.02	0.07	0.16	0.08	0.02	0.06	0.17	0.06	0.00	0.00
	Degree Days	27.00	19.29	24.07	11.97	1.31	3.61	16.54	28.87	10.34	14.90	16.30	15.42	30.21	29.46	28.80	25.96	8.96	20.41	26.64	22.49	11.60
Colfax	GMTE	0.76	0.84	0.86	0.77	1.00	0.72	0.95	0.68	0.94	0.93	1.00	0.92	0.83	0.91	0.73	0.80	1.00	0.87	0.88	1.00	0.84
	GMTI	0.24	0.17	0.14	0.23	0.00	0.28	0.05	0.33	0.06	0.07	0.00	0.08	0.17	0.09	0.27	0.20	0.00	0.13	0.12	0.00	0.17
	Degree Days	26.10	9.19	11.84	12.76	0.17	1.24	2.54	16.42	1.88	5.81	6.29	5.66	9.77	12.90	14.45	11.21	1.72	10.95	15.04	5.59	1.86
Custer	GMTE	0.80	0.69	0.92	0.84	0.94	0.83	0.93	0.79	0.96	0.91	1.00	1.00	0.83	1.00	1.00	0.98	0.95	0.96	1.00	1.00	0.89
	GMTI	0.20	0.32	0.08	0.16	0.06	0.18	0.08	0.21	0.04	0.09	0.00	0.00	0.17	0.00	0.00	0.03	0.05	0.04	0.00	0.00	0.11
	Degree Days	14.54	4.56	11.64	11.15	0.54	0.07	2.26	7.54	0.22	4.72	5.78	2.66	10.06	7.04	19.71	7.40	2.50	8.52	17.85	3.24	3.29
Dawson	GMTE	0.93	1.00	1.00	0.98	0.83	0.82	1.00	0.83	0.95	0.92	1.00	0.97	0.98	1.00	1.00	1.00	0.99	0.96	1.00	1.00	0.90
	GMTI	0.07	0.00	0.00	0.02	0.17	0.18	0.00	0.17	0.05	0.08	0.00	0.03	0.02	0.00	0.00	0.01	0.01	0.04	0.00	0.00	0.10
	Degree Days	24.82	8.09	17.80	15.74	0.44	0.64	3.28	17.76	1.13	8.60	10.83	6.56	16.44	16.45	25.23	13.27	5.80	15.00	20.90	9.06	3.14
Deuel	GMTE	0.95	0.83	0.96	1.00	0.90	0.96	1.00	1.00	1.00	0.85	1.00	1.00	0.90	0.80	0.95	1.00	0.88	0.80	0.85	1.00	1.00
	GMTI	0.05	0.17	0.04	0.00	0.10	0.04	0.00	0.00	0.00	0.15	0.00	0.00	0.10	0.20	0.05	0.00	0.12	0.20	0.15	0.00	0.00
	Degree Days	32.85	18.69	29.94	13.23	1.81	3.97	18.80	32.30	11.17	15.98	18.68	16.69	32.55	32.75	30.34	27.78	10.17	23.01	28.47	22.86	13.50
Dodge	GMTE	0.84	0.86	0.78	0.81	1.00	0.65	1.00	0.67	0.91	0.98	0.90	0.86	0.91	0.83	0.74	0.72	1.00	0.92	0.88	0.98	0.86
	GMTI	0.16	0.14	0.22	0.19	0.00	0.35	0.00	0.33	0.09	0.02	0.10	0.14	0.10	0.17	0.26	0.28	0.00	0.08	0.12	0.02	0.14
	Degree Days	25.78	8.78	12.43	10.66	0.11	1.39	1.58	15.90	2.35	6.11	7.65	8.33	10.31	11.20	17.96	12.93	1.55	11.59	15.14	6.56	1.86
Douglas	GMTE	0.94	0.91	0.96	0.94	1.00	0.69	1.00	0.67	0.90	1.00	0.93	0.91	0.86	0.91	0.71	0.74	1.00	0.92	0.86	1.00	1.00
	GMTI	0.06	0.09	0.04	0.06	0.00	0.32	0.00	0.33	0.10	0.00	0.07	0.09	0.14	0.09	0.29	0.26	0.00	0.08	0.14	0.00	0.00
	Degree Days	25.43	9.07	10.70	7.50	0.06	0.91	0.98	16.70	2.12	5.78	6.64	8.60	8.48	10.77	20.69	15.32	1.32	11.47	14.48	7.96	2.17
Hall	GMTE	0.89	0.98	0.97	0.99	0.94	0.69	0.97	0.82	0.96	0.89	0.91	0.85	0.92	0.96	1.00	1.00	1.00	0.98	0.96	1.00	0.88
	GMTI	0.11	0.02	0.04	0.02	0.06	0.31	0.03	0.18	0.04	0.12	0.09	0.15	0.08	0.04	0.00	0.00	0.00	0.03	0.05	0.00	0.12
	Degree Days	27.55	8.19	15.12	20.16	0.66	1.33	3.51	14.55	1.51	8.82	7.05	5.58	11.49	13.92	23.52	13.05	3.06	13.52	12.18	4.31	3.11
Hamilton	GMTE	0.92	1.00	0.99	1.00	0.97	0.67	0.95	0.82	1.00	0.94	0.96	0.95	0.90	0.96	1.00	0.96	1.00	1.00	0.94	1.00	0.98
	GMTI	0.09	0.00	0.01	0.00	0.03	0.33	0.05	0.18	0.00	0.06	0.04	0.05	0.10	0.04	0.00	0.04	0.00	0.00	0.06	0.00	0.02
	Degree Days	24.92	6.75	12.48	17.64	0.20	1.27	2.03	14.72	2.41	8.19	8.55	5.75	8.55	12.14	16.96	11.12	1.99	9.14	11.80	5.87	2.65
Howard	GMTE	0.87	1.00	1.00	1.00	0.94	0.80	1.00	0.77	0.99	0.86	1.00	0.95	1.00	0.96	1.00	0.95	0.92	1.00	1.00	1.00	0.93
	GMTI	0.13	0.00	0.00	0.00	0.06	0.20	0.00	0.23	0.01	0.14	0.00	0.05	0.00	0.04	0.00	0.05	0.08	0.00	0.00	0.00	0.07
	Degree Days	22.08	7.49	10.03	18.37	0.53	1.29	3.72	19.19	2.41	12.46	10.85	9.52	22.21	25.20	33.55	19.08	8.30	19.11	23.93	10.65	3.73
Keith	GMTE	0.84	0.83	0.83	0.91	0.77	0.78	0.80	0.72	0.79	0.94	1.00	1.00	0.97	1.00	1.00	0.99	1.00	0.91	0.99	1.00	1.00
	GMTI	0.16	0.17	0.17	0.09	0.24	0.22	0.20	0.28	0.21	0.06	0.00	0.00	0.03	0.00	0.00	0.01	0.00	0.09	0.01	0.00	0.00
	Degree Days	26.30	13.77	24.99	12.53	1.36	1.88	10.82	24.28	4.26	11.13	14.24	10.55	23.83	23.19	29.41	20.28	7.73	20.91	24.70	14.22	10.26
Kimball	GMTE	0.87	0.78	0.95	1.00	0.97	1.00	1.00	1.00	0.94	0.78	0.92	1.00	0.81	1.00	1.00	1.00	1.00	0.95	1.00	1.00	1.00
	GMTI	0.13	0.22	0.05	0.00	0.04	0.00	0.00	0.00	0.06	0.22	0.08	0.00	0.19	0.00	0.00	0.00	0.00	0.05	0.00	0.00	0.00
	Degree Days	12.20	11.91	12.10	9.99	2.15	3.06	12.53	22.01	7.22	6.93	7.81	7.16	14.74	15.47	22.75	20.61	7.91	8.46	10.34	9.85	5.61
Lincoln	GMTE	0.98	0.85	0.96	1.00	1.00	0.90	1.00	0.82	0.88	0.90	1.00	0.93	0.96	1.00	1.00	1.00	1.00	0.93	0.91	0.98	0.89
	GMTI	0.02	0.15	0.04	0.00	0.00	0.10	0.00	0.18	0.12	0.10	0.00	0.07	0.05	0.00	0.00	0.00	0.00	0.07	0.09	0.02	0.11
	Degree Days	24.63	12.75	24.95	13.18	2.02	2.20	11.01	22.80	3.79	10.40	13.27	10.26	23.66	21.37	30.66	19.37	7.36	20.38	24.41	12.15	11.39
Merrick	GMTE	1.00	0.99	0.98	1.00	0.89	0.70	0.96	0.81	1.00	0.94	0.95	0.91	0.80	0.94	0.89	0.96	1.00	0.96	0.98	1.00	0.91
	GMTI	0.00	0.01	0.02	0.00	0.11	0.30	0.05	0.19	0.00	0.06	0.05	0.09	0.20	0.06	0.11	0.04	0.00	0.04	0.02	0.00	0.09
	Degree Days	22.51	7.46	9.01	14.46	0.18	0.74	2.31	15.57	2.08	7.68	7.12	5.28	10.65	14.14	17.39	10.81	2.01	7.52	12.85	5.33	2.11
Nance	GMTE	0.81	1.00	0.91	0.94	1.00	0.82	1.00	0.72	0.95	1.00	1.00	0.90	0.99	0.89	0.83	0.77	0.96	1.00	1.00	1.00	1.00
	GMTI	0.19	0.00	0.09	0.06	0.00	0.18	0.01	0.28	0.05	0.00	0.00	0.11	0.01	0.12	0.17	0.23	0.04	0.00	0.00	0.00	0.00
	Degree Days	21.70	8.02	7.58	12.93	0.17	0.60	2.22	13.54	1.57	6.14	5.69	4.64	9.85	12.66	15.57	9.37	1.61	6.03	11.42	3.64	1.93
Perkins	GMTE	0.85	0.81	0.89	0.86	0.83	0.82	0.82	0.73	0.85	0.81	1.00	1.00	0.94	0.95	1.00	1.00	1.00	0.89	1.00	0.98	1.00
	GMTI	0.15	0.19	0.11	0.14	0.17	0.18	0.18	0.27	0.15	0.19	0.00	0.00	0.06	0.05	0.00	0.00	0.00	0.11	0.00	0.02	0.00
	Degree Days	24.63	12.75	24.95	13.18	2.02	2.20	11.01	22.80	3.79	10.40	13.27	10.26	23.66	21.37	30.66	19.37	7.36	20.38	24.41	12.15	11.39
Platte	GMTE	0.93	0.85	0.88	0.86	1.00	0.74	0.95	0.73	0.82	0.90	1.00	0.91	0.93	0.87	0.86	0.82	1.00	0.94	0.99	1.00	0.91
	GMTI	0.07	0.15	0.12	0.15	0.00	0.26	0.06	0.28	0.18	0.10	0.00	0.09	0.07	0.13	0.14	0.19	0.00	0.06	0.01	0.00	0.09
	Degree Days	24.49	9.10	8.81	13.00	0.19	0.51	2.43	15.65	1.86	5.89	5.90	4.80	10.07	12.70	14.99	10.07	1.35	6.23	11.20	3.31	1.40
Polk	GMTE	0.90	0.81	0.91	1.00	1.00	0.78	0.97	0.81	0.98	0.97	0.99	0.90	0.87	0.96	0.88	0.89	1.00	1.00	0.92	1.00	0.85
	GMTI	0.10	0.19	0.09	0.00	0.00	0.22	0.04	0.20	0.02	0.03	0.01	0.10	0.13	0.04	0.12	0.11	0.00	0.00	0.08	0.00	0.15
	Degree Days	25.62	8.40	11.51	14.99	0.19	0.93	2.58	17.41	2.73	7.80	7.97	6.03	10.10	13.45	15.62	10.76	1.89	8.76	14.10	6.03	2.32
Sarpy	GMTE	0.91	0.66	0.99	0.94	1.00	0.78	1.00	0.57	0.93	1.00	0.93	1.00	0.81	0.78	0.50	0.80	1.00	0.93	0.77	0.89	0.86
	GMTI	0.09	0.34	0.01	0.06	0.00	0.22	0.00	0.43	0.07	0.00	0.07	0.00	0.19	0.22	0.50	0.21	0.00	0.07	0.23	0.11	0.14
	Degree Days	23.82	8.52	10.05	7.19	0.01	0.69	0.77	15.84	1.82	4.84	6.72	8.54	8.17	10.03	20.67	15.37	1.46	11.12	13.65	6.86	1.85
Saunders	GMTE	0.87	0.85	0.93	0.89	1.00	0.72	0.94	0.59	0.85	0.83	0.96	0.90	0.80	0.87	0.72	0.75	1.00	0.91	0.88	0.98	0.86
	GMTI	0.13	0.15	0.07	0.11	0.00	0.28	0.06	0.41	0.15	0.17	0.04	0.10	0.20	0.13	0.28	0.25	0.00	0.10	0.12	0.02	0.14
	Degree Days	27.57	9.87	13.07	12.31	0.15	1.37	1.74	18.43	2.35	6.66	7.60	8.87	11.28	13.50	21.06	14.77	2.11	14.50	18.43	9.25	2.72
Sherman	GMTE	0.93	0.88	0.92	0.98	0.99	0.79	1.00	0.84	1.00	0.92	1.00	1.00	0.94	0.93	1.00	1.00	0.97	1.00	1.00	1.00	0.96
	GMTI	0.07	0.12	0.08	0.02	0.02	0.21	0.00	0.16	0.00	0.09	0.00	0.00	0.06	0.07	0.00	0.00	0.03	0.00	0.00	0.00	0.04
	Degree Days	14.87	5.29	9.65	12.75	0.28	0.22	1.85	11.31	0.55	6.48	4.27	3.77	9.68	9.83	16.95	8.47	2.82	8.36	13.99	4.26	2.91
Washington	GMTE	0.86	0.94	0.89	0.89	1.00	0.78	0.98	0.65	0.89	1.00	0.97	0.93	1.00	0.86	0.80	0.85	1.00	0.95	0.94	1.00	1.00
	GMTI	0.14	0.06	0.11	0.11	0.00	0.22	0.02	0.35	0.11	0.00	0.03	0.07	0.00	0.15	0.20	0.15	0.00	0.05	0.06	0.00	0.00
	Degree Days	24.21	8.00	9.55	6.43	0.09	0.75	1.11	14.63	1.68	5.01	5.08	6.88	5.96	9.19	15.68	12.36	0.93	9.71	12.73	6.58	1.68

Regression 4 – Effect of DDs on GMTI using a fixed effect model

```
Call:
  Model: GMTI ~ DDs | NULL
   Data: ineff2

Coefficients:
   (Intercept)
              Estimate Std. Error    t value    Pr(>|t|)
Banner      0.025156704 0.04098883  0.6137454 0.539693685
Buffalo     0.013366015 0.03149802  0.4243446 0.671517327
Butler      0.034727582 0.02863673  1.2126938 0.225883137
Cheyenne    0.091076521 0.04413563  2.0635602 0.039632315
Colfax      0.024155955 0.02954771  0.8175238 0.414061799
Custer      0.078413877 0.02806362  2.7941473 0.005425894
Dawson      0.056410543 0.03216587  1.7537392 0.080155969
Deuel       0.047189659 0.04393182  1.0741566 0.283328131
Dodge       0.033484978 0.03011160  1.1120291 0.266719382
Douglas     0.003141277 0.02892422  0.1086037 0.913565245
Hall        0.058946977 0.02952235  1.9966899 0.046460780
Hamilton    0.017735357 0.03016877  0.5878713 0.556913537
Howard      0.040189117 0.03191148  1.2593935 0.208541059
Keith       0.116852849 0.03885372  3.0075074 0.002781588
Kimball     0.072381936 0.03926559  1.8433935 0.065928961
Lincoln     0.055283919 0.03857704  1.4330785 0.152529772
Merrick     0.048489572 0.03029521  1.6005692 0.110174144
Nance      -0.010005767 0.02913756 -0.3433975 0.731459790
Perkins     0.115209451 0.03857704  2.9864776 0.002976171
Platte      0.054302944 0.02832754  1.9169664 0.055875139
Polk        0.035006155 0.03052674  1.1467375 0.252099506
Sarpy       0.017636713 0.02858621  0.6169657 0.537569366
Saunders    0.052777103 0.03057857  1.7259504 0.085042752
Sherman     0.022445418 0.03070203  0.7310727 0.465115262
Washington  0.005003680 0.02800632  0.1786625 0.858283115

   DDs
              Estimate  Std. Error     t value     Pr(>|t|)
Banner      8.636919e-03 0.003330851  2.59300681 9.823940e-03
Buffalo     1.697665e-03 0.002647757  0.64117105 5.217380e-01
Butler      1.215745e-02 0.002610624  4.65691374 4.231428e-06
Cheyenne   -4.853115e-04 0.002092775 -0.23189849 8.167223e-01
Colfax      1.114516e-02 0.002678709  4.16064703 3.802492e-05
Custer      3.699724e-04 0.003109139  0.11899516 9.053323e-01
Dawson     -1.553005e-03 0.002289241 -0.67839298 4.978713e-01
Deuel       8.902923e-04 0.001883658  0.47264008 6.366991e-01
Dodge       9.918118e-03 0.002656472  3.73356720 2.130007e-04
Douglas     9.584628e-03 0.002537906  3.77658858 1.803281e-04
Hall       -5.187361e-05 0.002310521 -0.02245104 9.820981e-01
Hamilton    2.242609e-03 0.002735182  0.81991197 4.127004e-01
Howard      2.132109e-04 0.001926768  0.11065731 9.119374e-01
Keith      -1.943841e-03 0.002134944 -0.91048818 3.630525e-01
Kimball    -1.811750e-03 0.003121717 -0.58036958 5.619559e-01
Lincoln    -2.741462e-04 0.002175427 -0.12601951 8.997728e-01
Merrick     9.928768e-04 0.002866744  0.34634301 7.292468e-01
Nance       9.935807e-03 0.003057335  3.24982560 1.241348e-03
Perkins    -1.573334e-03 0.002175427 -0.72322999 4.699143e-01
Platte      4.771947e-03 0.002802283  1.70287863 8.928130e-02
Polk        3.691213e-03 0.002716676  1.35872408 1.749147e-01
Sarpy       1.345309e-02 0.002619240  5.13625910 4.181971e-07
Saunders    7.224764e-03 0.002370507  3.04777140 2.441204e-03
Sherman     1.996052e-03 0.003475823  0.57426730 5.660739e-01
Washington  9.529709e-03 0.002857417  3.33507850 9.233261e-04
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Table 3 – GMTE with and without considering DDs as an input.

Table 3																						
County	Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Banner	GMTE1	0.92	0.87	0.91	1.00	1.00	0.96	1.00	0.93	0.87	0.92	0.83	0.98	0.76	0.86	0.77	0.74	0.70	0.98	0.82	0.70	1.00
	GMTE2	0.97	0.95	0.96	1.00	1.00	0.96	1.00	1.00	0.87	0.92	0.83	0.98	0.81	1.00	1.00	1.00	0.70	1.00	0.93	0.72	1.00
Buffalo	GMTE1	0.90	0.91	0.99	1.00	1.00	0.76	1.00	0.84	0.99	0.95	1.00	1.00	0.97	0.96	1.00	1.00	1.00	1.00	0.99	1.00	0.90
	GMTE2	1.00	0.91	1.00	1.00	1.00	0.76	1.00	0.90	0.99	0.95	1.00	1.00	0.97	0.97	1.00	1.00	1.00	1.00	1.00	1.00	0.90
Butler	GMTE1	0.78	0.71	0.83	0.85	1.00	0.75	0.99	0.67	0.92	0.91	0.95	0.91	0.75	0.81	0.67	0.74	1.00	0.88	0.84	1.00	0.96
	GMTE2	1.00	0.78	0.93	0.96	1.00	0.78	1.00	1.00	0.92	1.00	1.00	0.99	0.80	0.88	0.73	0.96	1.00	0.94	1.00	1.00	0.96
Cheyenne	GMTE1	0.93	0.76	0.84	0.77	0.89	0.71	1.00	1.00	0.95	0.88	0.99	0.98	0.93	0.84	0.92	0.98	0.94	0.83	0.94	1.00	1.00
	GMTE2	1.00	0.76	0.88	0.77	0.89	0.71	1.00	1.00	0.95	0.88	0.99	0.98	1.00	1.00	1.00	1.00	0.94	0.83	1.00	1.00	1.00
Colfax	GMTE1	0.76	0.84	0.86	0.77	1.00	0.72	0.95	0.68	0.94	0.93	1.00	0.92	0.83	0.91	0.73	0.80	1.00	0.87	0.88	1.00	0.84
	GMTE2	1.00	0.93	0.98	0.89	1.00	0.72	0.97	0.82	0.95	0.95	1.00	0.92	0.91	1.00	0.85	0.87	1.00	0.99	1.00	1.00	0.84
Custer	GMTE1	0.80	0.69	0.92	0.84	0.94	0.83	0.93	0.79	0.96	0.91	1.00	1.00	0.83	1.00	1.00	0.98	0.95	0.96	1.00	1.00	0.89
	GMTE2	1.00	0.70	0.96	0.95	0.94	0.83	0.93	0.84	0.96	0.91	1.00	1.00	0.83	1.00	1.00	0.98	0.95	0.96	1.00	1.00	0.89
Dawson	GMTE1	0.93	1.00	1.00	0.98	0.83	0.82	1.00	0.83	0.95	0.92	1.00	0.97	0.98	1.00	1.00	1.00	0.99	0.96	1.00	1.00	0.90
	GMTE2	1.00	1.00	1.00	1.00	0.83	0.82	1.00	0.87	0.95	0.92	1.00	0.97	0.98	1.00	1.00	1.00	0.99	0.96	1.00	1.00	0.90
Deuel	GMTE1	0.95	0.83	0.96	1.00	0.90	0.96	1.00	1.00	1.00	0.85	1.00	1.00	0.90	0.80	0.95	1.00	0.88	0.80	0.85	1.00	1.00
	GMTE2	1.00	0.83	1.00	1.00	0.90	0.96	1.00	1.00	1.00	0.85	1.00	1.00	1.00	0.93	1.00	1.00	0.88	0.80	1.00	1.00	1.00
Dodge	GMTE1	0.84	0.86	0.78	0.81	1.00	0.65	1.00	0.67	0.91	0.98	0.90	0.86	0.91	0.83	0.74	0.72	1.00	0.92	0.88	0.98	0.86
	GMTE2	1.00	0.92	0.85	0.86	1.00	0.66	1.00	0.80	0.93	1.00	0.97	0.92	0.98	0.91	0.92	0.83	1.00	1.00	1.00	1.00	0.87
Douglas	GMTE1	0.94	0.91	0.96	0.94	1.00	0.69	1.00	0.67	0.90	1.00	0.93	0.91	0.86	0.91	0.71	0.74	1.00	0.92	0.86	1.00	1.00
	GMTE2	1.00	0.93	0.99	0.97	1.00	0.69	1.00	0.76	0.90	1.00	0.99	0.95	0.98	1.00	1.00	0.88	1.00	1.00	1.00	1.00	1.00
Hall	GMTE1	0.89	0.98	0.97	0.99	0.94	0.69	0.97	0.82	0.96	0.89	0.91	0.85	0.92	0.96	1.00	1.00	1.00	0.98	0.96	1.00	0.88
	GMTE2	1.00	0.98	0.97	1.00	0.94	0.69	0.97	0.84	0.96	0.89	0.91	0.85	0.92	0.96	1.00	1.00	1.00	0.98	0.98	1.00	0.88
Hamilton	GMTE1	0.92	1.00	0.99	1.00	0.97	0.67	0.95	0.82	1.00	0.94	0.96	0.95	0.90	0.96	1.00	0.96	1.00	1.00	0.94	1.00	0.98
	GMTE2	1.00	1.00	1.00	1.00	0.97	0.67	0.95	0.83	1.00	0.94	0.96	0.95	0.90	0.96	1.00	0.96	1.00	1.00	0.96	1.00	0.98
Howard	GMTE1	0.87	1.00	1.00	1.00	0.94	0.80	1.00	0.77	0.99	0.86	1.00	0.95	1.00	0.96	1.00	0.95	0.92	1.00	1.00	1.00	0.93
	GMTE2	1.00	1.00	1.00	1.00	0.94	0.80	1.00	0.80	0.99	0.87	1.00	0.98	1.00	1.00	1.00	0.96	0.92	1.00	1.00	1.00	0.93
Keith	GMTE1	0.84	0.83	0.83	0.91	0.77	0.78	0.80	0.72	0.79	0.94	1.00	1.00	0.97	1.00	1.00	0.99	1.00	0.91	0.99	1.00	1.00
	GMTE2	1.00	0.86	1.00	0.92	0.77	0.78	0.80	0.96	0.79	0.94	1.00	1.00	1.00	1.00	1.00	0.99	1.00	0.92	1.00	1.00	1.00
Kimball	GMTE1	0.87	0.78	0.95	1.00	0.97	1.00	1.00	1.00	0.94	0.78	0.92	1.00	0.81	1.00	1.00	1.00	1.00	0.95	1.00	1.00	1.00
	GMTE2	0.91	0.81	0.98	1.00	0.97	1.00	1.00	1.00	0.94	0.78	0.92	1.00	0.81	1.00	1.00	1.00	1.00	0.95	1.00	1.00	1.00
Lincoln	GMTE1	0.98	0.85	0.96	1.00	1.00	0.90	1.00	0.82	0.88	0.90	1.00	0.93	0.96	1.00	1.00	1.00	1.00	0.93	0.91	0.98	0.89
	GMTE2	1.00	0.85	0.99	1.00	0.98	0.86	0.93	0.83	0.88	0.89	0.97	0.92	0.89	1.00	1.00	1.00	0.98	0.92	0.91	0.96	1.00
Merrick	GMTE1	1.00	0.99	0.98	1.00	0.89	0.70	0.96	0.81	1.00	0.94	0.95	0.91	0.80	0.94	0.89	0.96	1.00	0.96	0.98	1.00	0.91
	GMTE2	1.00	0.99	0.98	1.00	0.89	0.70	0.96	0.83	1.00	0.96	0.96	0.91	0.83	0.99	0.95	0.98	1.00	0.97	1.00	1.00	0.91
Nance	GMTE1	0.81	1.00	0.91	0.94	1.00	0.82	1.00	0.72	0.95	1.00	1.00	0.90	0.99	0.89	0.83	0.77	0.96	1.00	1.00	1.00	1.00
	GMTE2	1.00	1.00	0.98	1.00	1.00	0.82	1.00	0.81	0.95	1.00	1.00	0.90	1.00	0.97	1.00	0.78	0.96	1.00	1.00	1.00	1.00
Perkins	GMTE1	0.85	0.81	0.89	0.86	0.83	0.82	0.82	0.73	0.85	0.81	1.00	1.00	0.94	0.95	1.00	1.00	1.00	0.89	1.00	0.98	1.00
	GMTE2	1.00	0.84	1.00	0.88	0.83	0.82	0.82	0.82	0.85	0.81	1.00	1.00	1.00	0.99	1.00	1.00	1.00	0.91	1.00	0.98	1.00
Platte	GMTE1	0.93	0.85	0.88	0.86	1.00	0.74	0.95	0.73	0.82	0.90	1.00	0.91	0.93	0.87	0.86	0.82	1.00	0.94	0.99	1.00	0.91
	GMTE2	1.00	0.89	0.90	0.90	1.00	0.74	0.95	0.78	0.82	0.92	1.00	0.91	1.00	0.96	1.00	0.88	1.00	0.99	1.00	1.00	0.91
Polk	GMTE1	0.90	0.81	0.91	1.00	1.00	0.78	0.97	0.81	0.98	0.97	0.99	0.90	0.87	0.96	0.88	0.89	1.00	1.00	0.92	1.00	0.85
	GMTE2	1.00	0.82	0.97	1.00	1.00	0.78	0.98	0.88	0.99	0.98	1.00	0.92	0.95	1.00	0.93	0.92	1.00	1.00	0.96	1.00	0.85
Sarpy	GMTE1	0.91	0.66	0.99	0.94	1.00	0.78	1.00	0.57	0.93	1.00	0.93	1.00	0.81	0.78	0.50	0.80	1.00	0.93	0.77	0.89	0.86
	GMTE2	1.00	0.69	1.00	1.00	1.00	0.78	1.00	0.68	0.93	1.00	0.99	1.00	0.84	0.85	0.62	0.85	1.00	1.00	0.89	0.94	0.86
Saunders	GMTE1	0.87	0.85	0.93	0.89	1.00	0.72	0.94	0.59	0.85	0.83	0.96	0.90	0.80	0.87	0.72	0.75	1.00	0.91	0.88	0.98	0.86
	GMTE2	1.00	0.92	0.98	0.98	1.00	0.72	0.97	0.72	0.86	0.95	1.00	0.97	0.92	0.96	0.88	0.85	1.00	1.00	1.00	1.00	0.87
Sherman	GMTE1	0.93	0.88	0.92	0.98	0.99	0.79	1.00	0.84	1.00	0.92	1.00	1.00	0.94	0.93	1.00	1.00	0.97	1.00	1.00	1.00	0.96
	GMTE2	1.00	0.88	0.97	1.00	0.99	0.79	1.00	0.91	1.00	0.92	1.00	1.00	0.94	0.96	1.00	1.00	0.97	1.00	1.00	1.00	0.96
Washington	GMTE1	0.86	0.94	0.89	0.89	1.00	0.78	0.98	0.65	0.89	1.00	0.97	0.93	1.00	0.86	0.80	0.85	1.00	0.95	0.94	1.00	1.00
	GMTE2	1.00	0.98	0.95	0.92	1.00	0.78	0.98	0.75	0.89	1.00	1.00	1.00	1.00	0.93	0.93	0.91	1.00	1.00	1.00	1.00	1.00

Table 4 – GMTE1 across counties – not including DDs variable.

GMTE1	Table 4																				
County	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
Banner	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.885	0.844	0.950	0.723	0.850	0.801	0.717	0.840	0.725	0.570	0.901	0.681	0.597	0.909
Buffalo	0.887	0.787	0.843	0.964	1.000	0.771	0.831	0.874	0.885	0.859	0.854	0.874	0.880	0.851	0.875	0.883	0.943	0.922	0.910	0.935	0.943
Butler	0.913	0.981	0.947	0.992	1.000	1.000	1.000	0.806	1.000	1.000	1.000	1.000	0.850	0.822	0.779	0.773	1.000	0.904	0.887	1.000	1.000
Cheyenne	1.000	0.969	1.000	0.942	0.775	0.915	1.000	1.000	1.000	0.971	1.000	1.000	1.000	0.924	1.000	1.000	0.802	0.831	0.987	1.000	1.000
Colfax	0.944	1.000	1.000	0.929	1.000	0.952	1.000	0.888	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Custer	1.000	0.829	1.000	1.000	0.964	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.970	1.000	1.000	1.000	1.000
Dawson	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Deuel	0.961	0.863	0.892	0.855	0.700	0.881	0.823	0.925	0.967	0.815	0.903	0.982	0.904	0.799	0.831	0.975	0.659	0.705	0.670	0.825	0.776
Dodge	0.879	0.837	0.797	0.796	0.961	0.723	0.902	0.767	0.896	0.952	0.833	0.764	0.906	0.785	0.818	0.745	0.918	0.902	0.894	0.874	0.876
Douglas	0.938	0.882	0.960	0.994	0.973	0.860	0.958	0.932	0.925	0.993	0.941	0.958	0.965	1.000	0.876	0.869	0.933	0.951	0.883	0.965	0.597
Hall	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.995	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hamilton	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Howard	0.891	0.912	0.971	0.976	0.938	0.884	0.925	0.814	0.910	0.815	0.860	0.860	0.803	0.839	0.822	0.818	0.802	0.936	0.900	0.870	0.920
Keith	0.805	0.792	0.756	0.807	0.672	0.770	0.710	0.754	0.687	0.870	0.858	0.838	0.934	0.873	0.991	0.899	0.830	0.860	0.839	0.864	1.000
Kimball	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.909	0.984	0.974	0.917	0.973	0.907	1.000	0.910	0.968	0.952	0.832	1.000
Lincoln	1.000	0.917	0.954	1.000	0.953	0.986	0.942	0.991	0.886	0.985	0.993	0.851	1.000	1.000	1.000	1.000	0.949	0.931	0.885	0.935	0.943
Merrick	0.902	0.900	0.890	0.895	0.853	0.901	0.892	0.869	0.966	1.000	1.000	0.980	0.880	0.988	0.809	0.812	0.832	0.886	0.908	0.905	0.927
Nance	0.915	0.899	0.982	0.858	1.000	0.940	0.986	0.831	0.918	0.820	0.913	0.825	0.705	0.775	0.757	0.740	0.824	0.940	0.920	0.848	0.944
Perkins	0.796	0.765	0.831	0.732	0.674	0.776	0.687	0.733	0.707	0.783	0.873	0.824	0.975	0.806	0.934	0.894	0.767	0.796	0.878	0.804	1.000
Platte	0.943	0.852	0.820	0.793	0.919	0.757	0.818	0.786	0.759	0.865	0.902	0.804	0.793	0.786	0.864	0.773	0.987	0.952	0.958	0.927	0.953
Polk	0.866	0.762	0.893	0.932	1.000	0.851	0.850	0.812	0.905	0.900	0.801	0.753	0.721	0.755	0.757	0.727	0.828	0.929	0.897	0.992	0.896
Sarpy	1.000	0.745	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.967	0.998	1.000	0.959	0.747	0.982	1.000	1.000	0.826	1.000	1.000
Saunders	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.827	1.000	1.000	1.000	1.000	1.000	1.000	0.948	0.962	1.000	1.000	1.000	1.000	1.000
Sherman	0.937	0.834	0.863	0.855	0.978	0.859	0.876	0.935	0.961	0.863	0.902	0.875	0.984	0.928	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Washington	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Table 5 – GMTE2 across counties – including DDs variable.

GMTE2	Table 5																				
County	88	89	90	91	92	93	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08
Banner	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.955	1.000	0.800	0.959	0.955	0.917	1.000	1.000	1.000	1.000	0.916	0.776	1.000
Buffalo	0.887	1.000	0.843	1.000	1.000	0.779	0.834	0.875	0.888	0.873	0.854	0.877	0.880	0.851	0.875	0.883	0.943	0.922	0.910	0.935	0.944
Butler	0.913	1.000	0.947	1.000	1.000	1.000	1.000	0.806	1.000	1.000	1.000	1.000	0.850	0.872	0.779	0.777	1.000	0.913	0.890	1.000	1.000
Cheyenne	1.000	1.000	1.000	1.000	0.830	0.969	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Colfax	0.952	1.000	1.000	0.938	1.000	0.952	1.000	0.898	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Custer	1.000	1.000	1.000	1.000	0.965	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.970	1.000	1.000	1.000	1.000
Dawson	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Deuel	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Dodge	0.929	1.000	0.797	0.796	0.961	0.725	0.902	0.768	0.900	0.954	0.838	0.786	0.906	0.788	0.818	0.749	0.918	0.925	0.894	0.875	0.876
Douglas	1.000	1.000	1.000	1.000	0.975	0.927	0.967	1.000	0.967	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.980	1.000	1.000	1.000	0.614
Hall	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Hamilton	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Howard	0.942	1.000	0.977	1.000	0.938	0.955	0.925	1.000	0.947	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.947
Keith	0.825	1.000	0.778	0.824	0.746	0.773	0.720	0.803	0.742	0.979	1.000	0.968	1.000	1.000	1.000	0.958	1.000	1.000	0.999	0.965	1.000
Kimball	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.980	1.000	1.000	0.970	1.000	1.000	1.000	1.000	1.000	1.000	0.915	1.000
Lincoln	1.000	1.000	1.000	1.000	1.000	1.000	0.975	1.000	0.977	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.952	1.000	1.000
Merrick	0.931	1.000	0.890	0.903	0.853	0.911	0.892	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.809	1.000	0.832	0.886	0.976	1.000	0.932
Nance	0.922	1.000	0.982	0.899	1.000	0.940	0.986	0.855	0.937	0.854	0.930	0.831	0.726	0.817	0.770	0.749	0.831	0.940	0.926	0.848	0.944
Perkins	0.798	1.000	0.879	0.740	0.751	0.782	0.690	0.746	0.708	0.828	1.000	0.866	1.000	0.889	0.996	0.946	0.854	0.999	0.920	0.833	1.000
Platte	0.960	1.000	0.820	0.796	0.919	0.763	0.818	0.805	0.772	0.865	0.902	0.809	0.793	0.804	0.864	0.773	0.987	0.952	0.958	0.927	0.953
Polk	0.974	1.000	0.893	0.954	1.000	0.851	0.850	0.817	0.908	0.913	0.814	0.776	0.721	0.774	0.757	0.728	0.828	0.929	0.901	0.996	0.896
Sarpy	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Saunders	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.827	1.000	1.000	1.000	1.000	1.000	1.000	0.948	0.966	1.000	1.000	1.000	1.000	1.000
Sherman	0.944	1.000	0.883	1.000	0.998	0.867	0.883	0.954	0.962	0.930	0.921	0.932	0.989	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Washington	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Regression 5 – Crop yield analysis including SPI

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glm(formula = Prod.by.Acre ~ Fert.by.Acre + Chem.by.Acre + DDs32 +
    SPI0 + County, data = signif2)

Deviance Residuals:
     Min        1Q    Median        3Q       Max
-0.77974  -0.16798   0.01282   0.16867   0.60698

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)       1.460599   0.085224  17.138  < 2e-16 ***
Fert.by.Acre      3.442728   0.621212   5.542 4.99e-08 ***
Chem.by.Acre      0.757174   0.660491   1.146    0.252
DDs32            -0.012550   0.001977  -6.348 5.13e-10 ***
SPI0             -0.048711   0.009204  -5.292 1.85e-07 ***
CountyBuffalo     1.190990   0.109429  10.884  < 2e-16 ***
CountyButler      0.816395   0.087012   9.383  < 2e-16 ***
CountyCheyenne    0.045146   0.083429   0.541    0.589
CountyColfax      0.948118   0.089082  10.643  < 2e-16 ***
CountyCuster      1.237854   0.097211  12.734  < 2e-16 ***
CountyDawson      1.985755   0.095492  20.795  < 2e-16 ***
CountyDeuel      -0.069808   0.083590  -0.835    0.404
CountyDodge       0.642122   0.088269   7.275 1.46e-12 ***
CountyDouglas     0.410550   0.096556   4.252 2.56e-05 ***
CountyHall        1.538027   0.119867  12.831  < 2e-16 ***
CountyHamilton    1.639391   0.095544  17.158  < 2e-16 ***
CountyHoward      1.104752   0.115412   9.572  < 2e-16 ***
CountyKeith       0.668258   0.097297   6.868 2.06e-11 ***
CountyKimball    -0.099578   0.082948  -1.200    0.231
CountyLincoln     1.038811   0.106963   9.712  < 2e-16 ***
CountyMerrick     0.854497   0.143777   5.943 5.44e-09 ***
CountyNance       0.809669   0.098297   8.237 1.76e-15 ***
CountyPerkins     0.404495   0.094060   4.300 2.07e-05 ***
CountyPlatte      0.809643   0.102919   7.867 2.51e-14 ***
CountyPolk        1.110225   0.091562  12.125  < 2e-16 ***
CountySarpy       0.398492   0.092076   4.328 1.84e-05 ***
CountySaunders    0.667085   0.085769   7.778 4.70e-14 ***
CountySherman     1.149055   0.097697  11.761  < 2e-16 ***
CountyWashington  0.608665   0.088732   6.860 2.18e-11 ***
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