Is Climate Change Likely to Affect the Geographic Movement of Cattle Production within the U.S.?

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Abstract

The number of feeder cattle in prominent cattle-producing regions has been changing for several decades. This article provides the first known examination of geographic movement of cattle production in top five cattle producing states namely Texas, Kansas, Colorado, Nebraska, and Iowa and main factors that induce the movement. The results suggest that climate change in terms of temperature is having significant influence on the cattle placement and cattle share in all five states. Corn price and difference between cattle futures price and feeder cattle price are having mixed effect on cattle placement and the movement across regions. CRP rental prices are identified as the least important factor for cattle movement. This study will enable the simulation for future geographic movement of cattle production regionally and basic framework for understanding the climate change impact on U.S. agriculture.

Keywords: *Cattle production and placement; climate change; temperature; cattle prices; geographic movement*

1.Introduction

The United States' cattle industry is the largest fed-cattle industry in the world (ERS-USDA, 2017) and ranks 1st in cash receipts. The industry accounted for $78.2 billion cash receipts in 2015 (NASS, 2016). Changes in input costs, cattle prices, demand coupled with improved production efficiencies, climate change and land availability continued to shape the United States' cattle industry for many years.

Climate change plays a main role in cattle inventory numbers in the United States (NASS, 2016). Considering the time period from 2008-2013, in the beginning of 2008, 26% of the cattle inventory were in areas experiencing drought (i.e. southern eastern and western parts of the U.S.). Within 5-year period, the total cattle inventory from drought experiencing areas increased up to 73% (NASS, 2016). During the southern plains' drought occurred in 2011, the livestock producers moved to northward resulting 5-8% increase in livestock inventory in Colorado, Iowa, Nebraska, and Wyoming whereas 13-15% decrease in inventory in the states of New Mexico, Oklahoma, and Texas. Specifically, Oklahoma experienced 23.6% losses of cattle inventory during the period of 2011 to 2013 and Texas lost 16.5% of cattle inventory during the period of 2011-2014 (Rippey, 2015).

Apart from the climate change, there are several important factors which might impact on cattle movement geographically. Among those, one of the key factors is availability of suitable land. Recent high prices experienced for corn has provided incentives for land owners to convert the grasslands into corn fields which were historically used for grazing. In the period of 2006-2008, more than one million hectares of grasslands have been converted into corn and soybean fields resulted in crop movement to westward of the Corn Belt (Wright and Wimberly, 2013).

Since 1985, the Conservation Reserve Program (CRP) is also among the competitors that compete for the land. CRP is a land conservation program administered by the Farm Service Agency (FSA). The impact of CRP on cattle production is twofold. Increase in CRP which reduces the cropland area, leads to shortage of forage and high rental payments for remaining available lands. On the other hand, amended CRP regulations allow managed haying and grazing on CRP lands which may possibly increase the forage for cattle thus, increase in beef production resulting low cattle prices (Campiche, et al., 2011).

The objective of the study is to investigate the geographical movement of the cattle production in top five cattle producing states; Texas, Kansas, Colorado, Nebraska, and Iowa due to changes in monthly placement share of cattle inventory in past 20 years. Relative increase or decrease in cattle placement share among these states signals the geographical movement in cattle production. This study will enable simulation for possible future movements in regions and more broadly enhance the understanding of climate change impact on the United States' cattle production. However, many studies have focused on extreme weather impact on cattle production (Baker, et al., 1993, Lambert, 2014, Belasco, et al., 2015) and none of the studies have analyzed the geographic movement of cattle production over decades. This study is the first to evaluate such movement patterns and provide a basic framework for understanding possible future movement forecasting in the United States.

2.Methods:

2.1.Data**:**

The data set was restricted to 1996-2016 time period. Texas, Kansas, Colorado, Nebraska, and Iowa cattle inventory share variables represent the monthly total cattle placement share and it is the ratio between state's cattle placement number to total cattle placement number for five participating states. The cattle placement numbers are the number of cattle that are kept in the herd instead of marketing or culling. These numbers are reported monthly by Livestock Marketing Information Center (LMIC). As a robustness check, we use both number of cattle placements and cattle share models to investigate the impact of climate change and geographic movement of the cattle production.

In order to evaluate the impact of weather on cattle placement share, we used historical monthly weather data for temperature for five states from the National Oceanic and Atmospheric Administration (NOAA). Temperature was the monthly average temperature measured in Fahrenheit. Effect of temperature on cattle production can both be contemporaneous and lagged thus, current average monthly temperature together with lag temperature was included in the analysis.

To capture the impact of fed cattle prices, we used the difference between six months futures cattle price and feeder cattle prices due to high correlation between output cattle prices (i.e. cattle futures rice) and input cattle rices (i.e. feeder cattle price). Corn is the main cash crop in these five states and used as the main cattle feed. Monthly corn, prices for five states were obtained through quick stats from National Agricultural Statistics Service. Due to high correlation present in corn and other main cash crop prices (e.g. soybean, sorghum) only corn price was considered in the analysis. Annual CRP values recorded in FSA were extrapolated to have monthly CRP rental values using per hectare corn prices. Cattle production is highly seasonal. Therefore, seasonal dummies were included in order to capture the seasonality.

2.2.Model Estimation:

To assess the geographical movement of cattle production, we estimated the share equation model, comprised of five equations accounting for Texas, Kansas, Colorado, Nebraska, and Iowa.

$$w_{it} = \alpha_{it} + \sum_{j=1}^{3} d_{ij}\, D_j + \sum_{i=1}^{N}\sum_{l=0}^{L} \delta_{il} lagT_{il} + \sum_{i=1}^{N} c_i CP_{it} + \sum_{i=1}^{N} \theta_i P_{it} + \sum_{i=1}^{N}\sum_{l=0}^{N} \rho_i\, CRP_{il} + \sum_{i=1}^{N} w_{i,t-1} + \varepsilon_{it} \quad (1)$$

Where w_i is the cattle inventory share of *i*th state (*i*=1,2,3,4,5) at time t. D_j is the quarterly dummy variable included to capture the seasonality of cattle production, T_{il} is the temperature of *i*th state with lag length of l, CP_i is the corn price of *i*th state at time t, P_i is the cattle output and input price difference of *i*th state at time t, and CRP_i is the monthly CRP rental price of *i*th state with lag length of l. We estimated the model using Ordinary Least Squares regression (OLS) technique. The empirical analysis used in this study was conducted using different model specifications and with different lag lengths for all the explanatory variables after correction for autocorrelation.

Use of share model gives us the idea about how state's cattle share increase or decrease due to climate change. As a robustness check and to get the idea about direct impact of climate on cattle production, we run a separate model with number of heads instead of cattle share.

$$x_{it} = \beta_{it} + \sum_{j=1}^{3} d_{ij}\, D_j + \sum_{i=1}^{N}\sum_{l=0}^{L} \delta_{il} lagT_{il} + \sum_{i=1}^{N} c_i CP_{it} + \sum_{i=1}^{N} \theta_i P_{it} + \sum_{i=1}^{N}\sum_{l=0}^{N} \rho_i\, CRP_{il} + \sum_{i=1}^{N} x_{i,t-1} + \varepsilon_{it} \quad (2)$$

Where x_{it} is the number of heads (cattle) and all the other variables are same as above mentioned share model.

2.3. Summary Statistics

Table 1: Summary statistics of monthly data (1996-2016)

Variable	Mean	Std. Dev.	Min	Max
Temperature KS	55.251	17.299	24.200	84.900
Temperature NE	49.693	17.791	18.600	80.000
Temperature TX	65.871	13.2110	42.400	88.200
Temperature IA	48.496	19.250	10.000	79.600
Temperature CO	46.269	15.290	19.400	72.400
Corn price KS	3.476	1.546	1.680	7.450
Corn price NE	3.360	1.513	1.520	7.760
Corn price TX	3.744	1.525	1.630	7.740
Corn price IA	3.342	1.538	1.430	7.890
Corn price CO	3.484	1.460	1.740	7.600
CRP KS	40.941	2.813	38.425	52.727
CRP NE	59.774	7.127	45.861	79.820
CRP TX	36.150	1.348	27.645	39.475
CRP IA	106.855	47.759	-213.724	188.440
CRP CO	33.322	2.482	30.943	41.053
KS_cattle_price difference	-19.453	15.856	-71.845	6.030
NE_cattle_price difference	-22.698	16.917	-78.345	4.323
TX_cattle_price difference	-16.177	16.610	-70.112	10.046
IA_cattle_price difference	-18.222	18.442	-78.736	11.845
CO_cattle_price difference	-15.580	14.221	-61.918	7.8108

Summary statistics are presented in Table 1. Texas had the highest average temperature and corn price recorded in the period considered. Iowa state had the highest CRP rental prices almost twice as much as big as rest of the states. The average difference between cattle futures price and feeder cattle price was negative in all five states.

3.Results:

We identified the preferred model specification by conducting number of model selection tests. In particular, we evaluated the optimal lag length for all the explanatory variables. The best model comprised contemporaneous impact of temperature, corn price, cattle price difference and CRP prices with the lags for temperature and CRP prices. Table 1 presents the estimated coefficients of the preferred model for number of cattle placements as dependent variable.

Table 2 presents the coefficients estimates for number of cattle placements in five main cattle producing states. The contemporaneous impact of temperature is positive and significant for all five states. When temperature increases, producers tend to place more cattle in current month. The impact of temperature lags is having mixed effects in all five states. Seasonal dummies are having significant impacts on cattle placements. During the first three months of the year, producers place more cattle. In the second season, Texas, Kansas, and Colorado place more cattle and Nebraska and Iowa reduce the number of placements compared to fourth season of the year. In third season, less cattle placements in all states except Kansas.

Table 2: Coefficients estimates of number of cattle placement model, monthly data (1996-2016)

	No of heads				
	Texas	Kansas	Colorado	Nebraska	Iowa
Temperature	3.969***	3.678***	1.429*	3.296***	0.674***
	(0.597)	(0.753)	(0.729)	(0.817)	(0.150)
Temperature lag(1)			2.211***		
			(0.755)		
Temperature lag(2)			2.774***	2.711***	
			(0.733)	(0.781)	
Temperature lag(3)			-1.776**		
			(0.735)		
Temperature lag(4)	-6.638***	0.718**	-1.553**	-2.471***	
	(1.569)	(0.330)	(0.772)	(0.874)	
Temperature lag(5)	-6.771***	1.883**	-1.952***		
	(1.506)	(0.757)	(0.720)		
Temperature lag(6)			2.582***	2.763***	0.500***
			(0.738)	(0.796)	(0.150)
Temperature lag(7)			2.600***		
			(0.741)		
Temperature lag(9)					-0.633***
					(0.064)
Temperature lag(10)			-3.054***	-2.991***	
			(0.642)	(0.771)	
Corn price	-5.284	-5.047*	-5.888***	5.327*	1.562**
	(4.581)	(2.628)	(1.704)	(3.080)	(0.743)
Change in cattle futures and feeder price	1.611***	0.656**	0.619***	-0.786***	-0.240***
	(0.389)	(0.261)	(0.178)	(0.300)	(0.061)
CRP price	-3.911	0.463	1.346	-0.703	0.046*
	(6.090)	(1.367)	(0.947)	(0.777)	(0.024)
CRP lag(3)					
CRP lag(6)	-9.065*				
	(4.691)				
CRP lag(7)	8.075*				
	(4.542)				
Cattle number lag(1)	0.084	0.276***	0.359***	0.239***	0.408***
	(0.060)	(0.065)	(0.058)	(0.066)	(0.060)
First season dummy	31.480	73.541***	70.276***	84.081***	14.956***
	(23.165)	(15.272)	(10.092)	(17.549)	(4.188)
Second season dummy	-78.684***	-55.619***	-22.242**	1.354	4.031
	(23.661)	(15.642)	(9.725)	(15.581)	(3.714)
Third season dummy	-81.697***	37.197**	-12.499	-49.952***	-8.145**
	(22.859)	(16.028)	(10.312)	(16.075)	(3.731)
Intercept	1294.846***	-21.813	-50.255	151.361	-0.327
	(349.161)	(105.276)	(112.190)	(118.014)	(15.454)
R^2	44.79	46.06	66.61	63.85	71.75

Notes: Standard errors are in parentheses. ***,** and * denote statistical significances at 0.01, 0.05 and 0.10 levels respectively.

Table 3: Elasticity calculations for cattle placements–number of heads

	No of heads				
	Texas	Kansas	Colorado	Nebraska	Iowa
Temperature	0.546***	0.463***	0.362*	0.400***	0.468***
Temperature lag(1)			0.561***		
Temperature lag(2)			0.705***	0.330***	
Temperature lag(3)			-0.451**		
Temperature lag(4)	-0.913***	0.091**	-0.393**	-0.299***	
Temperature lag(5)			-0.492***		
Temperature lag(6)		0.235**	0.647***	0.330***	0.340***
Temperature lag(7)			0.650***		
Temperature lag(9)					-0.429***
Temperature lag(10)	-0.925***		-0.767***	-0.358***	
Corn price	-0.041	-0.040*	-0.112***	0.044*	0.074**
Change in cattle futures and feeder price	-0.056***	-0.029**	-0.054***	0.044***	0.064**
CRP price	-0.295	0.430	0.244	-0.102	0.069*
CRP lag(3)					
CRP lag(6)	-0.682*				
CRP lag(7)	-0.607*				
Cattle number lag(1)	0.084	0.276***	0.361***	0.240***	0.407***

Note: Elasticities are calculated at the mean value of explanatory variables. ***,** and * denote statistical significances at 0.01, 0.05 and 0.10 levels respectively.

Table 3.1: Long run elasticities for cattle placement- number of heads

	Texas	Kansas	Colorado	Nebraska	Iowa
Temperature	0.526***	0.185***	0.319***	0.314***	0.310***
CRP price	-0.226				

Table 3 presents the elasticity calculations for cattle placements. It is evident that 1% increase in temperature increases the number of cattle placement less than 1% in all five states. Lag temperature elasticities are having mixed significant impacts in all states. For example, temperature elasticities for 4th and 10th lags are having negative significant impact on cattle placement whereas 4th and 6th temperature lags are having positive significant impact on Kansa cattle placements. Corn price elasticity on cattle placement has negative impact on Texas, Kansas, and Colorado whereas positive impact on Nebraska and Iowa. 1% increase in the difference between futures cash price and feeder cattle price decreases the cattle placements in Texas, Kansa, and Colorado. In contrast, cattle placement will increase in Nebraska, and Colorado. Over the period of 1996-2016, average difference in cattle futures price and feeder prices are negative for Texas, Kansas, and Colorado and positive in Nebraska and Iowa. This might be the reason that increase in cattle prices decreases the cattle production in Texas, Kansas, and Colorado. As mentioned earlier, CRP program is one of the land competing programs in the U.S.. However, CRP elasticities are not significant. Over the long run period of increasing temperature has positive and significant impact on cattle placements in all the states (Table 3.1).

Table 4 presents the coefficient estimates of cattle share equations for five states. Compared to number of cattle placement model, model fit increases with the share model. Table 5 shows the respective elasticities for share model. 1% increase in temperature will increase the cattle share by 0.16% in Kansas. Corn price elasticity for Colorado and Nebraska is positive and significant and less than one percent. For Texas, Kansas, and Iowa, 1% increase in price difference of cattle (i.e. Cattle futures price less feeder cattle) will reduce the cattle share whereas Colorado and Nebraska will gain some cattle. CRP elasticity is negative and significant only for Iowa. Long run elasticities of temperature are only significant for Texas and Nebraska (Table 5.1).

Table 4: Coefficients estimates of cattle share model, monthly data (1996-2016)

	Cattle share				
	Texas	Kansas	Colorado	Nebraska	Iowa
Temperature	-0.0002 (0.0002)	-0.0008*** (0.0003)	0.0002 (0.0002)	0.0004 (0.0003)	0.00009 (0.0002)
Temperature lag(1)			-0.00005 (0.0002)		
Temperature lag(2)			-0.0001 (0.0002)	0.0004* (0.0003)	
Temperature lag(3)			0.0003 (0.0002)		
Temperature lag(4)	-0.002*** (0.0005)	-0.0003*** (0.0001)	0.0001 (0.0002)	0.0004 (0.0003)	
Temperature lag(5)			0.00002 (0.0002)		
Temperature lag(6)		-0.0002 (0.0003)	-0.0003** (0.0002)	0.0002 (0.0003)	0.0002 (0.0002)
Temperature lag(7)			0.0003 (0.0002)		
Temperature lag(9)					-0.0002*** (0.00006)
Temperature lag(10)	-0.0006 (0.0004)		-0.0003* (0.0002)	-0.0002 (0.0003)	
Corn price	-0.0005 (0.001)	-0.0007 (0.0009)	0.001*** (0.0004)	0.002** (0.001)	-0.001 (0.0008)
Change in cattle futures and feeder price	0.0005*** (0.0001)	0.0002** (0.00009)	-0.0002*** (0.00004)	-0.004*** (0.0001)	0.0001* (0.00007)
CRP price	-0.002 (0.002)	-0.0006 (0.0005)	-0.0001 (0.0002)	0.0003 (0.0003)	-0.00006** (0.00003)
CRP lag(3)					
CRP lag(6)	-0.002 (0.001)				
CRP lag(7)	0.003** (0.001)				
Cattle number lag(1)	0.386*** (0.054)	0.465*** (0.049)	0.579*** (0.056)	0.484*** (0.056)	0.414*** (0.063)
First season dummy	-0.022*** (0.007)	-0.002 (0.005)	0.001 (0.002)	0.017*** (0.005)	0.013*** (0.005)
Second season dummy	-0.032*** (0.007)	-0.015*** (0.005)	0.008*** (0.002)	0.031*** (0.005)	0.005 (0.004)
Third season dummy	-0.033*** (0.007)	0.059*** (0.005)	-0.003 (0.002)	-0.008 (0.005)	-0.004 (0.004)
Intercept	0.436*** (0.102)	0.250*** (0.036)	0.010 (0.026)	0.033 (0.038)	0.075** (0.017)
R^2	67.02	54.37	75.06	73.00	47.11

Notes: Standard errors are in parentheses. ***,** and * denote statistical significances at 0.01, 0.05 and 0.10 levels respectively.

Table 5: Elasticity calculations for share model

	Cattle share				
	Texas	Kansas	Colorado	Nebraska	Iowa
Temperature	-0.050	0.155***	0.217	0.082	0.036
Temperature lag(1)			-0.050		
Temperature lag(2)			-0.130	0.081*	
Temperature lag(3)			0.273		
Temperature lag(4)	-0.506***	-0.064***	0.133	0.071	
Temperature lag(5)			0.025		
Temperature lag(6)		-0.044	-0.331*	0.039	0.076
Temperature lag(7)			0.260		
Temperature lag(9)					-0.073***
Temperature lag(10)	-0.128		-0.283*	-0.033	
Corn price	-0.006	-0.009	0.103***	0.031**	-0.037
Change in cattle futures and feeder price	-0.027***	-0.012**	0.567***	0.037***	-0.019*
CRP price	-0.288	-0.091	-0.088	0.071	-0.059**
CRP lag(3)					
CRP lag(6)	-0.182				
CRP lag(7)	0.377**				
Cattle number lag(1)	0.387***	0.465***	0.577***	0.483***	0.415***

Note: Elasticities are calculated at the mean value of explanatory variables. ***,** and * denote statistical significances at 0.01, 0.05 and 0.10 levels respectively.

Table 5.1: Long run elasticities for cattle share

	No of heads				
	Texas	Kansas	Colorado	Nebraska	Iowa
Temperature	0.092**	-0.075***	0.055	0.064***	-0.026
CRP price	-0.139				

4.Discussion:

The key findings of this study can be summarized as temperature, corn price, and price difference between cattle futures price and feeder cattle price effects significantly changed the states' cattle share and cattle placement thus, influenced the relocation of cattle production. This finding warrants additional discussion. Considering the impact of temperature on cattle production, the optimal temperature range for best performance is between 40-60 degrees of Fahrenheit (Mark and Schroeder, 2012). High temperatures cause decline in feed consumption whereas cold temperatures cause high energy consumption in feeder cattle. On the other hand, precipitation matters due to its ability to increase stress on cattle. High precipitation can create muddy pen conditions and wet, matted hair coats (Mark and Schroeder, 2012). The existing high correlation between temperature and precipitation in the states considered in this study, we considered only the temperature effects. Further research has potential to focus on precipitation impact on cattle placement considering the timing and intensity of precipitation taking into the account.

Higher corn prices have significant impact on state’s cattle placement, but the effect is less prominent in cattle share model. Corn is considered as one of the main cash crops in those five states and it is used as the primary feed grain in cattle production. Higher price received for corn makes it more attractive for farmers thus, compete for land. On the other hand, it makes production of cattle more expensive. These two factors can possibly impact on geographic movement of cattle. For Texas, Kansas, and Colorado, higher corn prices reduce the cattle placement. The effect is opposite for Nebraska and Iowa. Future research can explore the reasons for this sign contradiction.

Higher CRP rental prices has no any significant effects on cattle placement and share except Iowa. The difference in cattle futures price and feeder cattle price is intended to capture the main component of producers’ profits from cattle production since feeder cattle price accounts nearly 90% of the production cost of cattle producers. It is evident that 1% increment in cattle price difference is having negative impact on Texas, Kansas, and Colorado. The possible reason for this is the average 6 months futures prices in those three states are less than the respective feeder cattle price. This difference makes negative impact on those states. For rest of the states, the sign is positive as we expected.

As conclusion, the response to weather can vary depending on cattle sex, placement weight, and placement month. Average placement number can mask the effect of above mentioned variations. Hence, future research inferences will be enhanced by including these variations into the account. The research implications are not limited to examine and understanding the geographic movement of cattle, but long-term producer decision making and land allocation between more profitable production of crops and cattle or mix of both. The research findings may also have potential geographic expansion across borders.

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