The Impact of Land Fragmentation on Beef Cattle Inventory

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Selcted Paper prepared for presentation at the Southern Agricultural Economics Association Annual Meetings, Dallas, Texas, February 2-6, 2008

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Abstract

Many groups have discussed with alarm the impact of agricultural land conversion to non-agricultural uses. This research indicates little evidence that beef cow inventory has been negatively affected by land fragmentation. Average acres per transaction, total transactions, or a fragmentation index did not have an important effect on cattle inventory.

Introduction

For years, many individuals and groups have discussed with growing alarm the impact of farm and ranch land conversion to non-agricultural uses. Statistics of farm land lost to urban sprawl are often used to support arguments about the survival of food production in the United States. The conversion of farmland to housing subdivisions or strip malls is a familiar example. Recently, those sales have been augmented by land purchases for recreational uses.

Research on the impacts of these sales, often called land fragmentation, on agricultural production is sparse, at best. While the sales are typically thought to affect cropland the most, these sales may also take ranch land out of livestock production. It is widely believed, based on anecdotal evidence, that ranch sales are reducing the number of cows and beef production and the industry's ability to respond to high prices.

To empirically test these notions, this research examines the impact of land fragmentation on beef cow-calf inventories in Texas. Annual real estate sales by region and statewide are used to model the relationship between land fragmentation and beef cow numbers. The following sections of the paper discuss a literature review of fragmentation research and cattle modeling, methods of analysis, results, and conclusions.

Literature Review

While there have been many attempts to define what exactly makes up urban sprawl, it can be generally defined as the outcome of four related factors: low residential density; a poor mix of homes, jobs, and services; limited activity centers and downtown areas; and limited options for walking or biking (Schmidt, 2004). There is little doubt that urban sprawl and land fragmentation are encroaching on the land available for crop and livestock production. Some research, such as Nechyba and Walsh (2004), claims that forests are a bigger threat to farmland than urban sprawl and land fragmentation. In a report by the Environmental Protection Agency, with the assistance of The American Farmland Trust, 70 percent of prime farmland is in the path of rapid development. (AFT, 2006). The American Farmland Trust also states that approximately half of the two billion acres of land in the United States is used for agriculture, and that an estimated 1.2 million acres of farmland is lost annually, much of it being the most productive farmland near major population centers (Farmland Protection Issues, 2007).

At the state level, Texas has more than 36.8 million acres of prime farmland, more than any other state (NRCS, 1995). From 1992 to 1997, Texas lost approximately 332,800 acres of farmland to development. In 1982, 6.8 million acres of the state's total surface area was classified as urban by the Texas Sunset Commission. By 1992 urban acreage had increased to 8.2 million acres (Agriculture and Urban Sprawl, 2007).

This study is due, in part, to the absence of readily available studies devoted to the analysis of land use for non-agricultural purposes and its effects on crop and livestock production. While there are studies on cropland usage and its effect on cattle supply, i.e. Bobst and Davis (1987), there is little in the way of research to analyze the effects of population growth and subsequent urbanization on cattle supply and inventories. Although there are multiple studies available regarding the national beef cattle supply; there are few, such as Rucker, Burt and LaFrance (1984) that focus on more defined regions or states when estimating equations.

The agricultural economics literature has a long history of cattle and beef industry research. A brief summary of that work is provided here. A fundamental determinant of the supply of cattle in a given time period is the number of cattle in previous time periods. Many studies, including Maki (1962), Reutlinger (1966), Tryfos (1974), Arzac and Wilkinson (1979), Rucker, Burt and LaFrance (1984), Marsh (1999), and Sarmiento and Allen (2000) have found that lagged cattle supplies/inventories are some of the most effective variables in explaining current and future cattle supplies. The reason is quite simple in that calves born are a function of the number of cows. The calf crop determines the number of replacements to add to the cow herd.

Calf prices represent the output price for a cow/calf operation. Many studies have used lagged cattle and calf prices as explanatory variables for cattle inventory (Bobst and Davis

(1987), Marsh (1994), Marsh (1999), and Sarmiento and Allen (2000), Martin and Garcia, and Ospina and Shumway (1980)).

As previously mentioned Rucker, Burt and LaFrance conducted a thorough examination of cattle inventories and included a price to cost ratio, in the form of beef prices over corn prices, as an explanatory variable for Montana beef cattle supplies. The study found that, along with lagged calf prices, the lagged price to cost ratio was one of the primary predictors of cattle supplies. The authors state their reason for the use of the ratio in lieu of corn prices is because, "…evidently, both the fed beef price and the corn price are contributing information jointly that cannot be obtained from the two prices separately." Use of the beef to feed prices ratio as a statistically significant explanatory variable can also be seen in studies by Reutlinger (1966), Kulshreshtha and Wilson (1972), and Marsh (1999).

Methodology

The lack of research regarding land fragmentation and beef cattle supply leads to a fundamental question. Is there a relationship between land fragmentation and cattle production or inventory? Land fragmentation is defined as the breaking up of large holdings into smaller holdings. Has urban sprawl reduced the number of beef cows in Texas? Using and measuring land fragmentation variables could provide the answer. Measuring fragmentation for analysis may take several forms.

One way to model land fragmentation is with the creation of a fragmentation index.

$$FIt = \frac{\sum L_t^{80}}{\sum L_t}$$

A fragmentation index is a ratio of the sum of all land sales, in acres, less than a reference number of acres chosen, in this case eighty acres, divided by the sum of all acres sold in that area for a specific time period for the state of Texas, and for the land market areas. It was assumed that the transactions of less than eighty acres would be more likely to lead to the divestment of beef cattle, and a subsequent drop in overall beef cattle supply as the index increased.

Another potential measure of land fragmentation is the number of land sales transactions in a given time period for the state, and for each land market area. Each transaction is given equal weight, whether 13 acres or 13,000 acres were sold. More sales were hypothesized to mean land changing hands perhaps to purchasers with no interest in cattle. The final measure of land fragmentation is the average acres per transaction in a given time period for the state, and for each land market region. These three components of land fragmentation are hypothesized to be predictors of beef cattle supply for each region and the state of Texas.

The general model is as follows:

$$QBC_t = \beta_0 + \beta_1 T + \beta_2 FP_{t-1} + \beta_3 FI + \beta_4 FI^2 + \beta_5 FI^3;$$

Where T is trend, FP is the feed price ratio consisting of lagged cattle prices divided by current feed prices, and FI is the fragmentation index variable. The dependent variable for all equations is the quantity of beef cattle (QBC) in each region or the state on January 1.

Data

Land sale data was obtained from the Real Estate Center at the Mays Business School at Texas A&M University. Annual data was obtained for the time period 1976 through 2005.

The land market areas used to better examine land fragmentation effects are a construct of the Real Estate Center at Texas A&M University. The Real Estate Center uses these areas to categorize, aggregate, and examine land sales (See figure 1). The land market areas roughly correspond to the natural geography of the state. For example, in Texas the central part of the state is known as the Hill country, and this area is divided up into three land market areas (Hill Country North, Hill Country West, and Hill Country South). The Trans-Pecos area (region 8) contains nearly every county west of the Pecos River in west Texas. This area is characterized by large ranches with fewer beef cattle per acre, and large amounts of land changing hands during real estate transactions, and a relatively low population.

The data, particularly the cattle and land fragmentation variables, were individually applied to twenty-six of the thirty-three land market areas in Texas. The twenty-six land market areas were aggregated to allow for analysis of the entire state. The markets not used in the study contained large population centers such as Houston, Dallas, Austin/San Antonio, and El Paso. The Texas land market areas are not the same as the crop reporting districts used by NASS, and are more numerous.

The real estate data initially examined included exact sales dates, financing amounts, price per acre, acres sold, and other identifying markers for each sale. This study only used the acres sold, and the number of transactions. No amount of acreage was considered too small or too large to be examined, given Texas' wide range of land types and county sizes.

Beef cow inventory, by county, was acquired from the National Agricultural Statistics Service (NASS). For the years 1988 through 1992, county-level beef cattle supplies were not available. However, beef cattle supplies were available by crop-reporting districts. County beef cow inventory was estimated using the percent of beef cows in each county in 1987 and applying the percent to the crop reporting district inventory. For the year 1988, NASS only reported the

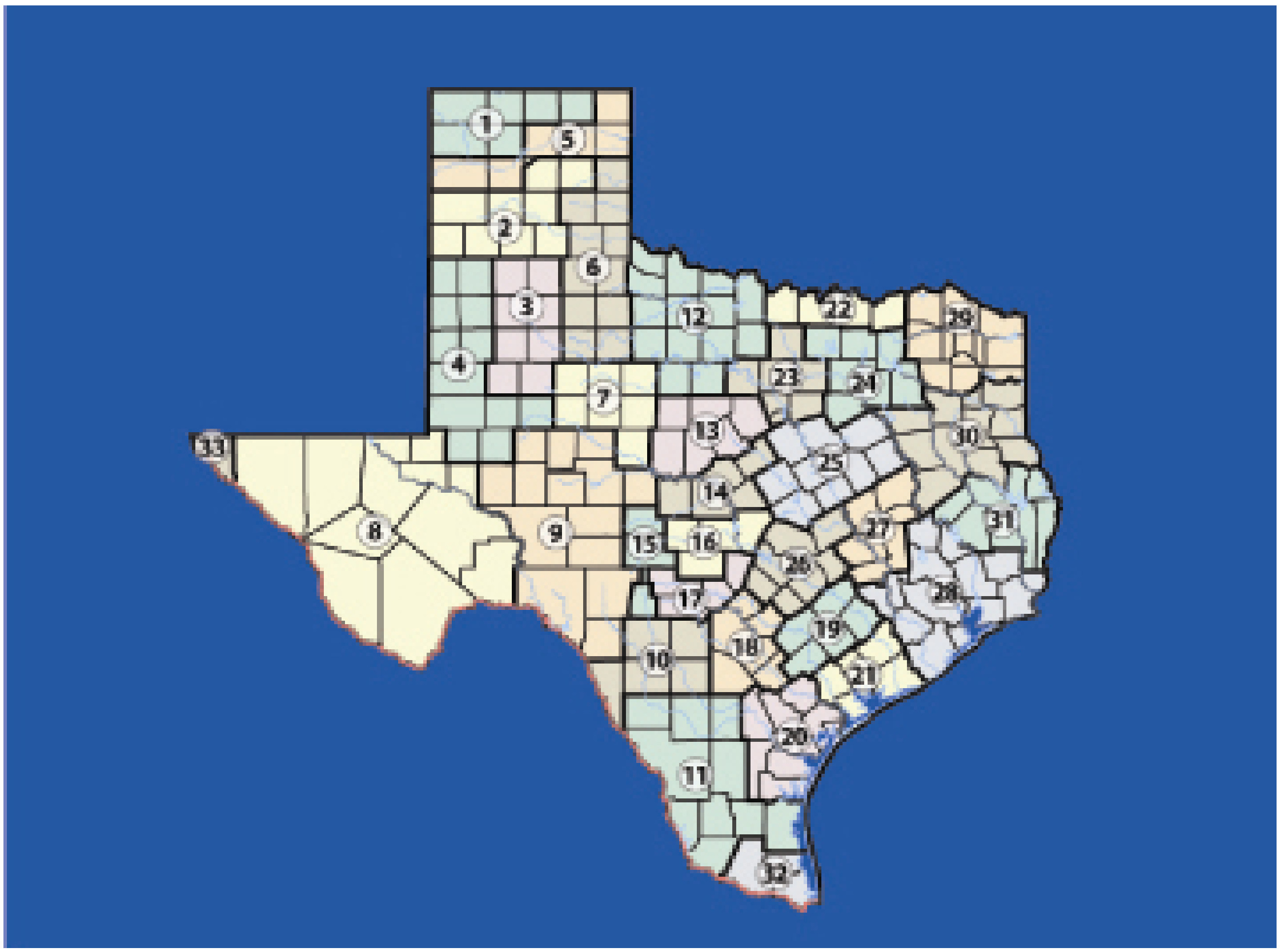

Figure 1. Texas Land Market Areas[1] as Categorized by the Real Estate Center at Texas A&M University.

[1]Area names can be found in Table 1

Source: Real Estate Center at Texas A&M University

state total and combined district cow inventory. A proxy for county beef cattle inventory was developed by using the 1987 percentage of cattle for each NASS crop reporting district to create approximate cattle inventories for the crop reporting districts in 1988. As a result, a dummy variable was included for the years 1988 through 1992, to account for possible differences due to this data situation. The county-level cattle inventories were then aggregated based on the land market area in which they resided. This aided in accurately measuring the land fragmentation variables against the dependent inventory levels at the smaller land market area level.

A feed price ratio was included as an explanatory variable which allowed for one less degree of freedom. Calf prices lagged one period, used as the denominator for the ratio, are the average price for Amarillo feeder steers, 500-600 pounds, in dollars per hundredweight. The NASS reported Texas annual corn price in dollars per bushel was used as the denominator of the price ratio.

The three land fragmentation models were analyzed using an ordinary least squares multiple regression. The Simetar (Richardson, et al.) software package was used to estimate the models.

Results

Table 1 provides the descriptive statistics for the data used in the analysis. Amarillo feeder steers, 500-600 pounds, averaged $77.25 per cwt., with a minimum price of $32.80 and a maximum price of $114.90 per cwt., over the period. Corn prices averaged $2.61 per bushel. Beef cow inventory ranged from a minimum of 3.9 million head, and a maximum of 4.9 million head. For the time period, Texas averaged 4.28 million head of beef cattle. The Northern Piney Woods (Region 30) had the highest average amount of cattle in the state with 396,367 head of beef cattle. The Lower Rio Grande Valley (Region 32) possessed the smallest number of beef cattle for any one year, with only 12,000 head. On the other end of the spectrum, the Rio Grande Plains (Region 11) held the highest one year number of beef cattle with 471,000 head. Table 2 contains descriptive statistics regarding the three fragmentation variables used for this study. For the state of Texas, once again an aggregation of the twenty six land market areas used, the average fragmentation index was 0.043, meaning that on average 4.3 percent of the land sales involved plots of less than eighty acres. Texas' smallest fragmentation index was 0.021, while the largest fragmentation index was 0.067. The largest average fragmentation index existed in the Southern Piney Woods land market area, a region very close to the Beaumont and Houston population centers, 0.245 for the time period. Meanwhile, the Trans-Pecos area had the smallest average fragmentation index at 0.0001. The state averaged 3,451 sales per year, with the Trans-Pecos and Northern Blacklands land market areas having the smallest and largest average land sales, respectively. The Trans-Pecos area had the highest average amount of land sold per transaction with 9,982 acres. The Northern Coastal Prairie had the smallest average amount of land sold with only 120 acres per transaction.

Table 1: Descriptive Statistics for Feed and Cattle prices and Beef Cow Inventory for Analysis of Land Fragmentation's Impact on Texas Beef Cattle Inventory

		Mean	Std. Dev.	C.V.	Min.	Max.
	Calf Price ($/cwt)	77.25	19.02	24.63	32.8	114.9
	Corn Price ($/bu)	2.61	0.39	14.84	1.87	3.44
	Cow Inventory					
Region #						
1	North Panhandle	51,564	8,922	17.30	30,000	68,000
2	Central Panhandle	96,088	14,636	15.23	74,427	123,000
3	South Plains	62,455	10,135	16.23	46,000	86,000
4	Permian West	79,374	8,540	10.76	60,000	95,000
5	Canadian Breaks	62,989	9,002	14.29	40,000	82,000
6	Rolling Plains North	163,929	17,044	10.40	133,000	191,000
7	Rolling Plains Central	108,857	14,426	13.25	75,000	132,000
8	Trans-Pecos	131,909	24,765	18.77	83,000	169,000
9	Edwards Plateau West	155,680	28,692	18.43	90,000	210,000
10	Edwards Plateau South	103,810	26,196	25.23	71,000	153,000
11	Rio Grande Plains	271,291	91,935	33.89	174,000	471,000
12	North Central Plains	253,117	16,114	6.37	220,000	279,000
13	Crosstimbers	178,188	16,410	9.21	143,000	220,000
14	Hill Country North	127,256	18,876	14.83	99,000	181,000
15	Hill Country West	32,084	5,087	15.86	23,000	42,000
16	Highland Lakes	109,024	9,065	8.31	91,000	125,000
17	Hill Country South	49,866	8,336	16.72	37,000	63,000
19	Coastal Prairie North	332,631	31,803	9.56	289,000	398,000
20	Coastal Prairie South	204,482	22,226	10.87	166,877	251,000
21	Coastal Prairie Middle	177,847	18,013	10.13	148,000	222,000
25	Blacklands North	345,583	38,254	11.07	279,276	434,000
27	Brazos	351,685	23,417	6.66	294,000	403,000
29	North East	317,464	29,346	9.24	281,000	387,000
30	Piney Woods North	396,367	24,595	6.21	352,000	460,000
31	Piney Woods South	83,953	6,068	7.23	68,000	68,000

32	Lower Rio Grande Valley	38,000	16,911	44.50	12,000	68,000
	State	4,285,492	296,018	6.91	3,915,110	4,907,000

Table 2: Descriptive Statistics for Land Sales for Analysis of Land Fragmentation's Impact on Beef Cow Inventory

Region #	State	Mean	Std. Dev.	C.V.	Min.	Max.
Region #	State	*.043; 3,451; 450	.012; 1,029.44; 81.15	28.44; 29.83; 18.04	.021; 2,388; 349	.067; 6,413; 712
1	North Panhandle	.003; 70; 774	.003; 21.82; 263.34	116.48; 31.39; 34.02	.000; 36; 460	.010; 130; 1,698
2	Central Panhandle	.007; 165; 505	.005; 46.48; 88.41	70.61; 28.19; 17.51	.001; 90; 312	.027; 274; 721
3	South Plains	.029; 165; 392	.015; 56.14; 616.07	52.22; 34.05; 157.05	.002; 94; 193	.069; 310; 3,629
4	Permian West	.014; 176; 398	.008; 82.82; 100.91	59.31; 47.09; 25.37	.005; 68; 266	.039; 367; 743
5	Canadian Breaks	.004; 27; 1,462	.006; 10.40; 1,097.21	129.29; 38.09; 75.03	.000; 8; 358	.020; 50; 4,309
6	Rolling Plains North	.012; 137; 745	.007; 40.53; 347.12	60.82; 29.65; 46.62	.002; 69; 320	.037; 227; 1,575
7	Rolling Plains Central	.035; 138; 324	.015; 55.57; 85.08	42.23; 40.18; 26.30	.014; 64; 192	.065; 291; 494
8	Trans-Pecos	.0001; 21; 9,982	.0004; 9.86; 3,599.31	298.02; 46.06; 36.06	.000; 12; 3,322	.002; 52; 16,845
9	Edwards Plateau West	.004; 127; 1,356	.004; 91.31; 341.80	109.34; 71.63; 25.21	.000; 47; 695	.020; 479; 2,191
10	Edwards Plateau South	.020; 134; 599	.011; 40.46; 191.18	54.64; 30.23; 31.92	.007; 68; 322	.049; 202; 1,122
11	Rio Grande Plains	.002; 76; 1,536	.002; 36.15; 622.11	119.72; 47.42; 40.50	.000; 18; 962	.010; 186; 4,387
12	North Central Plains	.035; 211; 404	.013; 88.06; 201.43	37.21; 41.68; 49.81	.012; 119; 227	.058; 459; 1,273
13	Crosstimbers	.053; 201; 267	.029; 118.16; 53.74	53.82; 58.65; 20.16	.015; 93; 146	.144; 567; 408
14	Hill Country North	.026; 189; 328	.014; 81.30; 72.61	53.65; 42.92; 22.12	.009; 78; 235	.063; 424; 515
15	Hill Country West	.016; 52; 543	.009; 27.28; 135.37	56.76; 52.06; 24.98	.005; 20; 318	.037; 142; 775
16	Highland Lakes	.051; 97; 270	.032; 53.50; 68.23	63.98; 55.27; 25.24	.009; 40; 136	.132; 268; 440
17	Hill Country South	.028; 43; 465	.045; 50.09; 292.83	160.94; 116.14; 62.91	.000; 10; 153	.151; 198; 1,358
19	Coastal Prairie North	.215; 194; 120	.042; 59.49; 16.15	19.32; 30.73; 13.51	.145; 111; 92	.319; 323; 153
20	Coastal Prairie South	.069; 126; 274	.029; 44.30; 90.65	42.40; 35.30; 33.04	.030; 59; 158	.140; 234; 529
21	Coastal Prairie Middle	.074; 98; 262	.030; 42.00; 101.67	40.35; 42.66; 38.80	.017; 21; 150	.147; 171; 704
25	Blacklands North	.108; 320; 177	.020; 107.81; 21.40	18.56; 33.70; 12.12	.076; 214; 143	.146; 606; 239
27	Brazos	.166; 207; 160	.069; 93.06; 63.69	41.49; 44.99; 39.70	.034; 85; 86	.277; 465; 385
29	North East	.150; 208; 175	.043; 42.37; 48.34	28.75; 20.37; 27.58	.070; 102; 121	.232; 272; 325
30	Piney Woods North	.175; 145; 143	.044; 27.35; 26.03	24.90; 18.80; 18.17	.099; 106; 104	.285; 216; 222
31	Piney Woods South	.245; 39; 124	.098; 13.08; 52.44	40.10; 33.69; 42.12	.059; 18; 73	.468; 71; 293
32	Lower Rio Grande Valley	.177; 83; 156	.074; 48.08; 64.00	41.95; 57.76; 41.08	.073; 35; 70	.344; 287; 308

*Numbers in each cell correspond to the Fragmentation Index, the number of land sales, and the average acres sold per period, respectively.

**All numbers are for the time period 1976 through 2005

For all time periods the Southern Piney Woods had the largest one year fragmentation index of 0.468, and the Trans-Pecos area had the smallest maximum fragmentation index of 0.002. The Northern Blacklands have the highest single period amount of land sales for a region with 606. The Canadian Breaks has the smallest amount with only eight land sales in one year. In keeping with the largest average acres sold for the entire time period, the Trans-Pecos area also had the largest average acres for a single time period with 16,845. The Lower Rio Grande Valley had the lowest average acreage sold in single year with seventy acres involved per each transaction.

Average Acres Sold

The results of the ordinary least squares regression using average acres sold as the fragmentation variable is contained in Table 3. The average acres per land sale are only significant, at the ten percent level, for four out of the twenty six regions. The common significant explanatory variable shared by the state and all regions, except the Brazos land market area, is beef cattle inventory lagged one year. The trend variable was only significant in the Brazos land market area. The feed price ratio was only significant in five of the regions and had the unexpected sign in four of those. R-squared for the state was 0.83, meaning that the seven independent variables successfully explain 83 percent of the variation in beef cow inventory. R-square ranged from 0.95 in the Rio Grande Plains (Region 11), to 0.35 in the North Central Plains (Region 12).

Land Sales

Table 4 contains the results of the regressions using land sale numbers as the fragmentation variable. Previous beef cattle inventories were the most commonly significant explanatory variable in this set of regressions, as well. However, the inventory for the state and for four of the land market areas was not significant at the ten percent level, but the expected sign occurred in all regressions. The feed price index showed little significance throughout the regressions. Land sales were hypothesized to have an inverse effect on beef cattle inventory, however, it only had the expected sign in twelve of the twenty six regions. It was only significant in four of the regions. R-squared for the state was lower than when average acres per sales was used, with 81 percent of variation explained. At 0.957, the Rio Grande Plains had the highest R-squared again, while the Crosstimbers area (Region 13) had the lowest R-squared at 0.401.

Table 3: Results of OLS Regression on Beef Cattle Quantities using Average Acres Sold

	State	Regions 1	2	3	4	5	6	7	8	9	10	11	12	13
Intercept	**7,807,428**	41,733	-104,889	**35,185**	**157,873**	**48,600**	17,272	-112,078	**91,839**	-28,564	19,036	94,726	109,056	-143,283
	(0.064)	(0.309)	(0.576)	(0.099)	(0.055)	(0.005)	(0.749)	(0.474)	(0.061)	(0.855)	(0.822)	(0.524)	(0.211)	(0.367)
Trend	2,548	253	437	141	413	191	5	181	-739	-698	-762	-1,355	-7	-402
	(0.672)	(0.408)	(0.290)	(0.592)	(0.16)	(0.59)	(0.991)	(0.675)	(0.181)	(0.300)	(0.255)	(0.420)	(0.990)	0.725
Cattle $_{t-1}$	**0.475**	**0.467**	**0.549**	**0.745**	**0.314**	**0.326**	**0.665**	**0.693**	**0.654**	**0.814**	**0.585**	**0.718**	**0.515**	**0.491**
	(0.014)	(0.024)	(0.010)	(0.000)	(0.084)	(0.085)	(0.001)	(0.001)	(0.000)	(0.000)	(0.011)	(0.000)	(0.008)	(0.014)
Feed Price Index $_{t-1}$	**-14,515**	-318	-411	77	-537	129	226	-316	-47	324	-162	-1,338	139	729
	(0.066)	(0.304)	(0.389)	(0.793)	(0.116)	(0.734)	(0.662)	(0.506)	(0.929)	(0.688)	(0.743)	(0.158)	(0.826)	(0.247)
Missing Cattle Dummy	-129,392	-6,308	-8,258	1,021	2,228	-4,285	-3,315	9,448	6,143	-1,658	-7,100	-5,574	4,274	-4,180
	(0.166)	(0.165)	(0.228)	(0.760)	(0.573)	(0.343)	(0.680)	(0.170)	(0.414)	(0.871)	(0.426)	(0.701)	(0.597)	(0.621)
Average Acres Sold	-33,525	-44	980	-153	-578	-23	152	1,297	-17	78	219	55	15	2,893
	(0.160)	(0.715)	(0.409)	(0.224)	(0.250)	(0.172)	(0.340)	(0.355)	(0.184)	(0.805)	(0.520)	(0.778)	(0.960)	(0.138)
Average Acres Sold ^{2}	71.14	0.07	-1.95	0.23	1.08	0.01	-0.20	-3.52	0.00	-0.03	-0.36	-0.02	0.02	-11.92
	(0.138)	(0.595)	(0.408)	(0.226)	(0.317)	(0.170)	(0.302)	(0.402)	(0.119)	(0.892)	(0.475)	(0.791)	(0.973)	(0.111)
Average Acres Sold ^{3}	-4.92E-02	-2.77E-05	1.23E-03	-5.27E-05	-6.01E-04	-2.00E-06	7.20E-05	3.01E-03	**-7.84E-08**	3.69E-06	1.85E-04	3.15E-06	-1.17E-05	**1.55E-02**
	(0.115)	(0.492)	(0.422)	(0.226)	(0.411)	(0.147)	(0.316)	(0.458)	(0.091)	(0.945)	(0.438)	(0.794)	(0.963)	(0.089)
R^2	0.830	0.567	0.629	0.730	0.466	0.501	0.566	0.569	0.789	0.715	0.839	0.952	0.394	0.478

Regions	14	15	16	17	19	20	21	25	27	29	30	31	32
Intercept	262,992	**-95,707**	-74,275	**27,618**	-989,994	**306,684**	41,584	-1,844,299	130,032	335,530	**-888,798**	**52,260**	44,845
	(0.377)	(0.075)	(0.132)	(0.097)	(0.423)	(0.003)	(0.523)	(0.253)	(0.202)	(0.219)	(0.044)	(0.046)	(0.151)
Trend	94	-118	-196	59	1,676	-410	189	912	**1,461**	279	-341	250	-284
	(0.843)	(0.341)	(0.507)	(0.794)	(0.108)	(0.363)	(0.758)	(0.345)	(0.097)	(0.752)	(0.559)	(0.179)	(0.525)
Cattle $_{t-1}$	**0.546**	**0.593**	**0.799**	**0.560**	**0.540**	**0.306**	**0.637**	**0.468**	0.231	**0.479**	**0.311**	**0.385**	**0.570**
	(0.003)	(0.006)	(0.000)	(0.014)	(0.008)	(0.089)	(0.001)	(0.016)	(0.220)	(0.011)	(0.023)	(0.015)	(0.003)
Feed Price Index $_{t-1}$	-446	64	**607**	-190	-648	**-1,102**	-335	-1,142	-722	-968	**-1,188**	**-475**	-545
	(0.406)	(0.652)	(0.036)	(0.461)	(0.450)	(0.032)	(0.558)	(0.323)	(0.327)	(0.309)	(0.069)	(0.020)	(0.119)
Missing Cattle Dummy	-9,110	-2,803	-1,357	-4,190	-10,271	**-16,657**	-2,410	**-29,457**	5,018	-9,074	-5,497	2,808	5,912
	(0.229)	(0.185)	(0.706)	(0.293)	(0.306)	(0.037)	(0.778)	(0.067)	(0.604)	(0.464)	(0.494)	(0.317)	(0.211)
Average Acres Sold	-1,845	**596**	749	-16	30,204	**-1,268**	314	35,199	**2,467**	-2,123	**23,253**	296	-28
	(0.445)	(0.049)	(0.153)	(0.697)	(0.332)	(0.085)	(0.614)	(0.179)	(0.032)	(0.567)	(0.012)	(0.452)	(0.959)
Average Acres Sold ^{2}	5.46	**-1.06**	-2.30	0.04	-265.57	**3.98**	-0.98	-198.15	**-12.82**	9.55	**-145.82**	-2.42	-0.62
	(0.405)	(0.061)	(0.227)	(0.577)	(0.303)	(0.083)	(0.580)	(0.160)	(0.022)	(0.591)	(0.014)	(0.313)	(0.844)
Average Acres Sold ^{3}	-4.97E-03	**6.07E-04**	2.43E-03	-1.72E-05	7.72E-01	**-3.80E-03**	8.46E-04	3.66E-01	**1.92E-02**	-1.33E-02	**2.95E-01**	5.15E-03	2.11E-03
	(0.390)	(0.073)	(0.271)	(0.583)	(0.273)	(0.094)	(0.567)	(0.142)	(0.019)	(0.624)	(0.016)	(0.251)	(0.710)
R^2	0.688	0.689	0.624	0.642	0.808	0.817	0.586	0.748	0.586	0.563	0.753	0.543	0.839

* Numbers in parentheses are associated p-values ** Significance is calculated at a 10% level

Table 4: Results of OLS Regression on Beef Cattle Quantities using Number of Sales

	State	Regions 1	2	3	4	5	6	7	8	9	10	11	12	13
Intercept	676,274	46,760	120,991	-25,862	**74,684**	23,435	100,666	-62,487	89,171	73,569	73,557	**238,458**	78,924	**114,870**
	(0.718)	(0.352)	(0.194)	(0.486)	(0.022)	(0.328)	(0.376)	(0.221)	(0.143)	(0.178)	(0.549)	0.023	(0.330)	(0.037)
Trend	-13,178.67	450.25	221.79	-63.40	417.25	-220.41	-150.62	-312.82	-1,045.78	-97.84	-1,208.93	-3,306.56	333.06	188
	(0.107)	(0.164)	(0.585)	(0.790)	(0.173)	(0.517)	(0.777)	(0.409)	(0.142)	(0.912)	(0.206)	0.106	(0.561)	(0.762)
Cattle $_{t-1}$	0.248	**0.384**	**0.641**	**0.754**	0.291	**0.401**	**0.668**	**0.671**	**0.649**	**0.483**	0.477	**0.574**	**0.728**	**0.499**
	(0.281)	(0.091)	(0.004)	(0.000)	(0.119)	(0.045)	(0.005)	(0.001)	(0.001)	(0.036)	(0.104)	0.002	(0.001)	(0.017)
Feed Price Index $_{t-1}$	-9,212	-235	-299	93	**-598**	**651**	276	121	125	-130	-293	**-1,622**	333	217
	(0.223)	(0.392)	(0.511)	(0.719)	(0.082)	(0.059)	(0.646)	(0.790)	(0.846)	(0.861)	(0.572)	0.083	(0.554)	(0.741)
Missing Cattle Dummy	**-210,027**	-4,617	-6,067	448	2	-5,795	-2,060	-563	6,872	-8,662	-7,947	-3,571	5,771	-13,925
	(0.060)	(0.317)	(0.366)	(0.895)	(1.000)	(0.228)	(0.819)	(0.919)	(0.425)	(0.399)	(0.435)	0.789	(0.493)	(0.171)
Land Sales	2,122	-63	-1,384	654	-143	730	-1,120	**1,841**	-5,025	453	342	-1,479	-65	-314
	(0.167)	(0.970)	(0.440)	(0.279)	(0.704)	(0.766)	(0.627)	(0.017)	(0.417)	(0.470)	(0.925)	0.325	(0.952)	(0.491)
Land Sales ^{2}	-0.469	-4.862	7.519	-3.503	0.998	-48.943	7.439	**-10.436**	214.028	-3.066	-4.291	17.998	-0.849	0.75
	(0.213)	(0.825)	(0.467)	(0.288)	(0.601)	(0.589)	(0.644)	(0.030)	(0.335)	(0.238)	(0.878)	0.277	(0.843)	(0.655)
Land Sales ^{3}	3.37E-05	3.62E-02	-1.30E-02	5.93E-03	-2.08E-03	7.17E-01	-1.55E-02	**1.83E-02**	-2.51E+00	4.24E-03	1.53E-02	-5.37E-02	2.00E-03	-5.31E-04
	(0.252)	(0.684)	(0.490)	(0.297)	(0.490)	(0.489)	(0.667)	(0.050)	(0.303)	(0.188)	(0.822)	0.318	(0.697)	(0.767)
R^2	0.814	0.582	0.620	0.726	0.420	0.434	0.467	0.662	0.768	0.757	0.846	0.957	0.471	0.401

Regions	14	15	16	17	19	20	21	25	27	29	30	31	32
Intercept	33,503	17,755	27,414	**28,404**	34,016	**222,534**	51,303	331,749	45,207	126,487	**1,158,786**	47,506	**82,552**
	(0.481)	(0.195)	(0.504)	(0.096)	(0.836)	(0.017)	(0.198)	(0.255)	(0.700)	(0.692)	(0.020)	(0.141)	(0.004)
Trend	-290	-74	-293	50	351	-95	285	992	-643	-232	**-1,275**	280	**-844**
	(0.647)	(0.623)	(0.452)	(0.832)	(0.745)	(0.876)	(0.718)	(0.350)	(0.713)	(0.801)	(0.068)	(0.166)	(0.099)
Cattle $_{t-1}$	**0.558**	**0.470**	**0.565**	**0.459**	**0.628**	**0.370**	**0.641**	0.335	**0.425**	**0.546**	0.220	**0.357**	**0.388**
	(0.054)	(0.055)	(0.056)	(0.071)	(0.002)	(0.048)	(0.001)	(0.148)	(0.050)	(0.008)	(0.198)	(0.048)	(0.061)
Feed Price Index $_{t-1}$	-45	-37	512	-159	-160	**-1,235**	-458	-1,833	112	-970	-312	**-435**	-508
	(0.941)	(0.818)	(0.133)	(0.546)	(0.839)	(0.068)	(0.451)	(0.186)	(0.893)	(0.317)	(0.605)	(0.060)	(0.104)
Missing Cattle Dummy	-6,819	-2,053	-981	-4,446	-16,245	-8,543	-472	**-31,929**	-8,668	-6,839	-5,948	1,085	**7,825**
	(0.474)	(0.400)	(0.815)	(0.300)	(0.111)	(0.337)	(0.967)	(0.074)	(0.468)	(0.584)	(0.535)	(0.744)	(0.093)
Land Sales	417	153	231	240	835	-1,202	730	-633	**1,890**	1,237	**-16,911**	1,271	**-1,051**
	(0.609)	(0.674)	(0.713)	(0.449)	(0.724)	(0.519)	(0.495)	(0.770)	(0.041)	(0.798)	(0.069)	(0.543)	(0.029)
Land Sales ^{2}	-1.74	-2.89	-1.47	-3.29	-1.87	7.99	-7.71	2.00	**-6.50**	-7.24	**111.65**	-32.85	**9.11**
	(0.618)	(0.579)	(0.783)	(0.382)	(0.872)	(0.555)	(0.495)	(0.730)	(0.061)	(0.778)	(0.064)	(0.514)	(0.024)
Land Sales ^{3}	2.12E-03	1.24E-02	2.28E-03	1.03E-02	8.31E-04	-1.63E-02	2.56E-02	-1.79E-03	**7.13E-03**	1.16E-02	**-2.36E-01**	2.55E-01	**-2.02E-02**
	(0.640)	(0.577)	(0.855)	(0.390)	(0.963)	(0.589)	(0.572)	(0.714)	(0.085)	(0.791)	(0.062)	(0.502)	(0.023)
R^2	0.580	0.626	0.503	0.630	0.803	0.781	0.594	0.703	0.556	0.587	0.718	0.409	0.855

* Numbers in parentheses are associated p-values ** Significance is calculated at a 10% level

Table 5: Results of OLS Regression on Beef Cattle Quantities using Fragmentation Index

	State	1	2	3	4	5	6	7	8	9	10	11	12	13
		Regions												
Intercept	973,239	**37,961**	**49,717**	10,482	**94,691**	**24,496**	29,550	17,492	**53,222**	68,906	58,555	**173,924**	**185,469**	**109,364**
	(0.482)	(0.006)	(0.041)	(0.396)	(0.001)	(0.063)	(0.388)	(0.695)	(0.089)	(0.110)	(0.144)	(0.031)	(0.006)	(0.049)
Trend	-2,379	249	562	101	294	-330	58	37	-643	-551	-1,041	-1,907	-431	67
	(0.688)	(0.332)	(0.176)	(0.699)	(0.325)	(0.290)	(0.908)	(0.929)	(0.310)	(0.328)	(0.119)	(0.300)	(0.401)	(0.908)
Cattle $_{t-1}$	0.316	**0.352**	**0.511**	**0.746**	0.258	**0.455**	**0.605**	**0.659**	**0.619**	**0.653**	**0.517**	**0.643**	**0.452**	**0.458**
	(0.151)	(0.072)	(0.007)	(0.000)	(0.154)	(0.038)	(0.002)	(0.001)	(0.001)	(0.001)	(0.018)	(0.000)	(0.004)	(0.034)
Feed Price Index $_{t-1}$	-11,216	-207	-484	33	**-567**	**603**	135	-348	243	221	-98	**-1,635**	92	185
	(0.140)	(0.434)	(0.246)	(0.915)	(0.100)	(0.073)	(0.793)	(0.462)	(0.680)	(0.751)	(0.844)	(0.095)	(0.862)	(0.782)
Missing Cattle Dummy	**-201,754**	-7,053	-6,315	-74	905	-7,661	-2,440	4,835	2,989	-7,285	-11,865	-5,546	323	-7,649
	(0.069)	(0.106)	(0.331)	(0.982)	(0.827)	(0.113)	(0.757)	(0.434)	(0.727)	(0.410)	(0.163)	(0.699)	(0.965)	(0.411)
F.I. 80	**1.81E+08**	-2.14E+03	-2.78E+05	-1.37E+05	**-4.79E+06**	-1.78E+06	**7.12E+06**	2.46E+06	-2.76E+07	-3.66E+06	2.42E+06	-1.09E+07	-2.22E+06	-1.04E+06
	(0.045)	(0.999)	(0.930)	(0.872)	(0.078)	(0.351)	(0.026)	(0.463)	(0.713)	(0.397)	(0.506)	(0.365)	(0.579)	(0.383)
F.I. 80 ^{2}	**-4.45E+09**	-4.85E+08	1.47E+08	1.27E+07	**2.67E+08**	2.61E+08	**-4.40E+08**	-6.04E+07	1.33E+10	-2.55E+08	-1.34E+08	3.52E+09	3.36E+07	1.59E+07
	(0.042)	(0.568)	(0.633)	(0.619)	(0.080)	(0.339)	(0.024)	(0.521)	(0.934)	(0.700)	(0.400)	(0.337)	(0.786)	(0.379)
F.I. 80 ^{3}	**3.48E+10**	5.64E+10	-4.92E+09	-1.70E+08	**-4.17E+09**	-9.31E+09	**7.51E+09**	4.24E+08	-2.27E+12	2.05E+10	1.96E+09	-2.26E+11	-2.09E+08	-6.76E+07
	(0.040)	(0.360)	(0.519)	(0.448)	(0.084)	(0.344)	(0.026)	(0.600)	(0.969)	(0.397)	(0.327)	(0.380)	(0.860)	(0.393)
R^2	0.822	0.606	0.643	0.744	0.394	0.408	0.574	0.572	0.757	0.793	0.853	0.955	0.533	0.371

Regions	**14**	**15**	**16**	**17**	**19**	**20**	**21**	**25**	**27**	**29**	**30**	**31**	**32**
Intercept	**149,562**	**25,287**	13,946	**28,545**	**1,264,926**	**163,720**	50,905	1,216,680	**254,319**	192,661	201,898	**49,435**	**46,910**
	(0.000)	(0.044)	(0.541)	(0.070)	(0.002)	(0.001)	(0.187)	(0.160)	(0.006)	(0.358)	(0.193)	(0.016)	(0.083)
Trend	257	-196	-275	8	**2,106**	-215	176	988	1,356	341	-799	231	-291
	(0.542)	(0.149)	(0.415)	(0.976)	(0.049)	(0.568)	(0.749)	(0.321)	(0.156)	(0.695)	(0.216)	(0.241)	(0.551)
Cattle $_{t-1}$	**0.555**	**0.498**	**0.775**	**0.520**	**0.494**	**0.472**	**0.637**	**0.435**	0.146	**0.466**	**0.283**	**0.389**	**0.577**
	(0.001)	(0.033)	(0.001)	(0.022)	(0.011)	(0.002)	(0.001)	(0.030)	(0.486)	(0.011)	(0.075)	(0.021)	(0.007)
Feed Price Index $_{t-1}$	**-940**	66	**608**	-141	-909	**-839**	-232	-994	-601	-902	-711	**-401**	-436
	(0.068)	(0.681)	(0.063)	(0.594)	(0.259)	(0.045)	(0.676)	(0.411)	(0.483)	(0.332)	(0.296)	(0.073)	(0.191)
Missing Cattle Dummy	-9,496	-1,332	-1,471	-4,044	-7,827	**-17,678**	-3,352	**-37,113**	4,123	-14,973	-9,583	1,185	4,830
	(0.133)	(0.554)	(0.721)	(0.318)	(0.354)	(0.004)	(0.687)	(0.031)	(0.713)	(0.259)	(0.275)	(0.677)	(0.309)
F.I. 80	**-6.66E+06**	-1.23E+06	-1.50E+04	1.48E+05	**-1.44E+07**	-3.30E+05	6.95E+05	-2.81E+07	6.03E+05	2.58E+05	1.82E+06	1.13E+05	-2.82E+05
	(0.005)	(0.378)	(0.977)	(0.507)	(0.003)	(0.780)	(0.536)	(0.245)	(0.508)	(0.944)	(0.447)	(0.412)	(0.552)
F.I. 80 ^{2}	**1.81E+08**	5.25E+07	-1.17E+06	-3.99E+06	**6.10E+07**	-5.40E+06	-7.19E+06	2.55E+08	-2.36E+06	-4.10E+06	-8.52E+06	-432,355	1,447,955
	(0.016)	(0.496)	(0.897)	(0.319)	(0.004)	(0.725)	(0.636)	(0.245)	(0.704)	(0.870)	(0.515)	(0.470)	(0.572)
F.I. 80 ^{3}	**-1.48E+09**	-7.07E+08	4.89E+06	2.11E+07	**-8.43E+07**	5.46E+07	1.99E+07	-7.48E+08	2.66E+06	1.42E+07	1.16E+07	563,530	-2,088,276
	(0.034)	(0.567)	(0.913)	(0.250)	(0.005)	(0.376)	(0.744)	(0.253)	(0.836)	(0.794)	(0.613)	(0.463)	(0.616)
R^2	0.779	0.648	0.520	0.631	0.845	0.873	0.598	0.726	0.504	0.576	0.706	0.489	0.826

* Numbers in parentheses are associated p-values ** Significance is calculated at a 10% level

Fragmentation Index

Table 5 presents the results of the regressions run with the created fragmentation index as the fragmentation explanatory variable. Once again, previous beef cattle inventories were the most statistically significant variables used in the regressions. The feed price index does not have the expected sign in eighteen of the twenty seven regressions, and is only significant in seven of them. The fragmentation index possesses the expected sign in a majority of regions, but is only significant in five of the regressions. R-squared for the state is 0.822, in between the R-squared for the state when average acres or land sales are used. For the third time, the Rio Grand Plains land market area had the highest R-squared among all regions, with 95 percent of the variation explained. The Crosstimbers area had the smallest R-squared for a second time, with only 37 percent of variation being explained by the independent variables.

Concluding Remarks

Contrary to a priori expectations, there was little evidence that beef cow inventory has been negatively affected by land fragmentation. None of the three measures of land fragmentation, average acres per transaction, total transactions, or a fragmentation index appeared to have an important effect on cattle inventory.

A possible explanation for these unexpected results is the agricultural valuation used for property taxes in Texas. In the 1960's, legislation was passed to value land at its agricultural use value to protect farmers and ranchers. That tax value continues today. Even a relatively few cattle can qualify a piece of land for the lower valuation. That may play a role in keeping cattle on the land. To better explain the agricultural valuation for property taxes, the Texas Farm Bureau's Austin Newsletter claims that the "market value of the 144 million acres of agricultural land in Texas averaged $624 per acre, substantially greater than the agricultural value of $80 per acre for the same land." It may also suggest that cattle numbers exceed the carrying capacity of the land as parcel size declines.

One drawback to this study is that land sales in the most urban counties, Travis, Bexar, Harris, Tarrant, and Dallas are not included in the data. These are counties that would encompass the rural-urban interface and would be expected to be most impacted by land fragmentation. While all of these counties' inventories have declined, on Dallas and Tarrant (Fort Worth) counties have lost a greater percentage of beef cows than the state average. Further data may allow testing of the hypothesis for those counties.

The authors would speculate one other explanation that is more cultural than economic. Texans have a strong attachment to the land. They have been raised on the ranching "mythology" of Texas and on classic Western movies. Many landowners have been successful in other careers and bought ranches and cattle. This may have played a role in maintaining cow numbers, as well. But, it would appear that this is changing with a younger generation. Recent legislation allows land owners to convert agricultural use to wildlife use and maintain lower values for property tax valuation purposes. There is a corresponding move to land ownership for more recreational purposes rather than cattle ranching, on whatever scale.

Although this study gives evidence that different types of land fragmentation do not negatively affect the supply of beef cattle in Texas; the impact of a growing population may present more negative effects in time. Other states, mostly eastern states, may have experienced negative effects due to encroaching urban and suburban areas, and Texas could be an anomaly in the system.

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