Entropy Based Measurement of Geographic Concentration in U.S. Hog Production

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Abstract
Geographic concentration in the U.S. hog industry from 1982 to 1995 is investigated using an entropy based measure. Results indicate that geographic concentration is occurring to the greatest degree in Kansas, Missouri, and North Carolina. Hog production is also increasing in North Carolina, indicating the potential for increased environmental problems.

Keywords
hog industry

Introduction

The industrialization of hog production has received much attention lately, both from academic researchers and in the national press. Much of this attention has focused on the negative impacts of large-scale hog operations on local communities and the environment. Perhaps of greater concern from an environmental perspective, however, is not the increase in the concentration of production in the hands of a few large firms, but the concentration of production within geographic areas. Geographic concentration, when coupled with increasing numbers of hogs, may lead to increased environmental and social problems, including offensive odors, increased potential for groundwater contamination from excess manure applications on cropland, and increased environmental damage from lagoon spills during localized weather phenomena.

The purpose of this paper is to examine trends in geographic concentration of hog production. An entropy based measure of concentration is used to compare concentration both between and within-states. Concentration is examined for both total hog numbers and total hog farms. Overall trends in geographic concentration are examined using agricultural census data from 1982, 1987, and 1992. Recent trends in key hog-producing states are examined using county estimates of hog production from 1989 to 1995.

Construction of Concentration Index

A commonly used measure of industrial concentration is Theil's entropy measure, defined as

$$H(\theta) = \sum_{i=1}^{n} \theta_i \log_2 \theta_i^{-1} \qquad (1)$$

where θ_i is the ith firm's share of production (Batten). In the case where geographic concentration is to be measured, θ_i represents the ith region's share of production (or farms). This discussion closely follows Sporleder, who applied this approach to the poultry processing industry.

The entropy measure is bounded such that $0 \leq H(\theta) \leq \log_2 n$. Higher values of $H(\theta)$ indicate more entropy, or dispersion, and lower values indicate more concentration. Detailed discussions of the properties of entropy measures can be found in Horowitz, Sporleder, and Theil. A more useful measure for examining geographic concentration is relative entropy, which is defined as

$$R(\theta) = \frac{H(\theta)}{\log_2 n} \qquad (2)$$

This is an index of concentration measuring how dispersed production (or the number of farms) is relative to the maximum level of dispersion. Thus, if there is complete concentration in one region, $R(\theta)$ will equal 0 and if there is complete dispersion, $R(\theta)$ will equal 1. If hog production is becoming more geographically concentrated, the values of $R(\theta)$ should be tending towards zero.

To examine concentration at different geographic levels, i.e. at the national level and state level, it is necessary to use a decomposed version of the entropy measure. For this application, given the set of 50 states, total entropy can be disaggregated into between-state entropy, defined as

$$H_{BS}(\theta) = \sum_{m=1}^{50} \psi_m \log_2 \psi_m^{-1}, \qquad (3)$$

where $\psi_m = \sum_{i \in m} \theta_i$ and i and m index counties and states, respectively; and total within-state entropy, defined as

(4) $$H_{WS}(\theta) = \sum_{m=1}^{50} \psi_m H_m(\theta),$$

where $H_m(\theta) = \sum_{i \in m} \left[(\theta_i/\psi_m)\log_2(\psi_m/\theta_i)\right]$. Within-state entropy for each state is equal to $H_m(\theta)$. Total entropy is calculated as the sum of between-state and total within-state entropy. Relative between-state entropy is calculated as $R_{BS}(\theta) = \frac{H_{BS}(\theta)}{\log_2 50}$ and relative within-state entropy is calculated as $R_m(\theta) = \frac{H_m(\theta)}{\log_2 n_m}$, where n_m is the number of counties in state m.

<u>Geographic Concentration in Hog Production</u>

Social and economic forces have shaped the transition of hog production from small, geographically dispersed operations, to fewer, larger, and as will be demonstrated, more geographically concentrated operations. Rhodes points out that hog producers today are facing stiff opposition from suburban and rural residents to the expansion of hog operations, especially in the Cornbelt area. Hog producers may be driven to locate in counties with low population densities, low incomes, low labor costs, or counties that already have high levels of existing hog production. In addition, hog producers may tend to cluster to reduce the costs of transporting finished hogs to processors.

These and other factors, including local nuisance and environmental laws, may cause hog production to be concentrated into relatively few counties. When total hog production in a region is also increasing, this can lead to problems. As the number of hogs per acre in a county increases, the capacity of the surrounding environment to process hog wastes may be exceeded, leading to potential ground and surface water contamination (Abdalla, Lanyon, and Hallberg; Letson and Gollehon). Boehlje suggests that "environmental adsorptive capacity" may become an important determinant in the location of hog operations, because it is a non-mobile resource. However, in states with little environmental regulation of hog operations, hog numbers may exceed the environemental adsorptive capacity, leading to potential environmental problems. In addition, as hog operations are clustered together, odor problems are compounded, leading to potential losses in property values for neighboring properties and reduced quality of life for residents of those counties.

Table 1 lists information on hog production for all 50 states for each of the past three agricultural census years: 1982, 1987, and 1992. The total number of hog farms in the U.S. fell consistently during the decade from 1982 to 1992, from a high of around 330,000 in 1982 to 191,000 in 1992. At the same time, hog numbers increased from 55.4 million in 1982 to 57.6 million in 1992. This suggests that more production is being concentrated into the hands of fewer farmers.

To examine whether geographic concentration is also occurring, both on a national level and within particular states, relative entropy is calculated for each of the three agricultural census years. Relative entropy is calculated for both the number of farms and the number of hogs. Table 2 presents estimates of total relative entropy, relative entropy between-states, and weighted average within-state entropy. Table 3 presents estimates of within-state relative entropy for all 50 states.

Table 1. Number of Hog Farms and Hogs by State for Census Years 1992, 1987, and 1982.

State	Rank by # of Farms	Rank by # of Hogs	# of Hog Farms			# of Hogs (000)		
			1992	1987	1982	1992	1987	1982
U.S. Total			191347	243398	329833	57563.1	52271.1	55366.2
Alabama	26	23	1880	3585	6061	307.7	353.1	463.8
Alaska	50	50	45	45	88	2.1	0.6	3.7
Arizona	45	31	281	331	543	83.3	135.4	160.8
Arkansas	25	16	1883	2467	3737	725.5	452.9	388.4
California	20	25	2221	2699	4800	258.1	150.9	184.6
Colorado	28	18	1643	1685	2518	464.5	258.7	333.4
Connecticut	43	45	293	254	379	5.6	5.4	6.9
Delaware	47	33	205	301	421	58.9	49.7	54.4
Florida	24	29	1926	2487	3602	114.9	156.1	203.2
Georgia	17	14	3844	5805	8911	1000.8	1060.4	1317.4
Hawaii	46	40	253	372	371	28.6	47.6	49.0
Idaho	31	32	1141	1258	1648	67.3	76.9	81.0
Illinois	2	2	13433	17084	21646	5641.1	5643.0	5989.0
Indiana	4	5	11987	14834	17654	4618.7	4372.3	4298.0
Iowa	1	1	31790	36670	45768	14153.2	12983.1	14332.6
Kansas	11	10	5684	6768	9241	1584.0	1516.9	1708.8
Kentucky	14	15	4879	8242	11436	782.4	838.5	869.7
Louisiana	34	38	844	1262	2188	37.5	51.9	55.7
Maine	41	47	377	421	804	4.8	9.0	8.6
Maryland	33	28	910	1322	1861	145.5	197.2	179.1
Massachusetts	39	43	404	498	619	16.4	25.8	39.6
Michigan	15	11	4774	5577	7433	1231.6	1227.1	1064.1
Minnesota	3	4	13125	16042	20813	4668.6	4236.5	4473.2
Mississippi	30	27	1270	2237	4081	160.9	179.1	223.3
Missouri	5	7	11894	14985	22589	2908.5	2582.0	3186.4
Montana	32	26	1056	1406	1643	223.0	200.7	195.9
Nebraska	6	6	10826	13363	15998	4187.4	3944.2	3963.4
Nevada	48	44	154	149	245	7.6	16.5	15.3
New Hampshire	44	48	289	264	443	4.5	5.0	6.3
New Jersey	37	39	640	680	889	29.6	32.0	53.8
New Mexico	38	42	496	592	914	20.2	44.2	39.5
New York	21	30	2094	2644	4325	90.3	99.6	118.4
North Carolina	16	3	4311	6921	11390	5101.0	2547.1	2047.1
North Dakota	23	21	1932	2365	2506	346.1	294.4	260.2
Ohio	7	9	9392	11421	13769	1957.9	2059.2	2076.8
Oklahoma	18	24	3415	3710	4225	260.7	187.4	212.5
Oregon	27	34	1669	1482	2500	58.3	86.3	105.2
Pennsylvania	12	13	5097	6983	9229	1074.6	919.8	869.4
Rhode Island	49	46	48	59	73	5.5	4.7	3.0
South Carolina	19	22	2237	3249	4709	327.6	352.4	399.8
South Dakota	9	8	6710	7906	9336	1978.2	1750.2	1764.7
Tennessee	13	17	4912	8465	12963	604.6	774.5	866.2
Texas	10	19	6537	7717	9484	460.2	527.9	559.6
Utah	36	36	727	748	1061	43.0	33.6	38.7
Vermont	42	49	347	370	732	3.7	5.1	4.2
Virginia	22	20	2085	3711	7239	412.7	345.1	474.4
Washington	29	35	1407	1525	2460	56.2	59.2	73.8
West Virginia	35	41	841	1226	1981	26.8	30.8	33.9
Wisconsin	8	12	6760	8737	11940	1173.8	1312.8	1479.0
Wyoming	40	37	379	474	567	39.1	28.4	30.4

Table 2. Relative Entropies for Number of Hog Farms and Hog Numbers for Census Years 1992, 1987, and 1982

	1992		1987		1982	
Relative Entropy Measure	Hog Farms	Hogs	Hog Farms	Hogs	Hog Farms	Hogs
Total	0.922	0.818	0.928	0.841	0.937	0.850
Between-states	0.824	0.692	0.832	0.701	0.846	0.701
Average of Within-state	0.937	0.854	0.939	0.886	0.945	0.902

For the U.S. as a whole, geographical concentration appears to be occurring, both in hog farms and hog numbers. The degree of concentration appears to be greater for hog numbers than hog farms, with the change in relative entropy between 1982 and 1992 equal to -0.032 for hog numbers and -0.015 for hog farms. In addition, hog numbers are more concentrated than hog farms on an absolute scale, with relative entropy equal to 0.82 in 1992 versus 0.92 for hog farms.

Concentration of hog production between states is more pronounced than on the national level, both in terms of hog farms and hog numbers. Relative between-state entropy in 1992 was 0.82 for hog farms and 0.69 for hog numbers. The rate of concentration of hog farms between states was greater than for the nation as a whole, with the change in relative entropy equal to -0.021. However, the rate of concentration of hog numbers was lower between states than for the nation as a whole, with the change in relative entropy equal to -0.010.

On average, concentration within states was not as pronounced as concentration between states. For 1992, the weighted average within-state relative entropy was 0.94 for hog farms and 0.85 for hog numbers. The average within-state change in concentration of hog farms between 1982 and 1992 was -0.008. For hog numbers, the average within-state change was -0.048.

Table 3. Within-state Entropies for Number of Hog Farms and Hog Numbers for Census Years 1992, 1987, and 1982.

	# of Hog Farms			# of Hogs		
State	1992	1987	1982	1992	1987	1982
Alabama	0.93	0.95	0.96	0.77	0.91	0.92
Alaska	0.82	0.76	0.81	0.50	0.54	0.58
Arizona	0.83	0.87	0.84	0.44	0.45	0.45
Arkansas	0.94	0.95	0.94	0.72	0.65	0.72
California	0.91	0.91	0.90	0.49	0.73	0.76
Colorado	0.86	0.86	0.86	0.45	0.66	0.68
Connecticut	0.99	0.96	0.97	0.95	0.89	0.90
Deleware	0.76	0.73	0.79	0.35	0.43	0.58
Florida	0.92	0.92	0.92	0.68	0.76	0.81
Georgia	0.89	0.90	0.91	0.68	0.80	0.82
Hawaii	0.94	0.92	0.94	0.78	0.72	0.73
Idaho	0.92	0.92	0.92	0.82	0.82	0.81
Illinois	0.95	0.96	0.96	0.92	0.93	0.93
Indiana	0.95	0.96	0.96	0.92	0.92	0.93
Iowa	0.97	0.98	0.98	0.96	0.96	0.97
Kansas	0.93	0.93	0.94	0.84	0.85	0.88
Kentucky	0.93	0.94	0.95	0.82	0.85	0.86
Louisiana	0.91	0.92	0.92	0.54	0.68	0.80
Maine	0.96	0.96	0.95	0.88	0.77	0.86
Maryland	0.92	0.93	0.95	0.84	0.83	0.88
Massachusetts	0.86	0.83	0.86	0.75	0.71	0.65
Michigan	0.89	0.89	0.90	0.73	0.77	0.77
Minnesota	0.93	0.93	0.94	0.88	0.89	0.89
Mississippi	0.96	0.97	0.97	0.67	0.78	0.86
Missouri	0.95	0.96	0.97	0.87	0.90	0.91
Montana	0.95	0.94	0.95	0.83	0.87	0.89
Nebraska	0.92	0.92	0.93	0.88	0.89	0.91
Nevada	0.87	0.86	0.87	0.35	0.27	0.21
New Hampshire	0.98	0.96	0.95	0.87	0.78	0.75
New Jersey	0.84	0.84	0.85	0.61	0.78	0.70
New Mexico	0.93	0.94	0.93	0.33	0.28	0.46
New York	0.92	0.92	0.93	0.79	0.79	0.82
North Carolina	0.88	0.90	0.92	0.61	0.75	0.82
North Dakota	0.94	0.95	0.94	0.87	0.89	0.89
Ohio	0.94	0.95	0.96	0.88	0.89	0.89
Oklahoma	0.97	0.97	0.97	0.77	0.88	0.92
Oregon	0.90	0.91	0.89	0.74	0.66	0.77
Pennsylvania	0.91	0.91	0.92	0.66	0.68	0.68
Rhode Island	0.86	0.84	0.78	0.37	0.38	0.42
South Carolina	0.91	0.90	0.91	0.82	0.79	0.85
South Dakota	0.93	0.93	0.92	0.90	0.90	0.88
Tennessee	0.95	0.95	0.96	0.85	0.88	0.89
Texas	0.93	0.92	0.93	0.68	0.69	0.78
Utah	0.88	0.90	0.91	0.67	0.75	0.80
Vermont	0.96	0.94	0.96	0.90	0.80	0.94
Virginia	0.92	0.92	0.93	0.53	0.73	0.81
Washington	0.92	0.93	0.92	0.75	0.79	0.83
West Virginia	0.92	0.93	0.94	0.67	0.75	0.80
Wisconsin	0.92	0.91	0.92	0.80	0.81	0.82
Wyoming	0.94	0.94	0.93	0.58	0.79	0.76

Thus, within-states, on average, hog numbers concentrated within counties at a faster rate than did farms. This makes sense, as hogs are more mobile than farms.

Within particular states, both the level of concentration and the rate of change were very high. Some highlights from Table 3 include: Several states with small and declining hog populations showed high levels of geographic concentration, suggesting that certain counties are becoming "hog counties", while others are reducing their hog production levels. For example, Virginia saw a 13 percent decrease in hogs from 474,000 in 1982 to 412,000 in 1992, and a 36 percent decrease in relative entropy from 0.81 to 0.52. Thus concentration increased faster than hog numbers decreased, suggesting a geographic shift in production. Out of the top ten hog-producing states (based on 1992 figures), nine showed increases in concentration, but only one showed a large increase. North Carolina increased hog production from 2 million hogs in 1982 to 5.1 million hogs in 1992 and decreased relative entropy from 0.82 to 0.61, a change of -0.21. This raises a flag indicating possible environmental problems, as more hogs are being loaded into fewer counties. Only South Dakota showed a decrease in concentration.

Recent Trends in Geographic Concentration for Key Hog-Producing States

In recent years, the industrialization of hog production has accelerated. Hog production in North Carolina, where contract production is booming and 82 percent of operations market more than 5,000 head (Rhodes), hog numbers have increased from 2.8 million in 1990 to 8.2 million in 1995, and increase of almost 200 percent. During that same period, hog numbers have remained at about 1990 levels in the other top states. As noted above, geographic concentration of hog production in North Carolina increased dramatically from 1982 to 1992. To explore whether this trend has continued, relative entropy is calculated for the top ten hog-producing states (excluding

Table 4. Within-state Relative Entropies for Key Hog-Producing States, 1989-1995

	Within-state Relative Entropy						
State	1989	1990	1991	1992	1993	1994	1995
Illinois	0.931	0.928	0.923	0.921	0.921	0.916	0.908
Indiana	0.923	0.922	0.920	0.921	0.923	0.924	0.918
Missouri	0.913	0.913	0.915	0.903	0.898	0.723	0.667
Nebraska	0.891	0.891	0.892	0.889	0.887	0.885	0.886
North Carolina	0.713	0.709	0.687	0.669	0.657	0.650	0.638
Minnesota	0.890	0.890	0.885	0.884	0.884	0.883	0.882
Kansas	0.843	0.834	0.825	0.821	0.803	0.798	0.751
Ohio	0.887	0.886	0.885	0.887	0.889	0.892	0.900

Iowa and South Dakota, for which no information is available) for the period 1989 to 1995. The data for these calculations are county level hog estimates provided by state agricultural statistics services.

Table 4 lists relative entropies for hog numbers for the top hog-producing states. Data on the number of hog farms was not available for these years. For seven out of the eight states, concentration in hog numbers increased, with large increases in Kansas, Missouri, and North Carolina. Ohio was the only state where concentration decreased.

As discussed earlier, geographic concentration in and of itself does not necessarily lead to increased environmental problems. A combination of both increased hog numbers and increased geographic concentration is necessary to increase the potential for environmental problems. Figures 1 through 3 chart the movements of hog numbers and geographic concentration for the three key hog-producing states with large increases in geographic concentration. In both Kansas and Missouri, hog numbers have decreased as concentration increased, suggesting that some

Figure 1. Trends in Hog Production and Geographic Concentration: Kansas

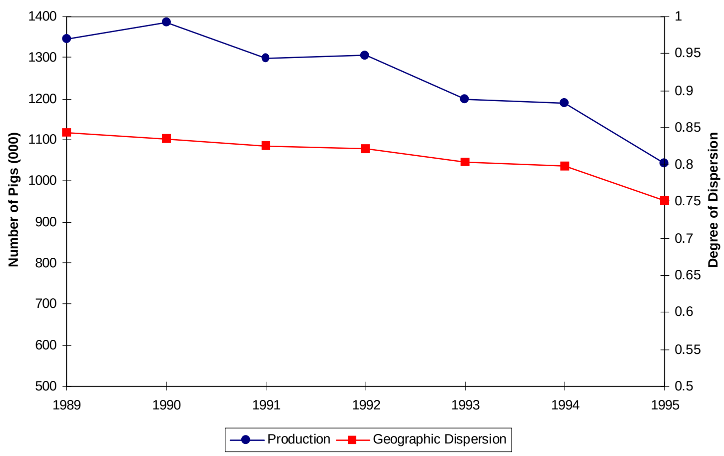


Figure 2. Trends in Hog Production and Geographic Concentration: Missouri

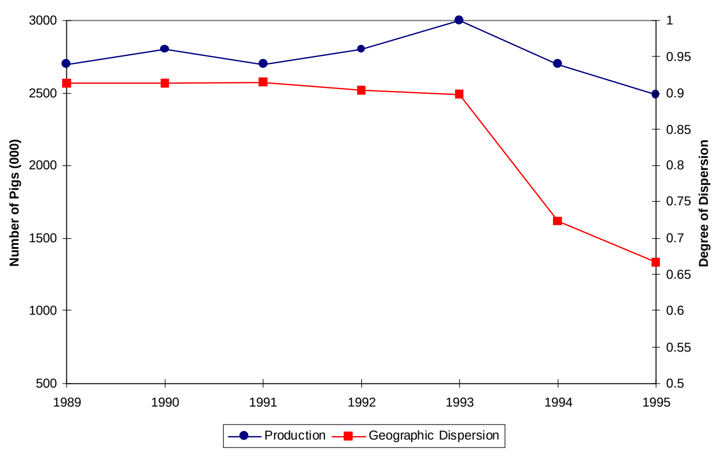
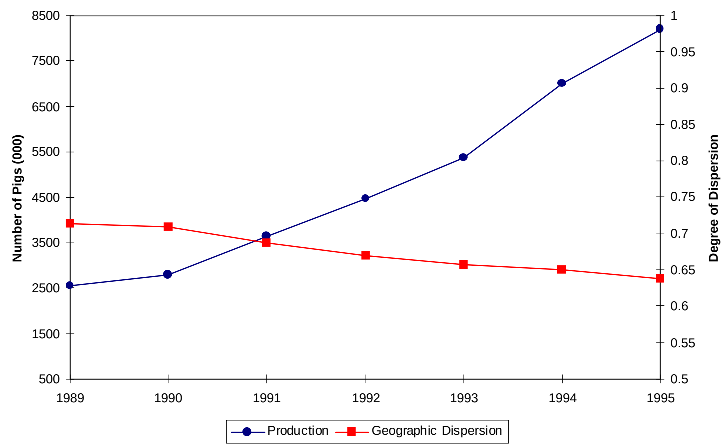


Figure 3. Trends in Hog Production and Geographic Concentration: North Carolina



counties are reducing hog production, while others are maintaining hog production levels. Only in North Carolina is there both an increase in production and an increase in concentration. Thus, this suggests that North Carolina may face unique environmental problems. Some of these problems have already begun manifesting, as evidenced by the 1995 spills of hog waste into North Carolina rivers.

Geographic concentration in North Carolina may be even more pronounced than is indicated by the entropy measures. The entropy measure employed in this paper does not take into account contiguity among counties. Figure 4 shows the proportion of hogs in each county in North Carolina in 1995. The four county area composed of Bladen, Duplin, Sampson, and Wayne counties accounted for 54.5 percent of hog production in North Carolina in 1995. That translates into 4.47

million hogs in a four county area. Future research will need to focus on developing measures of geographic concentration that can account for the clumping of production in contiguous counties.

<u>Conclusions</u>

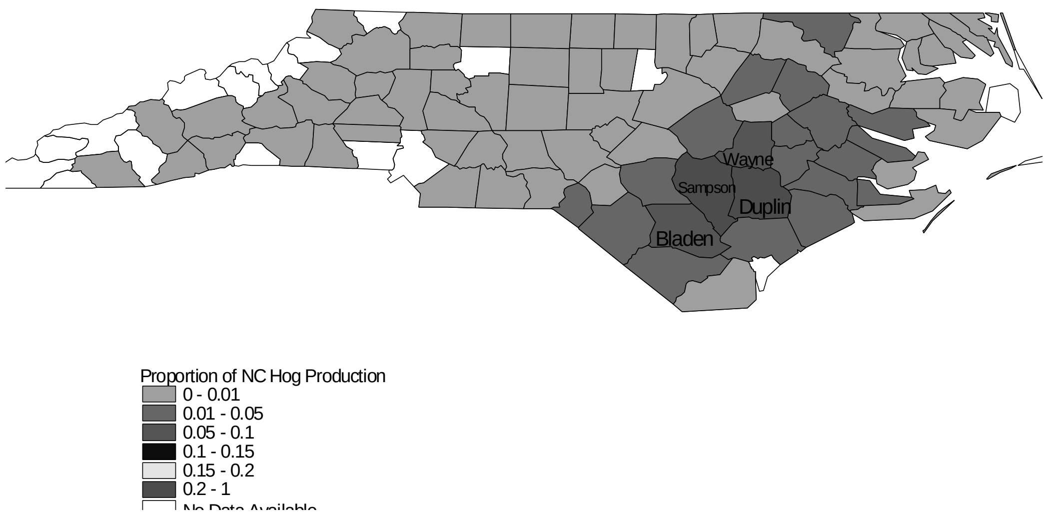
This paper has demonstrated that hog production, both on a national level and within-states, is becoming more geographically concentrated, as measured by the entropy of hog numbers and hog farms. In recent years, large increases in concentration have occurred in several key hog-producing states, and in North Carolina, this increase in concentration has been matched by an increase in hog numbers. This suggests that North Carolina may be more vulnerable to environmental problems from hog production.

In general concentration is highest between-states, however, the rate of increase in concentration between-states has been relatively small, only one percent during the ten year period from 1982 to 1992. Within-state concentration on average has been low, but for certain states, concentration is high and increasing. This suggests that the focus on hog production, both from and economic and environmental standpoint, should be at the state, rather than national level.

The next step in this research is to design new measures of geographic concentration that take into account clustering of hog-producing counties. This clustering effect may lead to even greater environmental problems if contiguous counties are located within a single watershed. Simple analysis of maps suggests that North Carolina exhibits a great deal of concentrated hog production in a four county area near the coast.

In addition, statistical analysis of within-state relative entropies will allow for investigation of the determinants of concentration. Some possible factors which may influence within-state concentration include: levels of contract production, average size of hog operations, state laws governing farm structure, i.e. anti-corporate farming laws, differentials in land costs between counties, and differentials in non-farm populations between counties.

Figure 4. Geographic Concentration in Hog Production for North Carolina, 1995



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