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An Examination of Trends in Geographic Concentration in U.S. Hog Production, 1974–96

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ABSTRACT

Geographic concentration in U.S. hog production from 1974–96 is investigated using a measure based on Theil's entropy index. For the U.S. as a whole, geographic concentration is occurring at a slow rate, both for hog farms and hog numbers. However, for particular states, primarily in the new Southern Atlantic production region, concentration is high and increasing at a rapid pace. Concentration was increasing for the 23-year period for 16 out of the 20 states in the analysis. Results indicate that geographic concentration by augmentation is occurring to the greatest degree in Arkansas, Missouri, North Carolina, Oklahoma, and Pennsylvania.

Key Words: entropy, geographic concentration, hog production.

The industrialization of hog production has received much attention lately, both from academic researchers and in the national press (Rhodes; Stith and Warrick). 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 social and environmental perspectives, however, is not the increase in the concentration of production in the hands of a few large firms, but the movement and concentration of production within geographic areas. Geographic concentration, when coupled with increasing numbers of hogs and limited acreage for waste application, may lead to increased environmental and social problems, including offensive odors, increased potential for groundwater contamination from excess manure applications on cropland, and increased potential for environmental damage from spills of manure storage facilities during localized weather phenomena.

For example, the U.S. General Accounting Office (GAO) reports, from U.S. Geological Survey data, that "increases in in-stream loadings of nitrogen and phosphorus are, in part, strongly correlated with increases in the concentration of livestock population in a watershed" (p. 13). Based on the findings published in the 1995 GAO report, in the northeast U.S., manure—especially from dairy operations—was the most significant source of nitrogen and phosphorus inputs to watersheds; in the southeast U.S., hog and poultry manure was the second most significant source of nitrogen and the primary source of phosphorus; and in the central and western regions of the U.S., manure was the second most important source of phosphorus and nitrogen.

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Previous research into geographic concentration either has been descriptive or has been analyzed within the context of case studies, with little theoretical or statistical support (Martin and Zering; Pagano and Abdalla; Rhodes). These studies have taken as given the geographic concentration of hog production and used this as a base from which the environmental and social consequences of concentration are discussed. The degree and speed of geographic concentration in hog production is of interest in identifying those regions where the environmental and social problems revealed in these investigations may be most severe.

The purpose of this study 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. Overall national trends in geographic concentration for both total hog numbers and total hog farms are investigated using agricultural census data from 1982, 1987, and 1992 [U.S. Department of Commerce (USDC)]. Longer-term trends in geographic concentration of hog production in major hog-producing states are examined using county estimates of hog production from 1974–96.

Geographic Concentration in Hog Production

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. A number of analysts believe that economic concentration—defined as an increased proportion of production controlled by fewer firms—in hog production is the result of changes in effective demand for food as well as food preferences in conjunction with technological production breakthroughs which have enabled firms to control disease even with very large numbers of animals in confined spaces, as well as improvements in nutrition and feeding regimes (see Barkema; Boehlje). Others argue that corporations, including food manufacturers, increased their debt loads in the 1980s, and therefore had incentives to more closely coordinate hog production and processing (O'Brien). This coordination was accomplished through both vertical integration and production contracts, and pushed the pork industry toward a more tightly organized structure.

These theories potentially explain why the hog industry is becoming more economically concentrated and coordinated; however, they do not help us understand why certain regions have seen increases in production and geographic concentration while others have not. To shed light on the latter issue, it is important to look at more local or regional factors that might influence specific manifestations of macro structural change. That is, at the macro level, factors such as capital accumulation, consumer demographics, or industry debt levels may result in a hog industry which is highly economically concentrated and coordinated. But how this change in structure is played out at the local level can be highly influenced by local factors.

For example, state regulatory regimes may have an impact on the degree and rate at which hog production increases or concentrates within the state. Nine states have adopted "anti-corporate farming" laws[1] which restrict the role of publicly held corporations in agricultural production (Hamilton). Such restrictions, depending on how they are written and enforced, can preclude vertical integration of production and processing (Hamilton), or hobble or proscribe contract production (Hamilton; Royer and Frederick). However, Boehlje (quoted in Hamilton, p. 1104) notes that "such limitations and/or regulations are more likely to influence the geographic location of various activities in the food production and distribution chain rather than the method of coordination unless such legislation is uniform from state to state." States or counties also may enact very restrictive environmental or nuisance laws which could potentially push hog production away from particular areas and toward others (Welsh 1996).

[1] The nine states are Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, Oklahoma, South Dakota, and Wisconsin. (For an overview of such laws and how they have changed over time, see Welsh 1997.)

Another potential "push" factor is property values. To date, three studies have examined the impacts of confined hog operations on property values in surrounding areas (Edelman; Palmquist, Roka, and Vukina; Taff, Tiffany, and Weisberg). While agricultural land values in close proximity to hog operations may be bid up due to demand for manure application rights, two of the three studies found a negative relationship between residential property values and proximity to hog operations. Palmquist, Roka, and Vukina examined the impact of hog operations on property values and found that such values are reduced more by the addition of a hog operation if there is little or no hog production in the area initially. If their results hold true, then property values may push hog production into counties where it already exists at substantial levels, because the marginal reduction in property values will be less in these counties.

In addition, there may be a number of significant "pull" factors that help to shape the geographic concentration of hog production. Hog production may be increasing in the southeastern U.S. due to a lack of economically viable options for farmers and lower land and labor costs relative to other regions of the country (Southard and Reed; Martin and Zering). Also, as hog operations continue to increase in scale and more closely resemble industrial production, they may begin locating in areas with low population densities, low incomes, and low labor costs (Rhodes). Further, Pagano and Abdalla note that livestock production tends to cluster where there is an established infrastructure to support specialized livestock production.

If geographic concentration is also combined with increased production, there is an increased potential for environmental problems to occur. As the number of hogs per acre in an area increases, the capacity of the surrounding environment to process hog by-products 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 nonmobile resource. However, in states with favorable regulatory regimes and economic factors, hog numbers may increase to the point where they exceed the environmental 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, some may argue, reduced quality of life for residents of those areas.

Table 1 lists information on hog production for the top 20 states for each of the agricultural census years, 1982 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 on fewer operations. What remains to be determined is whether production is also being geographically concentrated.

A Typology of Geographic Concentration

There are several ways in which geographic concentration can occur. To facilitate the discussion of trends in geographic concentration, this section defines several terms relating to different forms of geographic concentration and dispersion. For the purposes of this discussion, a "unit" refers to a geopolitical unit such as a state or county.

Total hog production in a region may decrease, with some units (states or counties) decreasing more than others. In this case, concentration may occur even if no units increase their production. This can be characterized as geographic concentration by *attrition.* A second possibility is that total hog production in the region increases, but a greater proportion of the increase goes to some units than to others. In addition, some units may decrease production during this period, causing the units that increase their production to have an even larger proportion of total regional production. This can be characterized as geographic concentration by *augmentation.* The third possible form of concentration is when total hog pro-

Table 1. Number of Hog Farms and Hogs in the Top 20 Producing States, Census Years 1982 and 1992

	Number of Hog Farms			Number of Hogs (000s)		
Rank	State	1982	1992	State	1982	1992
1	Iowa	45,768	31,790	Iowa	14,333	14,153
2	Illinois	21,646	13,433	Illinois	5,989	5,641
3	Minnesota	20,813	13,125	North Carolina	2,047	5,101
4	Indiana	17,654	11,987	Minnesota	4,473	4,669
5	Missouri	22,589	11,894	Indiana	4,298	4,619
6	Nebraska	15,998	10,826	Nebraska	3,963	4,187
7	Ohio	13,769	9,392	Missouri	3,186	2,909
8	Wisconsin	11,940	6,760	South Dakota	1,765	1,978
9	South Dakota	9,336	6,710	Ohio	2,077	1,958
10	Texas	9,484	6,537	Kansas	1,709	1,584
11	Kansas	9,241	5,684	Michigan	1,064	1,232
12	Pennsylvania	9,229	5,097	Wisconsin	1,479	1,174
13	Tennessee	12,963	4,912	Pennsylvania	869	1,075
14	Kentucky	11,436	4,879	Georgia	1,317	1,001
15	Michigan	7,433	4,774	Kentucky	870	782
16	North Carolina	11,390	4,311	Arkansas	388	726
17	Georgia	8,911	3,844	Tennessee	866	605
18	Oklahoma	4,225	3,415	Colorado	333	465
19	South Carolina	4,709	2,237	Texas	560	460
20	California	4,800	2,221	Virginia	474	413
	U.S. Total	329,833	191,347	U.S. Total	55,366	57,563

Source: U.S. Department of Commerce, *Census of Agriculture* for 1982 and 1992 census years.
Note: Complete data on production and farm numbers for all 50 states for census years 1982, 1987, and 1992 are available from the authors upon request.

duction in a region remains constant, but some units decrease production and others increase production to offset the difference. This type of concentration can be characterized as geographic concentration by *reallocation.*

Likewise, there are three different ways that dispersion can occur. Total hog production in a region can increase, with low production units increasing at a faster rate than high producing units. This can be characterized as geographic dispersion by *diffusion.* Or total production in a region may decrease, with the decreases occurring in units with a higher proportion of production. This can be characterized as geographic dispersion by *degeneration.* The final form of dispersion is when total hog production in a region remains constant, with high (low) production units decreasing (increasing) production. This can be characterized as geographic dispersion by *reallocation.*

These terms for concentration (attrition, augmentation, and reallocation) and dispersion (diffusion, degeneration, and reallocation) are used in the following discussion of trends in geographic concentration.

Construction of the Geographic Concentration Index

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

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

where θ_i is the ith firm's share of production (Levy and Chowdhury; O'Neill).[2] Entropy mea-

[2] Other measures of concentration include the Gini index and the coefficient of variation. However, these measures lack the desirable property of easy decomposition. (For discussions of measures of inequality, see Allison; Braun.)

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

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

sures indicate the degree of disorganization of a system. These measures are useful in examining how concentrated (organized) or dispersed (disorganized) units in a production system are. In the case where geographic concentration is to be measured, θ_i represents the *i*th 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 $0 \leq H(\theta) \leq \log_2(n)$, where n is the number of units to be analyzed. 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 Sporleder and in Theil. Because regions differ in size, $H(\theta)$ provides little insight into spatial dispersion. A more useful measure for examining geographic concentration is relative entropy, $R(\theta)$, which is defined as $H(\theta)/\log_2(n)$.

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 zero, and if there is complete dispersion, $R(\theta)$ will equal one. If hog production is becoming more geographically concentrated, i.e., at least one region is increasing its share of production or farms, the values of $R(\theta)$ should be tending toward zero.

A useful property of the relative entropy index is that it is easily decomposed, allowing for comparison of concentration both between and within regions. For this application, given the set of 50 states, total entropy can be disaggregated into between-state entropy and total within-state entropy. Between-state entropy is defined as:

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

where $\psi_m = \Sigma_{i \in m} \theta_i$, and i and m denote the index for counties and states, respectively. Total within-state entropy is defined as:

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

where

$$H_m(\theta) = \sum_{i \in m} [(\theta_i/\psi_m)\log_2(\psi_m/\theta_i)].$$

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 $R_{BS}(\theta) = H_{BS}(\theta)/\log_2(50)$, and relative within-state entropy is calculated as $R_m(\theta) = H_m(\theta)/\log_2(n_m)$, where n_m is the number of counties in state m.

Geographic Concentration in Hogs and Hog Farms for the U.S.

To examine whether overall geographic concentration is occurring, both on a national level and within particular states, relative entropy is calculated for each of the three agricultural census years, 1982, 1987, and 1992. 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. For the U.S. as a whole, geographical concentration appears to be occurring at a very slow rate, both in hog farms and hog numbers. The increase in 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 for hog numbers equal to 0.82 in 1992 versus 0.92 for hog farms. This indicates that concentration of hogs may be associated with large farms, as farms are more spread out than production, meaning that some farms have disproportionately high shares of production. This is corroborated by the fact that in 1992, hog farms with over 1,000 head of hogs accounted for only 6.2% of hog farms, but 50.3% of hogs (USDC 1994). Likewise, in 1994, operations with over 1,000 head of hogs accounted for only 9% of hog operations in the top 10 hog production states, but 55.4% of hog inventory (U.S. GAO, pp. 40–43).

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 (table 2). 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 during this period was −0.048. 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. Table 3 presents estimates of within-state relative entropy for the top 20 states for the 1982 and 1992 census years. Some highlights from table 3 reveal that 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% decrease in hogs from 474,000 in 1982 to 413,000 in 1992 (table 1), and a 35% decrease in relative entropy from 0.81 to 0.53 (table 3). Thus concentration increased faster than hog numbers decreased, suggesting a geographic shift in production. Out of the top 10 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 observation raises a flag indicating possible

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

	Number of Hog Farms		Number of Hogs	
State	1982	1992	1982	1992
Arkansas	0.94	0.94	0.72	0.72
Colorado	0.86	0.86	0.68	0.45
Georgia	0.91	0.89	0.82	0.68
Illinois	0.96	0.95	0.93	0.92
Indiana	0.96	0.95	0.93	0.92
Iowa	0.98	0.97	0.97	0.96
Kansas	0.94	0.93	0.88	0.84
Kentucky	0.95	0.93	0.86	0.82
Michigan	0.90	0.89	0.77	0.73
Minnesota	0.94	0.93	0.89	0.88
Missouri	0.97	0.95	0.91	0.87
Nebraska	0.93	0.92	0.91	0.88
North Carolina	0.92	0.88	0.82	0.61
Ohio	0.96	0.94	0.89	0.88
Pennsylvania	0.92	0.91	0.68	0.66
South Dakota	0.92	0.93	0.88	0.90
Tennessee	0.96	0.95	0.89	0.85
Texas	0.93	0.93	0.78	0.68
Virginia	0.93	0.92	0.81	0.53
Wisconsin	0.92	0.92	0.82	0.80

Note: A complete set of entropies for all 50 states for census years 1982, 1987, and 1992 is available from the authors upon request.

Table 4. Within-State Relative Entropies for Key Hog-Producing States, 1975–95

	Within-State Relative Entropy				
State	1975	1980	1985	1990	1995
Arkansas	0.86	—[a]	0.65	0.71	0.72
Georgia	0.85	0.86	0.85	0.83	0.82
Illinois	0.93	0.93	0.93	0.93	0.91
Indiana	0.95	0.94	0.94	0.92	0.92
Iowa	—	0.97	0.97	—	—
Kansas	0.92	0.94	0.91	0.89	0.84
Kentucky	0.87	0.88	0.85	0.85	0.81
Michigan	0.78	0.77	0.78	0.76	0.75
Minnesota	0.90	0.90	0.90	0.89	0.88
Missouri	0.94	0.94	0.92	0.91	0.81
Nebraska	0.92	0.91	0.90	0.89	0.89
North Carolina	0.84	0.83	0.79	0.71	0.64
North Dakota	0.90	0.90	0.89	0.87	0.86
Ohio	0.89	0.90	0.89	0.89	0.90
Oklahoma	0.95	0.93	0.88	0.79	—
Pennsylvania	0.79	0.72	0.69	0.68	0.67
South Carolina	0.88	0.85	0.85	0.85	0.79
Tennessee	0.91	0.90	0.89	0.87	0.83
Wisconsin	0.80	0.81	0.82	0.81	0.79

Note: A complete set of entropies for all 23 years is available from the authors upon request.

[a] Insufficient county-level data were available to estimate relative entropy.

environmental problems, as more hogs are being loaded into fewer counties.

In the last two decades, the industrialization of hog production has accelerated. In North Carolina, where contract production is booming and 82% of operations market more than 5,000 head (Rhodes), hog numbers have increased from 1.9 million in 1975 to 9.3 million in 1996—an increase of almost 400%. Much of this increase (342%) has occurred during the period from 1990–96. During that same period, hog numbers have remained at about 1990 levels in the other top states.

Trends in Geographic Concentration for Major Hog-Producing States

To explore trends in within-state hog concentration further, relative entropy is calculated for the top 20 hog-producing states for the period 1974–96. The data for these calculations are county-level hog estimates provided to the U.S. Department of Agriculture/National Agricultural Statistics Service by state agricultural statistics services.

Table 4 lists relative entropies for hog numbers for the top hog-producing states between 1975 and 1995. Data on the number of hog farms were not available for these years. The trends in geographic concentration for the 20 states in the analysis exhibited five distinct patterns, including the three types of increasing geographic concentration: increasing production/increasing concentration (augmentation), decreasing production/increasing concentration (attrition), and flat production/increasing concentration (reallocation), as well as two types of dispersion: increasing production/decreasing concentration (diffusion), and decreasing production/decreasing concentration (degeneration). Table 5 shows how 18 of the

Table 5. Major Trends in Geographic Concentration Among Top Hog-Producing States

Type of Geographic Concentration	State
Increasing Production / Increasing Concentration (Augmentation)	Arkansas (1974–77, 1993–96); Michigan; Minnesota; Missouri (1992–95); Nebraska (1974–93); North Carolina; Oklahoma; Pennsylvania
Decreasing Production / Increasing Concentration (Attrition)	Alabama; Georgia; Iowa; Kansas; Kentucky; Missouri (1974–91); Nebraska (1996); Tennessee
Flat Production / Increasing Concentration (Reallocation)	Illinois; Indiana; Wisconsin
Increasing Production / Decreasing Concentration (Diffusion)	Arkansas (1985–92)
Decreasing Production / Decreasing Concentration (Degeneration)	Nebraska (1993–95); South Carolina

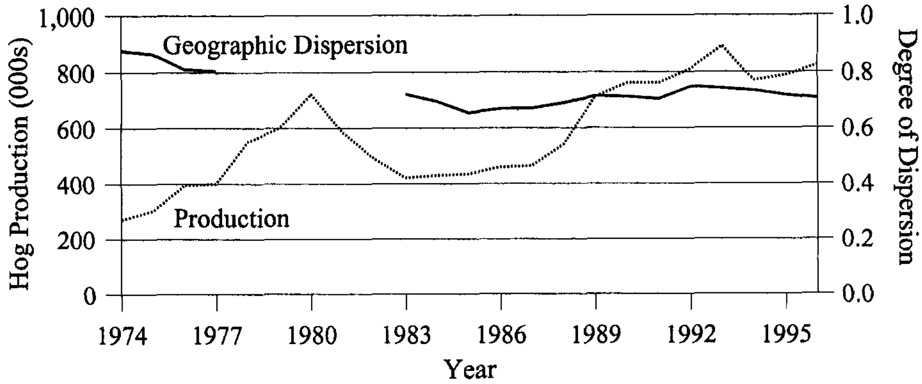

Figure 1. Trends in hog production and geographic concentration: Arkansas

20 states were divided based on these patterns. North Dakota and Ohio did not exhibit clear patterns in either production or concentration.

The dominant trend is toward increased geographic concentration within states. Concentration was increasing in general for the 23-year period for 16 out of the 20 states in the analysis. The exceptions were Arkansas, Illinois, North Dakota, Ohio, and Wisconsin. Arkansas displayed increasing concentration from 1974–85, but concentration decreased from 1985–92. Concentration began increasing again in 1993, and has continued to increase through 1996. Illinois has displayed a general upward trend in concentration over the 23-year period, but for the period 1978–83, concentration within the state decreased. North Dakota showed an increase in concentration over the 23-year period, but had many ups and downs, making it difficult to characterize the overall trend, although the last five years showed steadily increasing concentration. Ohio showed a slight decrease in concentration, but in general, concentration was flat over the 23-year period. Wisconsin displayed decreasing concentration for the period from 1974–84, and increasing concentration from 1984–96.

While the general trend has been toward increased geographic concentration, the degree and speed of concentration is quite variable among states. The total change in relative entropy over the 23-year period ranged from −0.31 (for California through 1991) to 0.01 (Ohio). The average rate of change over the 23-year period ranged from −0.018 per year for California to 0.0003 per year for Ohio. With the exceptions of Arkansas, Ohio, and Pennsylvania, the average rate of concentration was higher from 1985–96 than from 1974–84. This suggests that geographic concentration has been occurring at a faster pace during the last decade.

As discussed earlier, geographic concentration in and of itself does not necessarily lead to increased environmental problems. A combination of increased hog numbers and increased geographic concentration on a limited land base is necessary to indicate a definite increase in the potential for environmental problems (U.S. GAO). Figures 1–5 chart the movements of hog numbers and geographic concentration for the five expanding hog-producing states with the largest increases in geographic concentration: Arkansas, Missouri, North Carolina, Oklahoma, and Pennsylvania. The reader should be aware that the scales of the axes vary among figures 1–5. The following sections discuss in greater detail the concentration in each of the five states.

Arkansas

Figure 1 shows that Arkansas has experienced recent shifts in the trends of both hog production and geographic concentration. Relative entropy was decreasing throughout the 1970s and early 1980s, accompanied by large increases in hog production during the late 1970s and large decreases in hog production

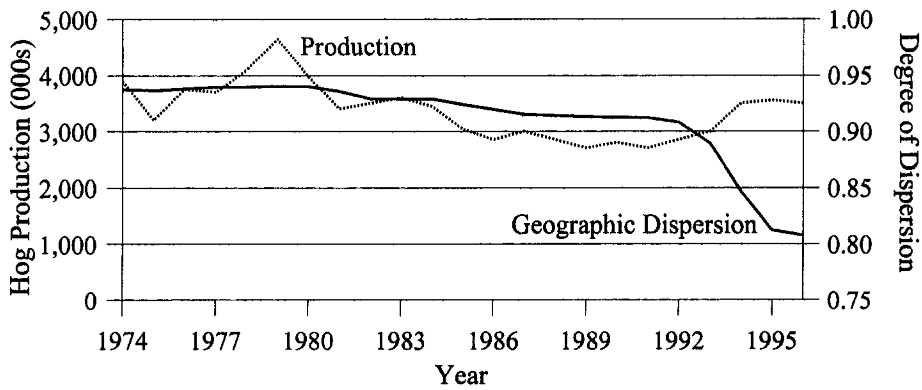

Figure 2. Trends in hog production and geographic concentration: Missouri

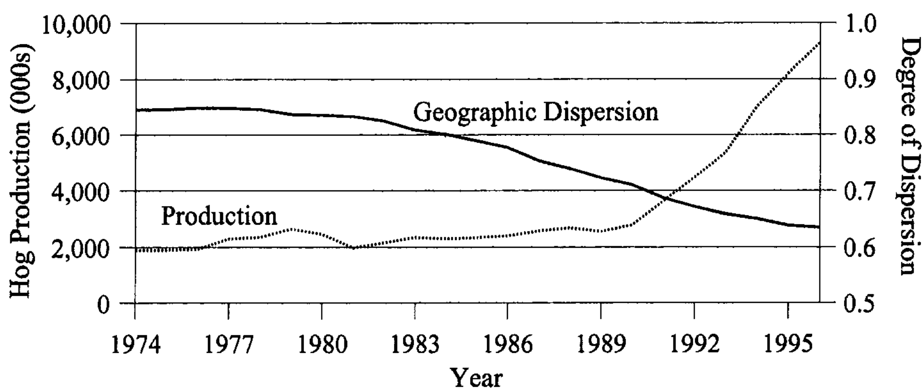

Figure 3. Trends in hog production and geographic concentration: North Carolina

during the early 1980s. This indicates geographic concentration by augmentation during the 1970s, and by attrition during the early 1980s. However, starting in 1986, both relative entropy and hog production began increasing. This suggests that Arkansas was experiencing a dispersal of hog production, which is unusual, compared to the overall trend of increased concentration. During the 1990s, entropy began falling again, but production has remained at a relatively high level.

Missouri

In Missouri, hog numbers have been declining while concentration has increased (figure 2), suggesting that some counties have been reducing hog production while others have maintained or increased production. Thus Missouri is characterized by concentration through a combination of attrition and reallocation. The primary locations where concentration and production have increased in Missouri consist of four counties: the three-county area of Mercer, Putnam, and Sullivan,[3] which, from 1990–96, increased production from 28,500 to 968,000 hogs, and went from 1% to 27.7% of state production; and Vernon County, which, during this same period, increased production from 20,500 to 165,000 hogs, and rose from

[3] Individual county-level information was not available for Mercer, Putnam, and Sullivan counties for 1991–96. However, total production for the three-county area was available. In calculating relative entropy for these years, it was assumed that production was divided equally among the three counties.

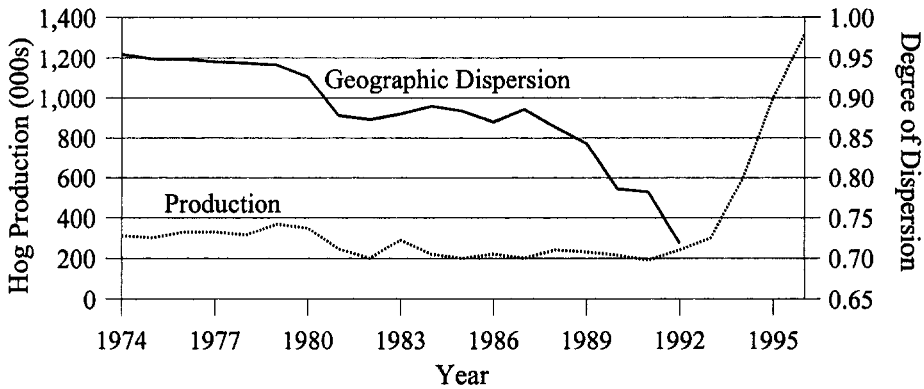

Figure 4. Trends in hog production and geographic concentration: Oklahoma

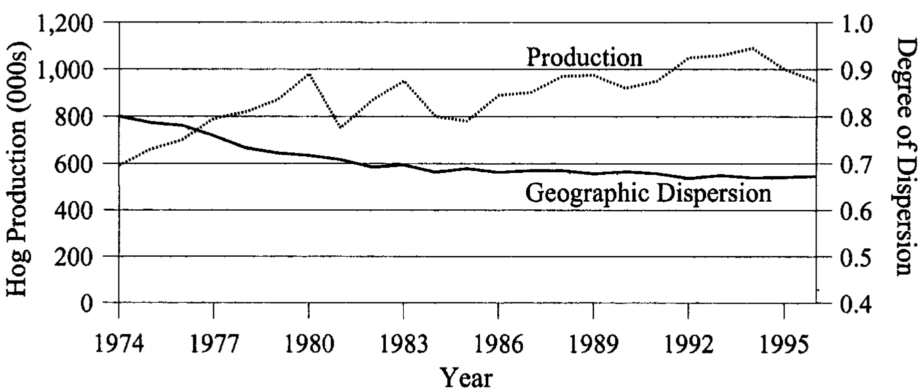

Figure 5. Trends in hog production and geographic concentration: Pennsylvania

0.7% to 4.7% of state production. On the whole, Missouri is not clearly identified as highly vulnerable to environmental risk from concentration. However, the four counties identified above demonstrate trends that may increase their vulnerability to environmental problems. Interestingly, three of these counties (Mercer, Putnam, and Sullivan) were exempted in 1993 from Missouri's anti-corporate farming law in order to allow Premium Standard Farms, a large swine company, to establish an operation in Missouri (Hamilton).

North Carolina

North Carolina has both sharply increasing production and sharply increasing geographic concentration (figure 3), indicating that geographic concentration by augmentation is occurring. Two counties in North Carolina, Duplin and Sampson, have experienced increases in hog production by over 1 million hogs each since 1990. These trends, coupled with the high absolute numbers of hogs in North Carolina (9.3 million in 1996), suggest 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. Duplin and Sampson counties, with a combined total of 3,900,000 hogs, have a total combined area of 1,785 square miles, or 2,185 hogs per square mile. This high density of hogs suggests that North Carolina may be exceeding the adsorptive capacity of its environment.

Oklahoma

Oklahoma had varying production levels throughout the 20-year period, but generally dis-

Table 6. Comparison of Hog Production and Concentration Means: Corn Belt and South Atlantic Production Regions

Description	Region: Corn Belt	Region: South Atlantic	*t*-Statistic
Production:			
State-Level Hog Production, 1996	3,705,000.00	1,897,143.00	1.04
Change in State-Level Hog Production, 1974–96	−10,870.00	1,084,285.00	0.93
% Change in State-Level Hog Production, 1974–96	−2.61	119.58	1.57
Concentration:			
Relative Entropy, 1996	0.86	0.74	3.52*
Change in Relative Entropy, 1974–96	−0.04	−0.13	2.82*
% Change in Relative Entropy, 1974–96	−4.00	−14.91	2.96*

An asterisk (*) denotes statistical significance at the 0.01 level.

played a downward trend in production (figure 4). This was accompanied by an increasing trend in concentration, suggesting that attrition was taking place. However, in 1992, a year after it relaxed its anti-corporate farming law so corporations could raise poultry and swine (Hamilton) and the last year for which county-level data were available, Oklahoma began experiencing an increase in production and a relatively sharp increase in concentration. This points toward augmentation in particular counties. The two counties accounting for the majority of the augmentation and concentration from 1974–92 are: Delaware County, which increased production from 6,500 to 65,000 hogs and went from 2.1% to 27.1% of state production; and McCurtain County, which increased production from 1,500 to 45,000 hogs and rose from 0.5% to 18.8% of state production. County data were not available from 1993–96. However, state-level data show an increase in total state hog production from 240,000 hogs to 1.32 million hogs during this period. It is difficult to determine precisely where these increases in production have taken place, as Tyson and Cargill have expanding operations in the eastern portion of Oklahoma, and Seaboard and Murphy farms have been expanding production in the western panhandle of Oklahoma, especially in Texas, Ellis, and Beaver counties (Hamilton; Marbery). In addition, the panhandle district of Oklahoma—which includes Texas, Ellis, and Beaver counties—accounted for 56.1% of state production in 1996. This suggests that production is becoming highly concentrated in the panhandle region.

Pennsylvania

Figure 5 illustrates that Pennsylvania has experienced trends in hog production and geographic concentration similar to North Carolina in form, but not in magnitude. Relative entropy has steadily decreased, while hog production has increased. This suggests that geographic concentration by augmentation is occurring. Several counties have experienced large increases in hog production, most notably, Lancaster and Lebanon counties, which realized gains of 178,600 and 55,200 hogs, respectively, from 1974 levels. Lancaster and Lebanon counties had densities of 332 and 201 hogs per square mile, respectively. These Pennsylvania counties where concentration is centered represent potential hot spots of environmental vulnerability.

Divergent Hog Production Trajectories in the Corn Belt and South Atlantic Regions

Although industrywide concentration of hog production is taking place, specific geographic manifestations of this concentration differ in different regions. This can occur for a number

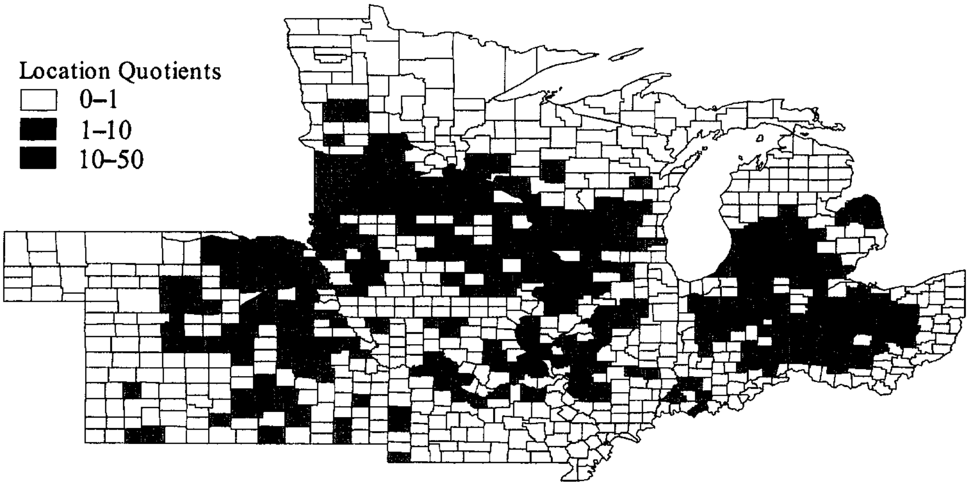

Figure 6. Concentration and clustering in Corn Belt states

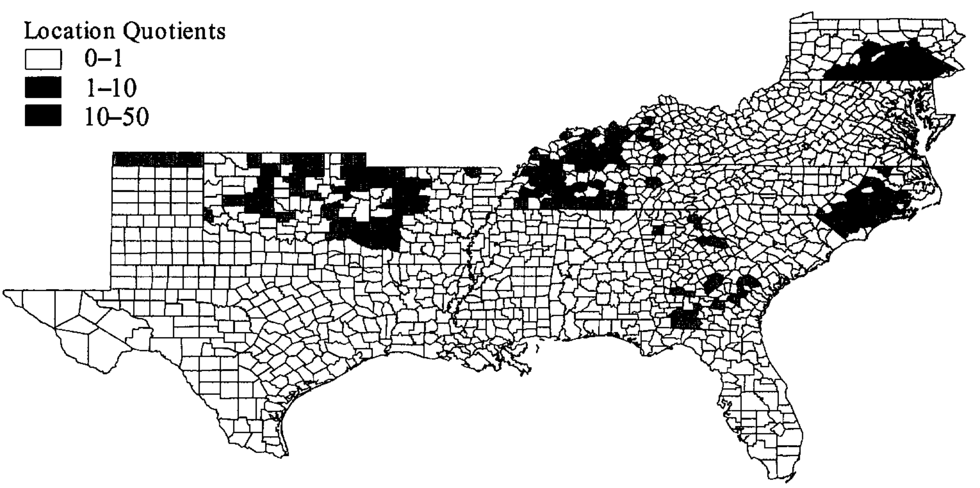

Figure 7. Concentration and clustering in South Atlantic states

of reasons, as previously argued. Table 6 presents data on concentration levels and rates of increase in concentration for major hog production states in the Corn Belt and South Atlantic regions.[4] These groups were highlighted since the Corn Belt states traditionally have maintained high hog production levels, while several South Atlantic states have witnessed relatively recent increases in hog production.

Mean changes in hog production concentration from 1974–96 between the two groups of states differed significantly. The South Atlantic states have lower mean entropy scores for 1996, indicating higher levels of concentration. In addition, the South Atlantic states have higher mean percentage changes in relative entropy from 1974–96. This implies that concentration is not only higher in the South Atlantic as compared to the Corn Belt, but that the rate of increase of concentration is higher in the South Atlantic region.

These changes are illustrated in figures 6 and 7 using a measure of concentration known as the location quotient (LQ) and 1995 hog

[4] Major hog-producing states are defined as those states with hog production levels greater than 500,000 hogs per year, based on 1996 hog production levels.

production data (Wikle). The LQ is calculated as the ratio of county production to average county production within the state. For example, an LQ of 0.50 indicates a county with one-half the state average, while an LQ of 2.00 indicates a county with twice the state average. In general, figures 6 and 7 help to illustrate the findings presented in table 6, i.e., that the Corn Belt states tend to have hog production spread out more evenly across more counties than in the South Atlantic states.[5] The latter states tend to have a few counties with the majority of the production, and the remainder of the counties with little or no production. In addition, high production counties in the South Atlantic region are often contiguous. This latter finding is important because contiguity between counties cannot be accounted for by single-value indices of concentration such as Theil's entropy measure.[6] Therefore, without the mapping of the changes, our analysis might underestimate the geographic concentration of hog production within and even between states.

For example, North Carolina and Pennsylvania have seen rapid increases in hog production as well as rapid concentration in a few adjacent counties. In addition, while Oklahoma's relaxation of its anti-corporate farming statute made possible increased corporate investment in hogs and an increase in production in selected counties, the legislative change also appears to have resulted in increased concentration in Arkansas counties near the Oklahoma-Arkansas border. These developments cannot be accounted for by the entropy measure, though they are important.

The different patterns observed for the Corn Belt relative to the South Atlantic states have other implications. There could be two discrete development trajectories emerging in U.S. hog production, originating in the different historical organizational and structural forms within the regions. Corn Belt hog production traditionally has been higher than in other parts of the U.S., and organized as part of independent household-based crop-livestock operations. In contrast, several South Atlantic states have only recently become major hog producers, with a large part of this increase being produced on nonfamily corporate operations or through production contracts between corporate processors or intermediary buyers and household-based operations (USDC 1988; Kliebenstein and Lawrence; Miller).

This analysis suggests that the traditional Corn Belt style of hog production results in a more geographically dispersed production pattern. The corporate-driven style seems to be associated with higher levels of geographic concentration. As the economic concentration of the entire hog industry continues, it will be interesting to see if these discrete development patterns are temporary or more permanent. That is, is the Corn Belt style of hog production an artifactual vestige of an outmoded and inefficient production regime doomed to extinction as some have argued? Or will two discrete patterns continue to emerge and stabilize? The answer probably lies in the ability of producers and consumers—as well as local and state governments, and the federal government—to construct institutions, rules, and legislation promoting the development of a hog industry infrastructure which allows for dispersed production.

Conclusions

This study 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. However, concentration is not occurring in the same manner in all states. Concentration of all three types (augmentation, attrition, and reallocation) is occurring in different regions of the U.S. In recent years, large increases in concentration have occurred

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[5] Exceptions are Georgia and Kentucky, where production has not concentrated as substantially as in Pennsylvania, North Carolina, Oklahoma, Arkansas, and Tennessee. Also, northern Missouri, southern Wisconsin, and Kansas have areas of significant concentration.

[6] While this is a weakness, other concentration measures, including the Gini index, also suffer from the inability to account for local clustering (Shelburne and Bednarzik).

in several key hog-producing states, especially in those states experiencing rapid expansion in hog production, indicating that concentration by augmentation is occurring in these states. Geographic concentration also appears to be occurring mainly in nontraditional hog-producing areas in the East and South. Traditional hog-producing states in the Midwest have not shown large increases in concentration, and hog production has remained relatively dispersed.

In North Carolina, the increase in concentration has been matched by an extremely large increase in hog numbers and high density of hogs per square mile. This suggests that North Carolina, exhibiting geographic concentration by augmentation, may be more vulnerable to environmental problems from hog production than states where geographic concentration by attrition or reallocation is occurring.

In general, concentration is highest between states; however, the rate of increase in concentration between states has been relatively small, only 1% during the 11-year period from 1982–92. Within-state concentration on average has been low, but for certain states, concentration is high and increasing. This suggests that the focus on concentration of hog production, from both an economic and environmental standpoint, should be at the local, state, or regional level rather than the national level. Focusing on national-level measures of geographic concentration masks the variability that exists in geographic concentration within states.

In addition, statistical analysis of within-state relative entropies will allow for investigation of the determinants of concentration. Some possible state- and local-level factors which may influence within-state concentration include: levels of contract production; average size of hog operations; state laws governing the organization of agricultural production (i.e., anti-corporate farming laws); differentials in land costs among counties; and differentials in nonfarm populations among counties, wage rates, and watershed or basin management plans. Further, regional factors such as location of processing facilities can cause hog production to concentrate or cluster within a state. Finally, external economies of scale may play a role in geographic concentration of hog production, as specialized production facilities and input suppliers locate in proximity to processing facilities.

Future analyses of geographic concentration in hog or other livestock production must take into account the fact that localized concentrations of hog production may not conform to easily defined geopolitical boundaries. Analyses should address how appropriate units of analysis should be defined, given the desired use of the data. For example, if economic policy is the issue, then it may be appropriate to define regions based on transport routes or location of processing facilities. Or, if environmental policy is the issue, it may be more appropriate to define regions based on watersheds or airsheds. Geographic concentration within these issue-derived regions will be dependent on multi-state factors, such as relative input prices, laws, etc., as well as the factors listed above for determination of within-state concentration.

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