**Geographic Changes in U.S. Dairy Production**

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Agriculture is traditionally land-intensive and thus has not been considered a mobile industry. Yet, geographic changes in certain sectors have been striking, such as the historical movement of the U.S. meat packing industry from Chicago to the Great Plains. Changes in spatial distribution of the hog industry have been noted (Hubbell and Welsh, 1998; Roe, Irwin, and Sharp, 2002). Recently, major regional shifts have occurred in U.S. dairy production. While the upper Midwest and the Northeast regions continue to be major dairy producing regions, a large share of the growth has taken place in the western part of the nation. Between 1980 and 2000, production in New Mexico, Idaho, and Arizona multiplied, raising them in ranking of state production from 38$^{th}$, 19$^{th}$, and 28$^{th}$, to tenth, sixth, and 13$^{th}$, respectively.

To date, our understanding of the factors impacting these regional differences in growth of dairy production remains anecdotal. For example, it is the "western" style of dairy farming, which purportedly contributes to the mobility of the industry, since it is less self-sufficient in feed and thus does not require land for expansion as does the "traditional" style. Lower population density in the West favors corporate farming and more lenient environmental policies. Dairy cows prefer arid warmer climates, and forage quality appears higher in regions with milk production growth than the rest of the country.

Similar to other agricultural sectors, the dairy industry has undergone significant structural change. The number of farms in 2000 declined to one half of that in 1990, while milk production has continued to increase, reflecting a larger average farm size. Larger dairy operations are confined animal feeding operations (CAFO) with potentially significant impacts on environmental quality. The 2002 Farm Bill will undoubtedly have an impact on the geographical distribution of the U.S. dairy industry, and it is critical to understand the factors that underlie these changes.

Numerous studies have examined forces of changes in the dairy industry structure (e.g., Chavas and Klemme, 1986; Adelaja, Miller, and Taslim, 1998), but those on the determinants of geographical changes are scarce. Yavuz et al. (1996) identified changes in supply factors among the regions as the most influential determinant of the spatial distribution of U.S. milk production, but provided no explanation of what brought about these changes. Osei and Lakshminarayan (1996) examined the determinants of dairy farm location at the state level, using a logit model that incorporated environmental indicators. The analysis of Rahelizatovo and Gillespie (1999), which found regional differences as a significant factor in the growth and survival pattern of dairy farms in Louisiana, associated the differences with agglomeration economies without explicitly modeling them.

The agglomeration effect refers to increases in the regional economy due to the size of neighboring economies. A recent development in theory of economic geography explains the effect by scale economies and transportation costs (see Fujita, Krugman, and Venables, 2000). One of the alternative theories attributes it to a pooled labor force (Marshall, 1920). In the case of U.S. production agriculture, the former theory might be more applicable. An extensive literature exists for location of nonfood industries, and many studies incorporate agglomeration as an endogenous determinant of location choices. In the agricultural economics literature, location theory has been applied to several studies of food processing establishments (Goetz, 1997; Henderson and McNamara, 1997; 2000). Roe, Irwin, and Sharp (2002) applied the framework to the U.S. hog sector and estimated agglomeration effects that differs across regions using spatial econometrics.

The objective of this paper is to identify determinants of geographical shifts that have occurred in the U.S. dairy industry in recent years. Specifically, changes in the county-level quantity of milk marketed through the Federal Milk Marketing Order are analyzed using spatial econometrics. A spatial lag model allows us to measure the impact of milk production in neighboring locations on milk production in a particular location, and test the agglomeration hypothesis of the new economic geography theory.

In the subsequent section, geographical changes that have occurred in the U.S. dairy industry are reviewed. Then, the location decision of a dairy farm is conceptualized to identify its determinants. Following the development of variable specification, the estimation procedure is discussed and results are presented. The paper concludes with the findings and directions for future research on the topic.

**Regional Trends in U.S. Dairy Production**

Historically, dairy farms were located in proximity to consumption centers due to the perishable nature of milk. Early studies analyzed dairy milk pricing using von Thünen's location theory, where price of a good is related to the distance from the market. Thus, milk production, cream production, and butter production conceptually formed concentric circles around the city, resulting in a piece-wise linear function for the fluid milk price (Cassels, 1937; Gaumnitz and Reed, 1937). Since the Great Depression, the dairy industry has been one of the most heavily regulated commodity sectors by the Federal government. Instituted by the Agricultural Marketing Agreement Act of 1937 and the Agricultural Act of 1949, the two main programs—the Federal Milk Marketing Order (FMMO) and the price support system through the Commodity Credit Corporation—institutionalized the dairy market for the remainder of the century. Particularly the price pooling disrupted von Thünen's concentric circles, since prices did not vary by distance any longer.

Nonetheless, the proximity to the market remained the key factor for the regional shift throughout the first half of the last century (Stephenson). The population centroid (geographically weighted mean), which was located in southern Indiana in 1930, has been moving south and west for many years, and is currently in Missouri. The corresponding centroid for milk production has always been to the northwest of the population, following it in a parallel fashion. Currently, the milk production centroid is near the area centroid of contiguous 48 states (i.e., the northeastern corner of Kansas). This illustrates that milk supplies have grown where there was a local population to demand dairy products. Yet, the milk production centroid has outpaced the population movement to the west during the past two decades.

Since late 1983, the price support level was lowered significantly, and by 1989, the milk price fluctuated above the support level, allowing it to be determined by market forces. According to the 1996 Federal Agriculture Improvement and Reform Act, price support levels were to be lowered further and the system was to be abolished after three years. However, it has been extended annually in subsequent years, and the new Farm Bill extends the support program at $9.90 per hundredweight through 2011. Since demand for dairy products is inelastic, small changes in quantity generate considerable movement in price. The post-1989 price volatility shocked the dairy industry, which had not been exposed to price volatility for the past half a century. It accelerated the structural and geographical changes in the industry. Financially weaker, smaller farms left the industry, while the remaining ones expanded in another location, if not locally, to remain financially viable.

In tandem with these changes, milk production continued to increase steadily during the last two decades, at a faster rate during the 1980s than the 1990s. The genetics of cows continue to improve, and better management practices have increased milk production per cow. Average annual milk production per cow has increased from slightly below 12,000 pounds in 1980 to 18,200 pounds by 2000, an average annual increase of around 2 percent. During this time frame, the number of cows has decreased by 14.8 percent, from 10.8 million to 9.2 million head.

Regionally, Wisconsin has been the long-standing leader in milk production for most of the twentieth century, but California became the number one dairy state in 1993. The top five dairy states in 1980—Wisconsin, California, Minnesota, New York, and Pennsylvania—were the same top five states in 2000. Idaho and New Mexico, which were insignificant dairy states in 1980, joined the top ten. The top ten milk producing states do not coincide with the ten states with the most number of cows, implying the regional differences in production per cow. In 1980, California led per-cow production, followed by many states in the West, with 20 states above the national average. By 2000, more cows moved to these more productive states, and management and genetics increased milk production per cow nationwide. Only eleven states currently produce above the national average of milk per cow.

The number of dairy farms has been declining in a linear fashion during the recent decade, and there were 105,250 dairy operations (with at least one cow) in 2000 according to the National Agricultural Statistics Service. Despite the large exodus of farms and cries of mourning for family farms, the majority of the dairy operations remain small. Today, more than 80 percent of all dairy farms milk less than 100 cows, accounting for 28.9 percent of milk production. Only seven years prior in 1993, operations below 100 cows accounted for 86.3 percent of all farms and

44.8 percent of production. Today, less than 0.3 percent of farms account for 10.5 percent of milk production.

California and Wisconsin, the two leading dairy states, have contrasting farm profiles. In 1993, 95.5 percent of the California production came from the 45 percent of the farms milking 200 or more cows. By 2000, 74.8 percent of dairy farms had more than 200 cows, producing 97 percent of the state output. In Wisconsin, only one percent of the dairy farms had more than 200 cows in 1993. Even in 2000, this number was only 3.8 percent. Over half of Wisconsin's production comes from dairy farms milking less than 100 cows, which comprise 86.7 percent of dairy farms in the state.

**Location Decision**

We could speculate various reasons why dairy operations are moving across the country and expanding in size. The natural environment in the West may be more favorable for the dairy and its supporting agriculture than the rest of the country. There may be differences in historic development of the industry that either accelerates or stagnates expansion. There may have been numerous manufacturing facilities, which were attracted to areas with increased milk production and subsequently demand additional milk to maintain their plant capacities. The efficiency of our food distribution system may have reduced costs to the point that it makes little difference where products are produced. Or, the business climate, including environmental regulations may be more advantageous in the relatively less populated areas in the western half of the country. Alternatively, it may be a more fundamental issue, where costs are actually lower, and thus, returns are higher, in the West, as is believed by some.

Consider the objective of a representative farmer in location *i* to be a function of the farm profit function $\Pi_i(\cdot)$, which depends on multiple outputs and inputs:

$$\Pi_i = P_i f_i(\mathbf{X}_i, \mathbf{Z}_i) - C_i(\mathbf{X}_i)$$

where $P_i$ is price of milk, $f_i$ is the production function, $\mathbf{X}_i$ is a vector of inputs, $\mathbf{Z}_i$ is a vector of supply shifters, and $C_i$ is the total cost function. Milk output in location *i* will increase if dairying is profitable, where a profitability increase may result from technological improvements in dairy management. In addition to local farmers expanding their operations, dairy farms in location *j* may move into location *i*, if expected costs are cheaper and marketing prospects are sufficient to cover the relocation expenses. The cost of dairying includes the costs of obtaining feed, water, and environmental compliance. In addition, non-regulatory pressure from the local community may be a significant cost to maintaining the operation at a given location. Relocation costs include procurement of land, equipment, and heifers. Given the marketing orders and the perishability of milk, it is likely that cost considerations have larger impacts than marketing opportunities for relocation and expansion decisions. Moreover, dairy farms large enough produce daily tanker-loads of milk gain from flexibility in marketing.

**Data and Variable Specification**

In order to identify determinants of geographical shifts in the U.S. dairy industry, spatial observations of milk output are explained by factors affecting producers' profit-maximization decisions. The location literature suggests that a profit-maximizing farm's location decision depends on access to output markets, availability of inputs, labor force composition and quality, transportation infrastructure, and local government policy. Economic geography theory implies that the importance of the dairy industry relative to all other economic activities is relevant to the location choice of dairy operations. The factors considered in the current analysis are: the agglomeration effect, environmental regulation, the urban encroachment effect, market accessibility, input availability, local economic conditions, and natural environment.

Many county-level observations on dairy herd size and milk production are not disclosed in the Census of Agriculture (COA). Hence, county-level milk marketing quantities reported by the Milk Market Administrator offices are used to measure county-level supply of milk. Ninety-five percent of grade A milk is marketed through the FMMO. In the current analysis, the milk marketing in May 2000 is compared to that in May 1995. There were 2033 counties in 48 states that marketed positive quantities in both time periods. Zero quantities in one of the periods may indeed signify no milk output, but it is more likely that milk was marketed outside FMMO. The dependent variable is defined as the difference in the logarithm of May 2000 milk marketed and the logarithm of May 1995 milk marketed. Table 1 summarizes distributions of the variables. County-level percentage changes in milk marketed are symmetrically distributed about the mean of negative 18.0 percent.

The agglomeration effect is captured by the spatial lag of the dependent variable. In locations where neighboring counties produce more milk, resource availability of feed and labor are likely to be similar, which are shared by other animal operations. In particular, a community's reception towards large animal operations, which may play a critical role in the location decision of a dairy farm, is likely shared in neighboring communities due to externalities. To capture the agglomeration effect of large animal operations, the number of large animal operations in the county (*LCAFO*) is included, which counts cattle farms with more than 500 head and hog farms with more than 1,000 head from the 1997 COA. About 11 percent of the counties had no large animal operations, while 68 percent of the counties had between one and 20 operations. The sample average was fourteen (Table 1). In addition, the number of animal units in the county (*ANIM*) is incorporated, which is calculated by assigning a weight of one for cattle and 0.4 for hog from the 1997 COA. Observations with missing variables are imputed to maintain spatial continuity.

Market accessibility depends on the price received for milk and the number of plants in proximity to the farm location. Mailbox prices (*MBPRICE*) are computed by the Market Administrator offices to represent average net price received by dairy farmers accounting for premiums, marketing costs, and fees. The price for 1999, when the mailbox prices were first computed for the current (post-reform) marketing orders, is used. Counties that do not belong to a marketing order were associated with simple averages of bordering marketing orders. Addresses of distribution and supply plants of the marketing orders were converted into latitudes and longitudes using the geocoding service of ArcGIS StreetMap USA by ESRI (formerly Environmental Systems Research Institute), and the number of plants within a 300-mile radius from county centroids (*NPLANTS*) was computed for each county, based on Haversine formula for a great circle distance. The number of proximate plants ranges between 0 and 19, with an average number of 1.4. The market structure of receiving plants is critical to marketing opportunities, and its incorporation will be explored in the future.

Given the perishability of milk, population has historically been a relevant indicator of local market accessibility. Moreover, environmental regulation factors and urban encroachment factors are related, since environmental concerns are typically higher in more populated areas. In addition to environmental issues, urbanization affects animal agriculture through higher land and opportunity costs, while the urban population may obtain amenity values through the sight of charmingly rustic (small) dairy farms. The natural logarithm of population in 1997 (*LNPOP*), the population growth rate (*DPOP*), the number of housing permits issued per capita in 1997 (*HOUS*), the percentage of land in farms in 1997 (*PCTFARM*), and change in the percentage of land in farms between 1992 and 1997 (*DPCTFARM*) in a county are specified as proxies for urban encroachment factors. U.S. county population is based on the 1990 and 2000 Census. Percentages of land in farms are based on the 1992 and 1997 COA. The average growth rate in county population between 1990 and 2000 was 9.7 percent, while percentages in land in farms declined on average by 30 percentage points. In some counties, the proportion of land used for farming increased by as much as 45 percent, while in other areas, as much as 47.5 percent was converted into non-farm use.

Major variable inputs for dairy are feed, labor, and water. Harvested quantities of corn (*CORN*) and hay (*HAY*) are taken from the 1997 COA. In order to apply the spatial lag, missing observations due to disclosure are imputed based on the number of farms. Both variables are skewed to the right in the sample, but the distribution of *CORN* is more skewed than that of *HAY*. Also, we expect the feed expenses to be lower, ceteris paribus, if large-scale feed processing facilities exist locally. The percentage of dollars spent on commercially mixed feed relative to total dollars spent on livestock feed (*COMMFD*) is included to capture the availability of local feed processing facilities.

To represent availability of local labor force, the county unemployment rate in 1996 (*UNEMP*) is incorporated. Since county-level wage rates were not imputable from the COA data, state-level wage rates for field and livestock (*WAGE*) in 1998 are used (USDA, Economic Research Service). Following Roe, Irwin, and Sharp, the percentage of farmers whose principle occupation is non-farming (*NONFM*) is included to capture the availability of managerial resources, where it is expected that when a smaller percentage of farmers specialize in farming, fewer resources to manage dairy operations are available. Lastly, the total land area (*LAND*) is included as another limiting input.

For local economic conditions, per capita personal income in 1994 (*INC*) and average per capita property tax collected in the county (*TAX*) are included. Higher property taxes are expected to deter new dairies from moving into the area. Also, a dummy variable is included to indicate whether the county belongs to a federal or California milk marketing order or not (*MMO*).

Milk production per cow is sensitive to extreme weather. State-level cumulative heating and cooling degree days for 1997 (*HDD*, *CDD*) are included to represent local climate. The results will be updated when weather-station level weather data become available. In the future, location-specific relative humidity values will be included as a proxy for the quality of hay. Lower relative humidity implies higher quality hay, in addition to a more favorable climate for the productivity of dairy cows. Since cows do not perform well in extreme temperature, days above and below comfort thresholds could be included as well.

**Estimation Procedure**

Spatial econometrics deals with autocorrelation across spatially contiguous units of observation. Spatial autocorrelation may result from arbitrary delineation of political boundaries such as counties, or aggregation over space when observations are reported. The economic relationships (e.g., functional forms) may vary across locations. Moreover, spatial externalities in terms of resource availability, convenience or scale economies, and technological spillover can cause spatial autocorrelation.

The spatial lag model assumes spatial correlation in the dependent variable, which is captured by a spatial autocorrelation coefficient and a spatial weights matrix (Anselin, 1988). The model can be stated as:

$$Y = \rho WY + X\beta + \varepsilon$$

where $Y$ is an $N$ by 1 vector of the dependent variable, $\rho$ (a scalar) is the spatial autocorrelation coefficient, $W$ is an $N$ by $N$ matrix of spatial weights, $X$ is an $N$ by $K$ matrix of exogenous explanatory variables, $\beta$ is a $K$ by 1 parameter vector, and $\varepsilon$ is an $N$ by 1 vector of i.i.d. error terms. This specification assumes that the influence of space is constant across the entire sample. In the future, region-specific (likely by FMMO) spatial autocorrelation coefficients will be specified and tested for the constancy of the spatial effect.

Each element of the spatial weights matrix is specified as an inverse of the distance between the two county centroids. The resulting matrix is symmetric, where diagonal elements are set to unity. This specification assumes geometric decay in the spatial lag structure. The further away the two locations are, the impact upon one another decreases at an increasing rate.

OLS estimation will yield biased and inconsistent coefficient estimates. Maximum likelihood estimation is required to obtain consistent estimates for the parameters, where normality is assumed for the error term and the following likelihood function is specified:

$$\ln L\left(\beta,\sigma^2,\rho\right)=\sum_{i=1}^{N}\ln\left(1-\rho\eta_i\right)-\frac{N}{2}\ln 2\pi-\frac{N}{2}\ln\sigma^2-\frac{\left(Y-\rho WY-X\beta\right)'\left(Y-\rho WY-X\beta\right)}{2\sigma^2}$$

where $\eta_i$ is the $i$-th eigen value of the spatial weights matrix and $\sigma^2$ is the variance of the error term. The maximum likelihood estimation is implemented in MATLAB.

**Results**

The estimation results are presented in Table 2, along with elasticity estimates evaluated at sample means of the independent variables. The elasticity estimates indicate the percentage change in the ratio of milk marketings in 1997 and 1992 given a percentage change in the independent variable. The spatial lag model identifies several determinants of the changes in milk marketings that are statistically significant.

The agglomeration effect measured by the spatial lag is positive and statistically significant, suggesting a strong presence of agglomeration effects in the changes occurring in the dairy industry. Increases in milk production in neighboring counties have a positive effect on changes in local milk production. This is in contrast to Roe, Irwin, and Sharp (2002), who found that agglomeration effects impacted the spatial pattern in the hog inventory but not its changes. Another agglomeration variable measured by the number of large animal operations in the county (*LCAFO*) was statistically significant with an expected sign, confirming that geographical changes in milk production is occurring parallel to structural changes in the industry. The negative and significant coefficient on the number of animal units (*ANIM*) suggests that perhaps environmental regulations or local responses to new livestock operation are no longer favorable in places where animal agriculture has already a large presence. In the future, an index of environmental regulation stringency analogous to one developed by Metcalf (2000) for selected states will be developed.

The coefficients on the two market accessibility variables (*MBPRICE* and *NPLANTS*) were of the expected sign. Higher output prices attract local expansion and relocation of dairy farms. The change in county milk production increases 0.8 percent given a percentage change in the output price. The magnitude of the impact of plant proximity is not as important as the output price.

The coefficient on population (*LNPOP*) is positive, suggesting that the impact of market proximity overweighs the conflict between animal agriculture and urbanization, but it is not statistically significant. Of the other urban encroachment variables, population growth rate (*DPOP*), the number of housing permits (*HOUS*), and change in the percentage of land in farms (*DPCTFARM*) had expected signs. The population growth rate and its squared term are both statistically significant, indicating that changes in milk production parallels changes in population at a decreasing rate. A one percent increase in population increases the milk production by 0.04 percent, all things equal.

Results suggest that input availability is important in dairy location decisions. Having both high corn and hay production locally contributes to milk production (*CORN*, *HAY*), particularly hay, since it is bulkier to transport than corn. Moreover, the nutritional value of hay differs across harvested quantity more than that of corn. Hence, measures to capture the spatial differences in hay quality should be explored. The results show that on average, counties with higher reliance on commercially mixed feed faced reduction in milk marketings (*COMMFD*).

Higher local unemployment is more beneficial for dairy operations (*UNEMP*) at a decreasing rate, with an elasiticity of –0.018 evaluated at the sample mean. The coefficient on the average wage rate (*WAGE*) is statistically significant with an unexpected sign and magnitude. Since the wage rate is an observation at the state level, it is likely that it is capturing state-level factors that are positively correlated with changes in milk marketings. The proxy variable for managerial resources (*NONFM*) is negative and statistically significant, suggesting that availability of managerial resources is critical to increases in local milk marketings. The results suggest that land is not a limiting resource for the dairy industry expansion.

Local income level (*INC*) is not statistically relevant in dairy location decisions, but locations with higher tax levels deter dairy operations from moving into the area. A one percentage increase in per capita property tax decreases the changes in milk production by 0.04 percent. The dummy variable for the membership in milk marketing orders (*MMO*) is negative and significant at 10 percent, suggesting that the majority of the growth in milk production has occurred in counties outside federal and California milk marketing orders.

**Concluding Remarks**

Geographical changes in the U.S. dairy industry have been noted, but their driving factors remained anecdotal. This paper uses spatial econometrics to identify determinants of the changes in spatial distribution of the industry. Results presented are preliminary but suggest a robust presence of an agglomeration effect in the dairy industry. Locations with growing dairy output stimulate local dairy expansion and attract more dairies from other locations. Geographical shifts in milk production are occurring parallel to structural changes. Milk production is increasing in locations that are amiable to larger animal operations. With increasing stringency of environmental compliances, dairy operations become more capital intensive. It would be of interest to identify the carrying capacity, so to speak, of animal operations.

In addition, both market accessibility and input availability play large roles in determining spatial distribution of the industry. In particular, output prices that are administered by the Federal Marketing Order have a large impact. Hence, any future revision of the FMMO would certainly induce geographical changes in the industry. Our results suggest how the current industry structure has diverged from the pre-Great Depression era, where prices were determined freely by shipping costs, rather than administered price differences. Local availability of feed, particularly the most bulky hay, was important in dairy location decisions, along with managerial resources, as dairy herd management requires more specialized skills.

The current findings suggest that climate is a critical factor in dairy location decisions, and warrant further examination with detailed weather data. In particular, it would be of interest to include relative humidity measures which can proxy for hay quality.

Knowledge of factors associated with the spatial growth of the dairy industry can assist local governments and communities in evaluating economic perspectives, where the immigration of livestock agriculture can counteract effects of rural population decline and job losses. In terms of local policy, the current results provide evidence that higher property taxes deter dairy operations from moving to an area, suggesting a possibility of successfully devising tax incentives to attract these operations. Understanding the association of structural changes in the dairy industry with these regional shifts provides a basis for the dairy industry lobbying policy initiatives that may mitigate undesirable spatial changes. Also, spatial study can provide a basis to predict levels of environmental damage from concentration of large animal operations.

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Table 1. Descriptive Statistics

| variable | units | mean | std. dev. | max | min |
|---|---|---|---|---|---|
| DMILK | percent change in milk marketings, 1995-00 | -0.180 | 0.672 | 5.914 | -4.618 |
| LCAFO | number of farms with more than 500 cattle and 1000 hogs, 1997 | 14.044 | 23.745 | 319.000 | 0.000 |
| ANIM | million animal units where cattle = 1 and hog = 0.4 | 0.046 | 0.058 | 0.827 | 0.000 |
| MBPRICE | cents/hundredweight in 1999 | 0.122 | 0.009 | 0.158 | 0.106 |
| NPLANTS | 100 plants within 300 mile radius | 0.523 | 0.346 | 1.330 | 0.000 |
| LNPOP | logarithm of population, 1997 | 10.428 | 1.252 | 14.965 | 6.859 |
| DPOP | percent change in population, 1990-00 | 0.097 | 0.117 | 0.723 | -0.228 |
| HOUS | 100 housing permits per capita, 1997 | 22.243 | 80.719 | 1522.970 | 0.000 |
| PCTFM | percentage of total land in farming, 1997 | 0.537 | 0.288 | 1.498 | 0.003 |
| DPCTFM | change in PCTFM, 1992-97 | -0.300 | 4.470 | 44.838 | -47.552 |
| CORN | billion bushels, 1997 | 0.004 | 0.007 | 0.047 | 0.000 |
| HAY | million tons, 1997 | 0.054 | 0.071 | 1.421 | 0.000 |
| COMMFD | percentage of feed expenses on commercially mixed feed, 1997 | 0.572 | 0.231 | 1.000 | 0.000 |
| UNEMP | unemployment rate, 1996 | 0.055 | 0.025 | 0.294 | 0.014 |
| WAGE | $/hour, 1998 | 6.896 | 0.606 | 8.010 | 5.750 |
| NONFM | percentage of farmers whose principle occupation is non-farming, 1997 | 0.500 | 0.123 | 0.754 | 0.142 |
| LAND | million acres, 1997 | 0.519 | 0.611 | 12.840 | 0.053 |
| INC | per capita personal income, million $, 1994 | 0.018 | 0.003 | 0.040 | 0.010 |
| TAX | per capita property tax, 1000 $, 1992 | 0.508 | 0.304 | 2.937 | 0.050 |
| HDD | 1,000 heating degree days, 1996/97 | 5.361 | 2.217 | 10.445 | 0.532 |
| CDD | 1,000 cooling degree days, 1997 | 1.059 | 0.700 | 3.596 | 0.186 |
| LNMILK95 | logarithm of milk marketings, 1995 | 14.194 | 1.648 | 19.883 | 9.501 |

Table 2. Maximum Likelihood Results (Dependent variable = DMILK)

| Variable | Coefficient[a] | Asym. t-value | p-value | Elasticity[b] |
|---|---|---|---|---|
| Constant | -0.3489 | -0.7004 | 0.484 | |
| ρ (spatial autocorrelation coefficient) | 0.2281 * | 8.5925 | 0.000 | |
| LCAFO | 0.0038 * | 2.8926 | 0.004 | 0.054 |
| ANIM | -1.6708 * | -2.9475 | 0.003 | -0.077 |
| MBPRICE | 6.8390 * | 2.6360 | 0.008 | 0.837 |
| NPLANTS | 0.1380 * | 2.2419 | 0.025 | 0.072 |
| LNPOP | 0.0213 | 1.1766 | 0.239 | 0.223 |
| DPOP | 0.7318 * | 2.8771 | 0.004 | 0.040 |
| DPOP^2 | -1.6459 * | -2.6657 | 0.008 | |
| HOUS | -0.0001 | -0.3886 | 0.698 | -0.002 |
| PCTFM | -0.0683 | -0.8173 | 0.414 | -0.037 |
| DPCTFM | 0.0260 | 0.8315 | 0.406 | -0.008 |
| CORN | 3.5055 | 0.9383 | 0.348 | 0.015 |
| HAY | 0.9875 * | 3.0905 | 0.002 | 0.053 |
| COMMFD | -0.2615 * | -3.5754 | 0.000 | -0.150 |
| UNEMP | 2.7096 | 1.3512 | 0.177 | -0.018 |
| UNEMP^2 | -27.3963 * | -2.3006 | 0.021 | |
| WAGE | 0.0805 * | 2.3199 | 0.020 | 0.555 |
| NONFM | -0.5838 * | -2.9352 | 0.003 | -0.292 |
| LAND | 0.0100 | 0.3304 | 0.741 | 0.005 |
| INC | 1.1202 | 0.0365 | 0.971 | -0.304 |
| INC^2 | -514.9646 | -0.7313 | 0.465 | |
| TAX | -0.2985 * | -1.9629 | 0.050 | -0.040 |
| TAX^2 | 0.2161 * | 2.6474 | 0.008 | |
| MMO | -0.1029 | -1.9040 | 0.057 | |
| HDD | -0.0314 | -1.8387 | 0.066 | -0.169 |
| CDD | -0.1302 * | -2.8537 | 0.004 | -0.138 |
| LNMILK95 | -0.0255 * | -2.2990 | 0.022 | -0.025 |
| | | | | |
| Number of observations: | 2033 | | | |
| R-square | 0.0913 | Adj.R-square | | 0.0796 |
| Log-likelihood | -8001.5435 | | | |

[a] * signifies significance at 5% level.

[b] Evaluated at the mean of the independent variable.