The Determinants of Dairy Farm Location

Livestock Series Report 7

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EXECUTIVE SUMMARY

The location of dairy feedlots has important implications for the future of the dairy industry. Knowing the possible trends in dairy farm location improves our ability to formulate policies affecting the industry. In this paper we investigate the role of traditional location factors as well as environmental policy indicators in the location of dairy farms. Since county-level rather than farm-level data were available, standard logit models were estimated to assess the impacts of possible location factors on the decision to locate a dairy in a given part of the country. A major limitation of this approach is that it explains the *probability* of location but does not consider the *degree* of location.

Based on the results of this study, higher milk prices, average temperatures, and surface water density encourage dairy farm location whereas higher annual precipitation, feed and land cost, population density, and the stringency of environmental policies (such as air, groundwater, and soil conservation policies) are deterrents. For small changes in the explanatory variables, the marginal elasticities show the response of the probability of location to a percentage change in the regressor of interest. A 1 percent increase in milk price relative to other counties leads to more than a 2 percent increase in the probability of dairy farm location in that county whereas a similar 1 percent increase in overall environmental policy stringency can affect the location of dairy farms, though the absolute impact might be small.

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Introduction

There have been significant changes in the U.S. dairy industry over the past few decades. There has been a nationwide trend of fewer and fewer dairy farms. According to the U.S. Census of Agriculture, there were 312,095 U.S. dairy farms in 1978, which declined by 50 percent to 155,339 dairy farms in 1992. At the same time the number of dairy cows per farm has increased, despite an overall decline in milk cow numbers nationwide, suggesting increased concentration and consolidation. Generally, the economies of scale inherent in the dairy industry have significantly increased farm sizes. Notwithstanding this decline in milk cow numbers and dairy farms, the level of milk output has risen over the same period. Total milk output computed from USDA sources was 121.5 billion pounds in 1978, 135.5 billion pounds in 1982 and 142.7 billion pounds in 1987. This indicates a tremendous increase in milk yield per cow, mainly attributable to technological advancements. A reduction in the number of dairy farms was thus unavoidable since domestic consumption and export demand for dairy products remained fairly stable over this period. No state in the continental United States was exempt from these effects. Table 1 shows that there was a decline in dairy farm numbers and an increase in number of cows per farm in each state between 1982 and 1992. The figures in that table were calculated from the 1992 Agricultural Census (CD-ROM version) distributed by the U.S. Bureau of the Census.

The second significant change in the U.S. dairy industry is the change in the distribution of dairies across the nation. This location effect is due to interregional or interstate factors that make dairying more attractive in some areas than in others, thus causing a movement of dairy farms from some parts of the country to more profitable locations. Figure 1 displays the changes in dairy farm numbers at the county level, showing the counties that gained and those that lost dairy farms during that same 10-year period.

The distribution of livestock feedlots across the nation is important for various reasons, especially the impact of livestock operations on the environment. The concentration of livestock operations in a given area presents the need for more careful livestock waste management because of the enormous amount of manure produced per unit land area, than is needed in a region with a more sparse livestock population. Another reason is that the potential distribution of livestock feedlots in the near future also provides some information about the growth prospects of regional economies.

An earlier report in this series (Lakshminarayan et al. 1994) discussed in more detail the dynamics and trends in the U.S. dairy industry. This report identifies the factors that have influenced the location decisions of dairy operators, thus leading to the changes in the distribution of dairies across the nation. Since the livestock industry has become the subject of increased attention for environmental regulation, one of the primary factors we investigate is the stringency of environmental policy. We also consider some standard location factors.

Potential Dairy Location Factors

Environmental Regulation

The livestock industry in the United States has become the subject of environmental regulation for two primary reasons. First, livestock feedlots have become concentrated and the animal waste generated in these confined animal feeding operations (CAFOs) has grown enormously in recent years contributing significantly to air and water pollution. It is estimated that currently feedlots contribute to 13% of impairments in rivers nationwide, which is higher than that from industrial sources (9%), storm sewers (11%) or combined sewer overflows (2%) (EPA 1993). Second, even though CAFOs are considered as point source dischargers, pollution from feedlots poses more of a nonpoint, rather than point, source problem. This means that it is more difficult to monitor such discharges.

In the 1972 Clean Water Act the U.S. EPA was required to administer a national permit program to regulate point source discharges of pollutants in U.S. waters. In 1974 the EPA established the National Pollutant Discharge Elimination System (NPDES), which prohibits any pollutant discharge into U.S. water from a point source, including CAFOs, unless the discharge is authorized by an NPDES permit (EPA 1993). Even though the EPA has been trying to minimize the disparity in implementation of the NPDES permits across states, significant differences do exist. These differences exist partly because of limited resources to implement and enforce permitting programs, difficulty in identifying contributing livestock facilities and difficulty in interpreting and administering NPDES regulations (EPA, 1993).

Since regulatory policy in most cases implies a cost to the regulated facility, livestock operations are expected to thrive more in regions with less stringent regulatory policy. Barring all limitations to the mobility of livestock facilities over time, we would expect a movement of livestock operations to less regulated regions. One of the key factors considered in this paper is the stringency of environmental regulation. We seek to investigate whether environmental policies have influenced the location of dairy feedlots. Various studies of business location have been done, but, to the best of our knowledge, this is the first consideration of the impact of regulatory policy on livestock operations. Carlton (1983) and Bartik (1985), for example, both looked at state tax differentials and found that these had negligible impact on business location decisions. Bartik (1988) also considered the influence of environmental regulation on business location and realized that there were no statistically significant effects of environmental regulation, even though he used several alternative measures of environmental regulation (stringency). However, he suggested that for highly polluting industries there might be some appreciable effect. McConnell and Schwab (1990) also looked at the impact of environmental regulation on location decisions in the motor vehicle industry. For one definition of environmental factors there were no significant effects. However, for another definition they found some marginal impacts. Most of these studies concentrated on start-up firms or plants.

In this study environmental policy stringency is based on four alternative environmental indicators, including (1) air quality, (2) groundwater quality, (3) soil conservation, and (4) an aggregate environmental policy stringency index. These stringency indicators were obtained at the state level and were chosen because the operators of dairy feedlots would more likely be affected by the regulations imposed to maintain or improve the quality of air, groundwater, and soil resources than by any other environmental regulatory measure. The impacts arise primarily from regulations related to the application of dairy manure and other dairy waste on land and are also concerned with dairy waste runoff. The potential for odor nuisance and leaching and runoff of nutrients from dairy wastes and excess dairy manure applied to crop fields are the principal causes of concern.

The values for these environmental indicators were obtained from data provided by the Fund for Renewable Energy and the Environment (FREE), as cited in Lester and Lombard (1990). These data are nonfiscal in nature and are reported annually and rate the states according to their approach to key environmental issues. States with higher scores are implied to have greater commitment to environmental protection.

Milk Price Distribution

The price of milk that dairy farmers received, as of 1992, was affected by two major programs: the federal milk marketing order (MMO) system and the dairy price support system. Under the MMO system, the prices received by dairy farmers is higher the farther away they are from the major surplus centers, which are regarded to be the regions around Eau Claire, Wisconsin. It is expected that dairy farms will move to states or regions with higher milk prices.

Other Location Factors

Studies by Wheat (1973), Morgan (1967), Calzonetti and Walker (1991), Arpan and Ricks (1975), and Fox and Murray (1991) suggest that the chief location factors also include demand for products; costs of factors of production such as labor and raw materials, transportation (proximity to markets), land, and infrastructure; climate and other weather-related factors; and a threshold influence that implies that a minimum level of development is required to attract an industry to a given location. In this study we have chosen to use, in addition to milk price and environmental policy indicators, the following location factors: costs of production, including feed and land costs; climate, proxied by average temperature and precipitation; population density; and the proportion of land area covered by water.

Our a priori expectations are that higher production costs will be a deterrent to dairy farming. Thus we expect the coefficients on the feed cost and land cost variables to be negative. The impact of the climate variables depends on the level of the variable. It may be expected that extremely low temperatures would be a deterrent to dairying as well as extremely high temperatures. However, since much of the continental United States rarely experiences extremely high temperatures, the coefficient on the temperature variable is expected to be positive. On the other hand, by similar reasoning the coefficient on the rainfall variable is expected to be negative. We expect dairies to locate away from densely populated areas. The impact of surface water density is, for the most part, less obvious.

The Model

To derive an empirical model for explaining dairy location, let us consider a prospective dairy farmer who has the intention of starting a dairy farm. We assume that the required capital is available, financed through either equity or debt means. Furthermore, he is also assured that it is profitable to run a dairy operation somewhere in the country. Thus, unlike the usual business location problem, his problem does not involve the decision of whether or not to start a dairy farm. Rather, in our analysis we assume that he finds it profitable to run a dairy. The problem is where to locate his dairy. We also assume that, unlike the new (small business) firm case of Carlton (1979), our prospective dairy farmer is not constrained by any circumstances to be immobile. However, it is costly to move to a different location once the dairy has been started (cost-based rigidity). Thus, the producer will locate the dairy at the site that will bring the most profit. Specifically, if the farmer locates the facility at site k out of n possible sites, then it must be that

$$r_k > r_j \quad \forall j \neq k, j = 1,2,\dots,n \tag{1}$$

where r_j refers to the profit of the typical dairy feedlot in location j. We might think of r_j as representing the discounted sum of net returns accruing to the dairy feedlot over its life span, in excess of all overhead and operating costs. However, for empirical purposes, it is easier to tackle this problem by first specifying a restricted profit function for the farmer. Then by duality (see McFadden 1978), given a suitable formulation of his restricted profit function, we can obtain estimates of various useful relationships between the location factors, economies of scale, herd size, and some input elasticities. Suppose as in McFadden (1978) that the milk production process can be represented by the Cobb Douglas transformation function

$$y \le [K_0 x_1^{\alpha_1} x_2^{\alpha_2} \dots x_N^{\alpha_N}]^1, \tag{2}$$

where $K_0 > 0$ is a parameter, $x_1,\dots,x_N \ge 0$ are inputs, $\alpha_i > 0$, $\sum_{i=1}^{N} \alpha = 1$ and $\mu < 1$, the returns to scale parameter. This says that the level of milk output depends upon the levels of each x_i and some parameters α_i, K_0 ,and μ . In the short run we would expect that not all the inputs in a production process are variable, while in the long run we usually think of all inputs as being variable, freely chosen by the farmer in a standard profit maximization framework. However, it is intuitive to suppose that the production possibilities open to the farmer depend not only on the set of inputs he can choose freely but also on certain location-specific factors that he cannot alter even in the long run, if we assume cost-based rigidity. Let us suppose that the first S inputs are the traditional inputs, variable and freely chosen by the farmer, while inputs S+1, . . ., N are fixed location-specific "inputs" or factors. Then from McFadden (1978) the restricted profit function of the dairy farmer is

$$r = K_1 [p_1^{-\alpha_1} \dots p_S^{-\alpha_S}]^{\upsilon} p_y^{1+\upsilon\lambda}, \tag{3}$$

where $\upsilon = \mu / (1-\mu\lambda)$, $\lambda = \sum_{i=1}^{S} \alpha_i$ and $K_1 = (1-\mu\lambda)[K_0 \mu^{\lambda} \alpha_1^{\alpha_1} \ldots \alpha_S^{\alpha_S} x_{S+1}^{\alpha_{S+1}} \ldots x_N^{\alpha_N}]^{\upsilon}$.

Here p_i, i = 1, …, S refers to the price of input i. We can rearrange terms and express (3) alternatively as

$$r = K_2 [p_1^{-\alpha_1} \ldots p_S^{-\alpha_S} x_{S+1}^{\alpha_{S+1}}, \ldots, x_N^{\alpha_N}]^{\upsilon} p_y^{1+\upsilon\lambda} \tag{4}$$

where $K_2 = (1-\mu\lambda)[K_0 \mu^{\lambda} \alpha_1^{\alpha_1} \ldots \alpha_S^{\alpha_S}]^{\upsilon}$.

Taking logarithms of (4) we can write

$$\ln r = \ln K_2 - \alpha_1 \upsilon \ln p_1 - \ldots - \alpha_S \upsilon \ln p_S + \alpha_{S+1} \upsilon \ln x_{S+1} + \ldots + \alpha_N \upsilon \ln x_N + (1+\upsilon\lambda) \ln p_y \tag{5}$$

Let $X = [\ln(p_1) \ldots \ln(p_S) \ln(p_y) \ln(x_{S+1}) \ldots \ln(x_N)]'$. Then for estimation purposes we can write the logarithm of the profit at location j in terms of the exogenous variables at that location:

$$\pi_j = \ln r_j = B' X_j + u_j \tag{6}$$

where u_j is an error term that captures any variation in π_j that is not explained by the X_j vector.

From (1) and (6) the farmer chooses site k as long as

$$B' X_k + u_k > B' X_j + u_j \quad \forall j \neq k, j = 1, \ldots, n \tag{7}$$

$$\Leftrightarrow u_j - u_k \leq B' X_k - B' X_j . \tag{8}$$

One approach at estimation is to assume that the u_j's are iid normally distributed and use an OLS regression procedure. However, the response variable in a location decision is partly discrete or truncated. Thus, OLS regression results would be biased (Maddala 1983). A more appropriate procedure is to use a logit or probit approach. The logit approach is computationally easier to handle and since the results are usually not significantly different from the probit approach, the former has been extended more considerably in the literature. Using a conditional (multinomial) logit model that accounts for both location-specific and firm-specific factors, McFadden (1978) has shown that if the u_j's are independently distributed Weibull then the probability that the farmer will locate in region k, $\Pr(k)$, is

$$\Pr(k) = \frac{exp(B'X_k)}{\sum_{j=1}^{n} exp(B'X_j)}. \tag{9}$$

Estimation of (9) by maximum likelihood methods enables us to obtain an estimate of the coefficient vector B.

An empirical application of this model requires data at the farm level. Unfortunately, data on individual dairy farms are not readily available. Rather, county-level data on the number of dairy farms for any given census year are widely available. Whereas an exact conditional logit estimation is impossible given the unavailability of data, we can estimate a standard logit modification of the model. To estimate with county-level data we first let z be the change in dairy farm numbers in a given county between the two census years of 1987 and 1992. This change is due to two main effects, a location effect and a nationwide trend effect. The location effect captures the movement of dairies from one county to another. The nationwide trend effect, on the other hand, reflects a general decline in dairy farm numbers over the years due to size economies and changes in the farm structure. In order to avoid any biases due to the trend effect we correct for this by defining a new variable,

$$y = z - d, \tag{10}$$

where y is the net change in dairy farm numbers due to the location effect and d is the effect of the nationwide trend on the county's dairy farm numbers. In this study we assume an equal value of d across all counties.

We expect that for any two counties k and l, $y_l > y_k \Leftrightarrow \pi_l > \pi_k$ in general, where π_l and π_k are the typical profits of dairy farms in counties l and k. If for a given county k, $y_k = 0$, then we expect that $y_j \geq 0 \ \forall j \ s.t. \ \pi_j > \pi_k$. Thus an appropriate modification of the multinomial logit model can be used to estimate the impacts of various location-specific factors on the probability that a given county would experience an increase in dairy farm numbers. Accordingly, we define the discrete dependent variable as

$$\begin{aligned} f &= 1 \quad if\ y \geq 0 \\ f &= 0 \quad otherwise. \end{aligned} \tag{11}$$

Assuming a logistic distribution for the error term (Agresti 1990),

$$Pr(f = 1) = \frac{exp(B'X)}{1 + exp(B'X)} . \qquad (12)$$

To explain location decisions made between the 1987 and 1992 census years, the values of the explanatory variables were taken as those that prevailed in the base census year, 1987, and the standard logit model is estimated with cross-section county-level data using the LOGISTIC procedure in SAS®.

The interpretation of the coefficients of the logit model is not immediately obvious. Insight into the effect that the explanatory variables have on dairy location can be captured by examining the derivatives of the probability that the number of dairies in a given county will increase with respect to the kth explanatory variable. Since the components of the X matrix are in logarithmic form, these derivatives are defined as

$$\frac{\partial \Pr(f = 1)}{\partial X_k} = \Pr(f = 1)\ B_k\ [1 - \Pr(f = 1)] / X_k . \qquad (13)$$

However, since the values of these marginal effects depend on the units of the variables of interest, comparison between two or more regressors of their marginal impacts is more difficult. To obtain more easily comparable marginal impacts, we estimated elasticities of a change in probability of location (probability of an increase in dairy farm numbers) with respect to the explanatory variables. This is given as

$$\varepsilon_k = \frac{\partial \ln \Pr(f = 1)}{\partial \ln X_k} = B_k\ [1 - \Pr(f = 1)] \qquad (14)$$

In interpreting the estimated model, we estimated these elasticities at the means of the regressors. These elasticities generally provide a reasonable approximation of the change in the probability of location due to a small change in X_k. It is important to realize that the values of the elasticity are functions of X_k so they do not necessarily apply to large changes in the explanatory variables. A positive coefficient indicates that an increase in the value of the independent variable will increase the probability of location. In other words, counties with higher values of that independent variable have a greater chance of increasing dairy farms. Conversely, a negative coefficient indicates that an increase in the value of that independent variable will decrease the probability of location.

Based on the definition of the response variable, the model provides information on the factors that promote location and those that do not, but does not provide an explanation of the degree of location.

Variable Definitions and Sources of Data

In order to explain dairy location at the county level in 1992 relative to 1987, as much as possible the levels of the independent variables used were their values for the base year, 1987. Annual milk price state-level data are from various issues of the USDA Agricultural Prices Annual Survey. These annual averages for each state are computed as weighted means over all the blend prices prevailing in the different milk marketing orders within the state.

The climate data for this study were long-term averages of minimum, maximum, and average temperature and precipitation. These values were computed from monthly values from weather generator files developed for the USDA Erosion Productivity Impact Calculator (EPIC) model (Williams 1990). The weather generator files were originally constructed for the USDA Water Erosion Prediction Project (WEPP) model as described by Nicks and Lane (1989). Since the climate data existed for 1,000 weather stations, we needed to compute the most likely weather data for each of the approximately 3,000 counties in the United States. To do this we calculated the distance from each weather station to the center of each county. The center of each county was estimated as the intersection of the two diagonals of the smallest rectangle that encloses that county entirely. Then we associated with each county the weather station closest to its center to obtain the weather data.

The two weather variables used here are average annual temperature and average annual precipitation. Average temperature was measured in degrees Centigrade and average annual precipitation in millimeters. Average temperature at the county level represents 30 year annual mean temperatures computed for each of the associated weather stations. Rainfall data also represent 30-year mean annual precipitation for each of the corresponding weather stations.

The 1992 Agricultural Census (CD-ROM) provided data on county-level farm numbers and animal numbers for dairy cows, other livestock, and poultry. From the same source we had data on average and total farm costs, total feed expenses for livestock and poultry farms, and the value of land and buildings per farm and per acre. The feed cost variable in this study is defined as feed cost per animal unit. This was computed as total feed expense for livestock and poultry farms divided by the total number of animal units in the given county. Feed cost data specific for dairy farms was not available at the county level. The land cost variable used in this study is defined as the value of land and buildings per acre divided by average farm expenditure. Since land cost per acre was not available at the county level, the value of land and buildings, the closest available indicator of land cost, was normalized by the average farm expenditure to reduce the bias introduced by the value of buildings.

The 1990 Census of Population and Housing (CD-ROM) was the source for mid-1990 population by county. We divided this number by total land area to obtain population density. Similarly, the proportion of land area covered by water was computed as water area divided by total land area. Population, land area, and surface water area data were also obtained from the 1990 Census of the Population.. As mentioned, four different state-level environmental policy indices were used in this study, all of which were obtained from Lester and Lombard (1990). These are the extent of each state's devotion to groundwater programs, air quality programs, soil conservation programs, as well as an aggregate environmental policy stringency rating index.

Even though dairy farmers might include Hawaii, Puerto Rico, and Alaska in their location decisions, these were excluded from the analysis since it is likely that some major noneconomic factors might also influence the decision to locate in those areas. Thus, the list of counties was constrained to the continental United States. Furthermore, counties with no dairy farms in at least one of the 1982, 1987, and 1992 census years were excluded. These exclusions involved about 180 counties, about 6 percent of counties in the United States.

Empirical Results

The logit model in equation (12) was estimated using the SAS® LOGISTIC procedure. This procedure uses a maximum likelihood approach with a modified Newton's algorithm to compute the parameter estimates. Note that the Hessian (second derivative of the log likelihood function) is always negative definite, so that the log likelihood is globally concave. Newton's method usually converges to the global maximum of the log likelihood function no matter what the initial values are. Empirical results obtained by estimating various logit models are in Tables 2 and 4.

Estimations without Environmental Policy Variables

In Table 2 we show the results of five models that do not include an environmental policy variable. Four of these models—A, B, C, and E—had the highest proportions of correctly predicted probabilities. The results for Model D were reported in order to compare with the estimations including environmental policy indicators, but without the population density variable. This is because introducing the population density variable was found to significantly affect the coefficients of the regulatory stringency variables, as is E. Thus, we found it expedient to report the results of D, excluding the population density variable, as well as those of E that include the population density variable. The figures in parentheses represent $\Pr(\chi^2 > \chi_e^2)$, the probability of observing a χ^2 value greater than that which was estimated. These figures represent the levels at which the coefficients are significant. Using $\alpha = 0.05$ as our level of significance implies that any figure in parentheses less than 0.05 means the corresponding coefficient is significant. In all cases the signs on the coefficients are in accordance with our a priori expectations.

The milk price coefficients are all positive and highly significant, suggesting that a higher milk price seems to be an inducement for dairy farm location in any given county.
The coefficients estimated for average temperature are also positive and highly significant, suggesting that on average counties with higher mean annual temperatures would have a higher probability for increasing dairy farms. Conversely, more rainfall seems to be a deterrent to dairy farm location; the coefficient on rainfall is negative and highly significant.

Costs of production also play a role in dairy farm locations, as we expected. Higher land values per acre and feed costs per animal unit both discourage location in favor of counties with lower production costs. Since the land value variable is not an accurate indicator of land costs, caution needs to be exercised in interpreting the values of the associated coefficients and elasticities. The county population density seems to be a deterrent to dairy farm location. In other words, dairies seem to locate in less densely populated counties, perhaps to avoid complaints and costly litigation from local residential communities. Model E, which includes all the regressors we have discussed, was used in estimating the models with environmental policy variables, as well as D, which includes all regressors except the population density variable.

In the logit models the marginal elasticities, estimated at the mean values of the regressor, are easier to interpret than the marginal effects that depend on the units of the variables. Table 3 reports the marginal elasticities of the regressors used in Models A to E. From E, we can interpret that a 1 percent increase in the price of milk from its mean level will increase the probability of dairy location by about 2.4 percent. We note again that these marginal elasticities apply to small changes. Similarly, an increase in the mean annual temperature of 1 percent increases the probability of location by about 0.4 percent while a 1 percent increase in mean annual precipitation will decrease the probability of location by less than 0.15 percent. The marginal effect of a 1 percent increase in feed cost is an 0.8 percent decrease in the probability of location. Finally, a 1 percent increase in the population density will decrease the probability by 0.1 percent.

Estimations with Environmental Policy Variables

Three major environmental policy indicators were of interest to us: air policy, groundwater policy, and soil conservation policy. Models D and E were fitted with these three environmental policy variables and also with a cumulative environmental policy stringency index. The results are shown in Table 4. As with the results in Table 2, the results in Table 4 satisfy our a priori expectations. In all these models the signs of the nonenvironmental policy variables were preserved, as were the significance of the model coefficients. Furthermore, the environmental policy variables had a negative sign for all estimations and for the most part (except in the case of the air and groundwater policy variables in Model E), were significant. This means that, in general, counties in states with more stringent environmental regulations tend to lose dairy farms to those counties in states with less stringent policies.

Table 5 shows the estimated marginal elasticities for the models with environmental variables. For the nonenvironmental policy variables, the marginal elasticities do not significantly differ when the environmental policy variables are included in the model. On the contrary, the marginal elasticities of the environmental variables differ markedly if the population density variable is included in the model. On the contrary, the marginal elasticities of the environmental variables differ markedly depending on whether or not the population density variable is included in the model. In the absence of the population density indicator, a 1 percent increase in air policy stringency leads to a 0.07 percent decrease in the probability of location. However, when population density is accounted for, the same increase in air policy stringency elicits only a 0.014 percent decrease in the probability, a five-fold decrease in its absolute impact. In the case of groundwater policy, the elasticities are −0.06 and −0.02, whereas for soil conservation policy they are −0.07 and −0.05. The marginal elasticity of the environmental policy index is halved when population density is accounted for, −0.12 as opposed to −0.24. It is clear then that among the regulatory indicators, air policy is most highly affected by the introduction of population density in the model. The intuition behind this is clear when we realize that air policy issues arise in relation to odor and other air quality problems, which are most prominent when dairies are located in residential or densely populated areas. Thus, by locating away from densely populated areas, dairies avoid most of the regulatory pressures relating to odor and other air pollutants. In general, the impact of the overall environmental policy index is higher than that of the three individual indicators. Judging from the results for Model E, a 1 percent increase in total environmental policy rating has the potential impact of reducing the probability of location by 0.12 percent. As mentioned before, all these impacts were evaluated at the means of the regressors.

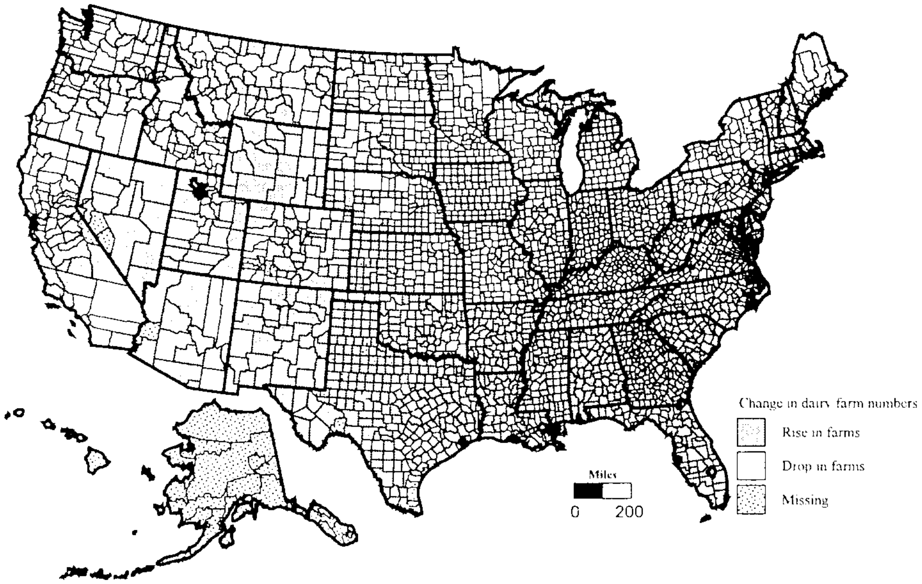
Summary

Dairy farming across the United States has been characterized by very dynamic trends over the past half century. The number of dairy farms has fallen and the number of milk cows has been declining, whereas the number of milk cows per farm has risen over time as well as the total level of milk production. In addition, the location of dairy farms across the nation has also undergone a substantial regional shift.

This paper investigates the role of traditional location factors in the location of dairy farms. Due to the nature of the available data, a standard logit specification was used and various models were estimated. The results of these estimations were in accordance with our intuitive expectations. A higher milk price seems to be a favorable factor for dairy farm location. Likewise it appears that dairies locate in counties with higher average temperatures. As was also expected, higher feed costs and land costs seem to be deterrents to location to a given county.

It was also of interest to investigate the hypothesis that more stringent environmental regulations have no effect on dairy location. It was found that, contrary to this null hypothesis, counties in states with more stringent environmental regulations seemed to be associated with lower probabilities of dairy farm location. This was true for all the environmental policy indicators examined, although in some cases the impact might be insignificant. This suggests that the differences in state-level environmental regulations might have contributed to a migration of dairy farms across regional boundaries to locations with less stringent environmental regulations.

Given our model specifications, the estimated marginal elasticities of the regressors indicate the relative impact on the probability of location for each percentage change in the corresponding regressor. Regressors such as milk price, feed cost, and temperature seem to elicit a greater absolute probability response per unit change than others such as precipitation, land value, and population. The impact of these and other location factors may have moved dairy farm concentration from the traditional states in the Midwest, particularly Wisconsin and Minnesota, to southern states such as Florida, Texas, and California especially when California enjoyed a greater milk price differential from the Eau Claire, Wisconsin, base.



Map Source: Center for Agricultural and Rural Development, Iowa State University

Figure 1. County-level change in dairy farm numbers adjusted for national trend

Table 1. Changes in Dairy Farm Number and Farm Size

State	No. of farms in 1992	% change from 1982	Cows per farm in 1992	% change from 1982
Alabama	995	-57.86	45	80.00
Alaska	34	-46.88	21	40.00
Arizona	305	-58.22	283	174.76
Arkansas	1688	-55.21	38	65.22
California	3124	-32.64	398	96.06
Colorado	1162	-57.51	70	150.00
Connecticut	486	-44.77	71	20.34
Delaware	137	-44.76	63	57.50
Florida	877	-36.68	179	43.20
Georgia	1168	-55.47	80	70.21
Hawaii	57	-35.23	166	29.69
Idaho	1990	-52.61	91	116.67
Illinois	3050	-47.52	49	36.11
Indiana	3958	-41.75	36	28.57
Iowa	5878	-43.94	44	37.50
Kansas	2165	-53.25	39	50.00
Kentucky	4984	-53.92	37	60.87
Louisiana	1279	-51.77	60	57.89
Maine	836	-53.14	51	59.38
Maryland	1329	-40.08	71	22.41
Massachusetts	606	-45.45	51	13.33
Michigan	5198	-43.14	61	38.64
Minnesota	13380	-44.66	46	31.43
Mississippi	1216	-60.55	51	64.52
Missouri	5626	-50.30	38	58.33
Montana	1092	-57.90	20	81.82
Nebraska	2122	-54.72	39	56.00
Nevada	208	-40.23	91	102.22
New Hampshire	389	-50.45	56	43.59
New Jersey	450	-41.56	53	6.00
New Mexico	650	-52.10	159	341.67
New York	10696	-37.94	67	31.37
North Carolina	1552	-64.35	62	113.79
North Dakota	1925	-47.82	39	39.29
Ohio	6980	-38.65	42	31.25
Oklahoma	2297	-49.00	39	62.50
Oregon	1541	-53.15	64	113.33
Pennsylvania	12448	-30.43	50	28.21
Rhode Island	55	-55.28	47	51.61
South Carolina	540	-55.70	57	50.00
South Dakota	2873	-48.79	41	46.43
Tennessee	3295	-59.31	46	70.37
Texas	5381	-38.30	71	97.22
Utah	1082	-53.46	74	89.74
Vermont	2373	-33.81	68	28.30
Virginia	2369	-57.52	58	87.10
Washington	1842	-48.95	132	127.59
West Virginia	972	-66.49	24	100.00
Wisconsin	30156	-31.61	50	19.05
Wyoming	523	-58.92	14	40.00

Table 2. Logit Estimations Without Environmental Policy Variables

Variable	Model A	Model B	Model C	Model D	Model E
Intercept	-24.741	-23.579	-23.825	-23.844	-22.218
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
Milk Price for 1987	7.803	8.744	7.646	8.437	8.692
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
Average Temperature	1.290	1.372	1.397	1.344	1.512
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
Mean Annual Precipitation		-0.447		-0.656	-0.526
		(.0006)		(.0001)	(.0001)
Feed Cost	-0.322	-0.300	-0.323	-0.317	-0.297
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
Value of Land Per Acre[a]	-0.528	-0.428	-0.544	-0.450	-0.426
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
Population Density	-0.337	-0.321	-0.392		-0.381
	(.0001)	(.0001)	(.0001)		(.0001)
Surface Water Density			0.104	0.026	0.119
			(.0001)	(.2922)	(.0001)
Percent Correct Prediction	77.7	77.8	77.9	76.8	78.2
Log Likelihood	-1511.6	-1505.5	-1502.0	-1546.3	-1493.6

[a] Value of land per acre was weighted by average farm expenditure.

Table 3. Estimated Elasticities

Variable	Model A	Model B	Model C	Model D	Model E
Milk Price for 1987	2.220	2.479	2.148	2.445	2.439
Average Temperature	0.367	0.389	0.392	0.389	0.424
Mean Annual Precipitation		-0.127		-0.190	-0.148
Feed Cost	-0.092	-0.085	-0.091	-0.092	-0.083
Value of Land per acre	-0.150	-0.121	-0.153	-0.130	-0.120
Population Density	-0.096	-0.091	-0.110		-0.107
Surface Water Density			0.029	0.008	0.033

*Value of land per acre was weighted by average farm expenditure.

Table 4. Logit Estimations with Environmental Policy Variables

Variable	Air		Groundwater		Soil conservation		Env.Index	
	Model D	Model E	Model D	Model E	Model D	Model E	Model D	Model E
Intercept	-23.850	-22.240	-23.624	-22.152	-23.892	-22.360	-21.096	-20.904
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
Milk Price for 1987	8.393	8.671	8.389	8.675	8.364	8.660	7.759	8.316
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
Average Temperature	1.367	1.514	1.286	1.485	1.243	1.427	1.290	1.472
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
Mean Annual Precipitation	-0.572	-0.510	-0.651	-0.526	-0.566	-0.451	-0.437	-0.421
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0009)	(.0015)	(.0021)
Feed Cost	-0.307	-0.295	-0.312	-0.295	-0.314	-0.294	-0.306	-0.292
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
Value of Land Per Acre[a]	-0.441	-0.425	-0.493	-0.444	-0.475	-0.447	-0.518	-0.464
	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)	(.0001)
Population Density		-0.374		-0.376		-0.377		-0.354
		(.0001)		(.0001)		(.0001)		(.0001)
Surface Water Density	0.037	0.120	0.035	0.122	0.022	0.115	0.048	0.125
	(.1382)	(.0001)	(.1592)	(.0001)	(.3679)	(.0001)	(.0536)	(.0001)
Air Policy	-0.249	-0.049						
	(.0006)	(.5178)						
Groundwater Policy			-0.205	-0.087				
			(.0252)	(.3567)				
Soil Conservation Policy					0.234	0.193		
					(.0100)	(.0373)		
Environmental Index							-0.832	-0.430
							(.0001)	(.0097)
Percent Correct Prediction	76.8	78.1	76.7	78.1	76.6	78.1	77.0	78.1
Log Likelihood	-1540.4	-1493.4	-1543.8	-1493.2	-1543.0	-1491.4	-1532.7	-1490.2

[a]Value of land per acre was weighted by average farm expenditure.

Table 5. Estimated Elasticities in Models with Environmental Policy Variables

Variable	Air		Groundwater		Soil Conservation		Env. Index	
	Model D	Model E	Model D	Model E	Model D	Model E	Model D	Model E
Milk Price for 1987	2.443	2.431	2.433	2.434	2.420	2.415	2.230	2.330
Average Temperature	0.398	0.425	0.373	0.417	0.360	0.398	0.371	0.412
Mean Annual Precipitation	-0.166	-0.143	-0.189	-0.148	-0.164	-0.126	-0.126	-0.118
Feed Cost	-0.089	-0.083	-0.090	-0.083	-0.091	-0.082	-0.088	-0.082
Value of Land Per Acre[a]	-0.128	-0.119	-0.143	-0.125	-0.137	-0.125	-0.149	-0.130
Population Density		-0.105		-0.106		-0.105		-0.099
Surface Water Density	0.011	0.034	0.010	0.034	0.006	0.032	0.014	0.035
Air Policy	-0.072	-0.014						
Groundwater Policy			-0.059	-0.024				
Soil Conservation Policy					-0.068	-0.054		
Environmental Index							-0.239	-0.120

[a] Value of land per acre was weighted by average farm expenditure.

REFERENCES

Arpan, Jeffery and David Ricks. 1975. *Directory of Foreign Manufacturers in the United States*. Atlanta: School of Business Administration, Georgia State University.

Agresti, Alan. 1990. *Categorical Data Analysis*. New York: John Wiley & Sons.

Bartik, Timothy. 1985. Business location decisions in the United States: Estimates of the effects of unionization, taxes, and other characteristics of states. *Journal of Business and Economic Statistics* 3(1): 14-22.

Bartik, Timothy. 1986. The effects of environmental regulation on business location in the United States. *Growth and Change* Summer: 22-24.

Calzonetti, F. J. and Robert T. Walker. 1991. "Factors affecting industrial location decisions: A survey approach," In *Industrial location and public policy*, Henry W. Herzog, Jr., and Alan M. Schlottmann. Knoxville: The University of Tennessee Press.

Carlton, Dennis W. 1983. The location and employment choices of new firms: an econometric model with discrete and continuous endogenous variables. *Review of Economics and Statistics* 65: 440-9.

Carlton, Dennis W. 1983. Why new firms locate where they do: an econometric model. In *Interregional Movements and Regional Growth*, W. Wheaton, Ed. Washington, D.C.: The Urban Institute.

Fox, William F. and Matthew N. Murray. 1991. "The effects of local government public policies on the location of business activity. In *Industrial location and public policy*, Henry W Herzog, Jr., and Alan M. Schlottmann. Knoxville: The University of Tennessee Press.

Lakshminarayan, P. G., Aziz Bouzaher, Shannon Neibergs, Shih-Neng Chen, Edward Osei, and Stanley R. Johnson. 1994. *Dynamics and Trends in the U.S. Dairy Industry. Livestock Series Report 3 CARD Staff Report 94-SR 71.* Ames: Center for Agricultural and Rural Development, Iowa State University.

Lester, James P. and Emmett N. Lombard. 1990. The comparative analysis of state environmental policy. *Natural Resources Journal* 30 (Spring): 301-19.

Maddala, G. S. 1983. *Limited-dependent and qualitative variables in econometrics.* Cambridge: Cambridge University Press.

McConnell, Virginia D., and Robert M. Schwab. 1990. The impact of environmental regulation on industry location decisions: the motor vehicle industry. *Land Economics* 66(1): 67-81.

McFadden, Daniel. 1978. Cost, revenue, and profit functions. In *Production Economics: A Dual Approach to Theory and Applications (Vol. 1).* D. McFadden and M. Fuss, ed. Amsterdam: North-Holland.

Morgan, William E. 1987. *Taxes and the location of industry.* Boulder, Colorado: University of Colorado Press.

Nicks, A. D. and L. J. Lane. 1989. Weather Generator. Chapter 2 in *USDA Water Erosion Prediction Project: Hillslope Profile Model Documentation.* NSERL Report No. 2. L. J. Lane and M A. Nearing, (ed.)

U.S. Environmental Protection Agency (USEPA). 1993. The Report of the EPA/state Feedlot Workgroup. Washington, D.C.: USEPA Office of Wastewater Enforcement and Compliance.

U.S. Department of Agriculture, Natural Agricultural Statistics Service. Various issues. *Agricultural Prices Annual Summary.* Washington, D.C.: USDA.

Wheat, Leonard F. 1973. *Regional growth and industrial location: An empirical viewpoint.* Lexington, Mass: Lexington Books.

Williams, J. R. 1990. The Erosion-Productivity Impact Calculator (EPIC) Model: A Case History. *Philosophical Transactions of the Royal Society of London* 329: 421-28.