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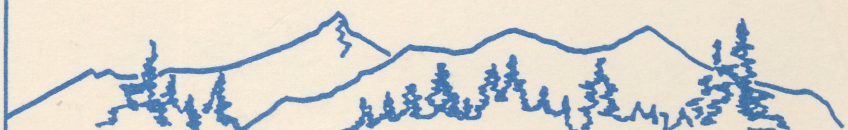

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THE STRUCTURE OF WISCONSIN MILK PRODUCTION: A DYNAMIC ANALYSIS

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ABSTRACT

A dynamic model is developed to investigate the evolution of production in the Wisconsin dairy industry and to test hypotheses on factors affecting it. Estimation procedures are chosen to overcome the problem of lack of data on individual entry or movement between size categories.

INTRODUCTION

In 1965, the first year such statistics were reported, there were 86,000 dairy farms in the state of Wisconsin with an average 24 cows per farm (DATCP, 1977). A generation later, in 1989, there were 34,000 dairies with an average herd size of 51 cows (DATCP, 1990). Since Cochrane, many researchers have examined the factors driving the process of structural change in agriculture. However, several questions concerning the dynamics of the structure of production, exemplified by the Wisconsin dairy industry, remain unanswered. Who exactly is going out of business? Are smaller farms at greater risk of going out of business? What factors influence the growth of farms? Is farm growth different across farm size categories?

Two problems confound the analysis. The first is that the process of change in the structure of production is necessarily dynamic. The other is that available time series data on farms by size category typically estimate only the number of farms. Information on the number of entries or exits, or growth in existing farms is not typically reported. This paper derives a model and develops a method to overcome these problems in analyzing the evolution of the structure of milk production in Wisconsin. The theoretical formulation is estimated with maximum likelihood as a Markov process. The estimated model incorporates the dynamics of the structure of milk production using imperfectly observed data on those changes. The objective is to determine the process of structural change and the factors which influence it over time.

THE MODEL

Given that individual farmers in Wisconsin cannot influence the price of milk, an individual's product supply function at any point in time can be represented as $y_i^*=y_i^*(p,r)$, where p is milk price and r is input prices. Over time, t, the supply curve shifts due to technological and structural change, which is represented by T in the supply function:

$$y_{it}^*=y_{it}^*(p_t,r_t,T_t) \tag{1}$$

Divide the farms into s categories according to some measure of farm size. Let n_{jt} be the number of farms in size category j at time t, j=1,...,s. Like the supply function in equation 1, we assume that the determinants of the number of farms take the form:

$$n_{jt} = n_{jt}\,(p_t,r_t,T_{jt}) \tag{2}$$

The first issue is to model the dynamics of the number of farms n_{jt}, j=1,...,s. Suppose that the structure of Wisconsin milk producers can be characterized by size categories using the following Markov process (Chavas and Magand):

$$n_{jt} = a_{jt} + \sum_{i=1}^{s} P_{ijt}n_{i(t-1)} \tag{3}$$

where a_{jt} is the net entries (i.e. entries minus exits) in the number of firms in category j between time t-1 and t; P_{ijt} is the transition probability from category i to j between time t-1 and t; and $n_{i(t-1)}$ is the number of firms in category i at time t-1. Note that the transition probabilities and net exits vary over time.

Based on equation 2, net exits and transition probabilities in equation 3 can be characterized as follows:

$$a_{jt} = g_j(y^*_{t-1}, p_{t-1}, r_{t-1}, t_{jt-1}) \qquad (4a)$$

$$P_{ijt} = f_{ij}(y^*_{t-1}, p_{t-1}, r_{t-1}, t_{jt-1}) \qquad (4b)$$

where f and g are functions of the independent variables. Note that these variables are lagged to reflect a slow adjustment process; current independent variable values affect exits and transition probabilities in future periods. Lagged supply is included as an explanatory variable in the characterization of the structure of Wisconsin milk production because of the influence of non-price effects on farm exit. The 1988 drought and the 1986-1987 Dairy Termination Program are two such effects which cannot be accurately represented with dummy variables.

Since the transition probabilities are non-negative and the sum over j of the transition probabilities for each category i must equal one, the choice of functional form is limited (Maddala). A multinomial logit is chosen:

$$P_{ijt} = \exp F_{ijt}/[1 + \sum_{k=1}^{s-1} \exp F_{ikt}] \qquad j=1,\ldots,s \qquad (5a)$$

$$P_{ist} = 1/[1 + \sum_{k=1}^{s-1} \exp F_{ikt}] \qquad (5b)$$

Note that constant transition probabilities are a subcase of this.

Research by Willett indicates that dairy farms typically do not decrease in size without going out of business. This implies that for i greater than j, P_{ij} equals zero, thus reducing the number of parameters to be estimated. In addition, since the transition probabilities sum over j to one, then $P_{ss}=1$.

Equations 4a, 4b, 5a, and 5b are substituted into equation 3 to form a system of equations to be estimated. The result is time varying transition probabilities and net entries modeled in terms of the explanatory variables. Tests can be performed on the factors influencing entry and movement from one size category to another.

This formulation does not require data on individual movement, aggregate data by size category is all that is necessary. Errors in variables due to the error term being serially correlated in a model with a lagged dependent variable imply inconsistent least squares estimates. Thus, parameters for the s equations estimated by least squares would be biased and inconsistent. Estimates of the coefficients of the model are obtained from nonlinear seemingly unrelated regression estimation (MacRae). Efficiency is gained by estimating via maximum likelihood.

DATA

Data on three size categories is available for Wisconsin dairy farms (DATCP): one to 29 cows, 30 to 49, and 50 or more milking cows.[1/] The independent variables as indicated in equations 4a and 4b are milk supply, output and input prices and technological change. Data for Wisconsin milk supply is readily available. Output and prices are represented by the milk-feed price ratio. Technological change is reflected by the production per cow by herd size category over time. These variables are used to investigate how profitability and technological efficiency influence net entry, and transition from one size category to another. Data on productivity per cow by herd size is the most limiting factor, since estimates were first calculated in 1980.

1/ For a dairy farm the number of cows rather than acres of land measure the scale or size of the farm because of the capital and labor costs associated with the herd size.

RESULTS

The nonlinear system of equations represented by 4a, 4b, 5a and 5b substituted appropriately into equation 3 is estimated using maximum likelihood techniques. The resulting coefficients are consistent and asymptotically efficient.

Since there are three size categories, there are three equations estimated in the system. Each equation contains coefficients which determine the net entries and transition probabilities to each category. The R^2 for small farms is .98 with a Durbin-Watson statistic of 1.57.[2/] The R^2 for medium farms is .98 with a Durbin-Watson statistic of 1.28. The R^2 for large farms is .92 with a Durbin-Watson statistic of 2.33. Coefficients of the model are listed in Table 1 and discussed below.

For small farms, predicted net entry fluctuates between 235 and 1292 exits per year (Table 2). The significant negative constant verifies the trend in the exit of small farms. As expected, increases in the milk feed price ratio increase entry and increases in the supply of milk decrease entry. Increases in the productivity of small farms has a significant positive impact on entry. Or put another way, decreases in productivity stimulate increases in exits. Since small farms tend to be less productive than medium and large farms, this may explain why small farm exits are numerous.

The transition probabilities for small farms indicate virtually all small farms stay small. The explanatory variables for the probability of staying the same size, P_{11}, have significant, positive coefficients. That is, increases in the milk-feed price ratio have a positive effect on remaining small. This seems counter-intuitive and may reflect inadequate returns over the time examined to expand. As one might expect, increases in milk supply increase the probability that small farms will not expand. Unexpectedly, improvements in small farm technology increase the probability of remaining small. This may not reflect the alternative of expansion so much as a means of staying in business.

The predicted probabilities of increasing farm size from small to medium, P_{12}, or large, P_{13}, are very small. Moreover, a negative, significant coefficient on the milk feed price ratio and supply for P_{12} imply that increases in the price ratio or in supply decrease the (already small) probability of becoming a medium sized farm.

The predicted net entries for medium sized farms in Table 2 range from 388 to 1086 farms per year during the 1980's. Entry is generally decreasing over time. Unfortunately, all the explanatory coefficients for net entry are statistically insignificant. However, the signs of the relationships are as expected: increases in the milk-feed price ratio are linked to increased entry; increases in supply are tied to exits; and increased technological change is associated with entry.

The transition possibilities for medium farms in Table 3 consist of remaining the same size or becoming a large farm. The possibility of becoming smaller was ruled out a priori based on work by Willett. Over time, a higher percentage of medium farms become large: from 6.5 to 12.1 percent per year. The 93.5 to 87.9 percent per year that remain medium sized have a positive association with the milk-feed price ratio and supply, and a negative association with technological change. None of these coefficient values are statistically significant, however.

Among large farms, 50+ cows, there are the largest predicted net exits: fluctuating from 401 to 2,144 farms per year (Table 2). They are generally increasing over time. The signs of the coefficient values are as expected, though insignificant: increases in the milk-feed price ratio increase entries; increases in supply decrease entries; increases in productivity are associated with exits. The latter makes sense if it is the less productive farms which go out of business.

CONCLUSIONS AND IMPLICATIONS

Perhaps the most significant implication of this work is the ability to track structural change between different sized farms without data on individual farm movement. From this analysis, several patterns emerge that are not clear from simple inspection of numbers on farms by category. Small

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2/ A Durbin Watson statistic is not appropriate for a model with lagged dependent variables, however, a Darbin-h statistic assumes a linear model. Specification of an appropriate statistic to measure autocorrelation for a nonlinear model with lagged dependent variables, is beyond the scope of this paper.

farms apparently are not becoming larger; they are either staying the same size or going out of business. Medium farms are becoming larger, at an increasing rate over time. They are also the only category that is attracting new entrants, indicating that medium farms provide a scale of operation optimal for beginning a business. Finally, even with many medium farms becoming larger, the net result for large farms is that they are going out of business at greater rate than small farms.

Not surprisingly, increases in the milk-feed price ratio, that is, the profitability of dairying, attracts entrants, while increases in supply reduce entrants. Technology improvements are associated with entry to small and medium farms, and with exits among large farms. This reflects low levels of productivity among existing small and medium farms. For large farms it would appear those exiting are less productive, further increasing the level of productivity of remaining large farms.

That increases in the milk feed price ratio improve ones odds at staying in business is expected. However, one would expect it to have a positive effect on the transition probability of getting larger, too. The negative coefficient on P_{12} could imply that farms get larger as a way to cope with price decreases. This is what is often observed; as prices fall, farmers expand to maintain income at the same level.

Supply expansion is associated with increases in the probability of remaining the same size rather than becoming larger. To put it another way, reduction in milk supply due to the Dairy Termination Program and the 1988 drought resulted in a greater probability of increasing herd size relative to remaining the same size. However, for small farms increasing productivity enhances the probability of remaining small versus growing larger. Improvements in medium farm productivity decrease the probability of staying the same size. Hence, there is a link between improving productivity and growth of medium farms, but not of small farms.

The implication appears to be that the safe strategy to weather adverse effects by the milk feed price ratio is to be "average." Medium sized farms appear to be able to stay in business, and attract new entrants. However, improving technology is linked with entry and an incentive to grow larger. How policies are linked to this incentive to expand despite the risks larger farms face requires further study. The model does indicate that policies to increase milk prices would not appear to encourage dairy farms to enlarge, however, they would attract new entrants.

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Table 1. Coefficient Values and Standard Errors of the Model

	Constant	Price Ratio	Supply	Technology
Net Entries:				
1. Small	-18.9	1.3[a]	-0.69[a]	15.8
	(4.3)	(0.68)	(1.2)	(3.7)
2. Medium	-1.2	1.3	-0.69	0.97
	(6.4)	(0.68)	(1.2)	(5.5)
3. Large	5.27	1.3	-0.69	-5.1
	(5.88)	(0.68)	(1.2)	(3.56)
Transition Probabilities				
P_{11}: small-small	1.98	4.06	3.59	1.99
	(0.98)	(0.91)	(0.93)	(0.98)
P_{12}: small-medium	-1.02	-3.09	-2.69	-1.03
	(0.98)	(0.91)	(0.93)	(0.98)
P_{22}: medium-medium	4.5	0.53	1.22	-4.62
	(4.27)	(0.43)	(1.24)	(3.48)

[a] Coefficient values for price ratio and supply are restricted to be equal across all three net entry categories.

Table 2. Predicted Net Entry of Dairy Farms in Wisconsin by Year by Size Category (number of farms)

	Small: 1 to 29 Cows	Medium: 30 to 49 Cows	Large: 50+ Cows
1981	-1,114	1,086	- 401
1982	- 879	1,032	- 587
1983	-1,142	1,019	- 574
1984	-1,235	865	- 809
1985	-1,125	654	-1,004
1986	- 719	665	-1,320
1987	-1,169	727	-1,227
1988	- 235	724	-1,496
1989	- 523	388	-2,144
1990	-1,292	542	-1,710

Table 3. Predicted Transition Probabilities for Wisconsin Dairy Farms by Size Category

	P_{22}	P_{23}
1981	.935	.065
1982	.931	.069
1983	.931	.069
1984	.922	.078
1985	.92	.08
1986	.917	.083
1987	.924	.076
1988	.905	.095
1989	.879	.121
1990	.89	.11