Practices Used by Dairy Farmers to Reduce Seasonal Production Variability

Andrew A. Washington, Richard L. Kilmer, and Richard N. Weldon

The objective of this analysis was to identify the production practices used by farmers to change seasonal production. Production practices included milk production per cow, proportion of cows milking, number of first lactation animals entering the herd, number of cows leaving the herd, number of days to first breeding, and calves born. Farms that participated in a seasonal pricing plan during 1993, 1994, and 1995 decreased production practice seasonality in response to price premiums, which caused a decrease in production seasonality compared to nonparticipating farms. Participating farms showed a preference for adjusting entering first lactation animals and number of calves born, but did make adjustments in other practices as well.

Key Words: dairy, deficit, pricing, production, seasonality, surplus

Florida milk production is seasonal,[1] with production being highest in the spring and lowest in the late summer and early fall. Two primary reasons account for this seasonality: (*a*) biological factors that are affected by moderate temperatures in the spring and hot temperatures in the summer, and (*b*) farmers' perceptions of the profitability of spring production.

During the cooler spring months of the year, more milk per cow is produced at lower input cost levels (Kaiser, Otenacu, and Smith, 1988). Demand for milk in Florida varies throughout the year, due to school lunch programs and tourism. However, as observed in figure 1, milk consumption tends to be less volatile than production.

These seasonal patterns of milk production and consumption result in supply and demand imbalances requiring Florida's cooperatives to import and export bulk fluid milk during various times of the year. During the spring months, milk production exceeds milk consumption and milk is exported out of Florida (figure 1). The opposite is true during the late summer and early fall months when fluid milk from as far away as Minnesota, Wisconsin, and Arizona is moved into Florida to make up for the lack of production (U.S. Department of Agriculture, 2001).

Correcting these disequilibriums in seasonal supply and demand of milk is the responsibility of the Florida cooperatives, based on their "full supply" contracts with milk processors (i.e., cooperatives deliver no more and no less than the amount of milk ordered by the processors). These contracts benefit individual farmers as well as processors by facilitating the ease of selling and buying milk. However, cooperatives are faced with the responsibility of exporting fluid milk in the spring and importing milk during the late summer and early fall months, at a substantial cost to the cooperatives (Lawson, 1997).

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The content of the introductory discussion was first published in Washington, Lawson, and Kilmer (2000, pp. 113–115). It has been reworded and included in this article to facilitate the reader's understanding of the problem and the problem background.

[1] Seasonal behavior of a variable is a regularly repeating pattern of the variable, completed once every 12 months (Tomek and Robinson, 1990, p. 158). Florida milk production is an example of a seasonal variable. Tomek and Robinson (pp. 163–164) describe how to quantify a seasonal variable.

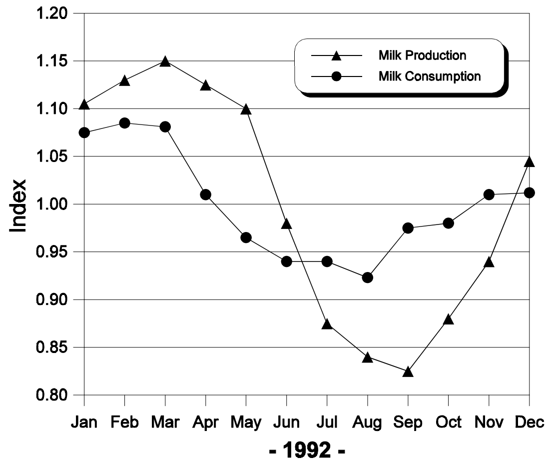
Seasonal pricing plans act as an incentive for farmers to change their patterns of production over the months within the year. Historically, numerous seasonal pricing plans have been used in various U.S. markets. Researchers have studied seasonal price plans and found that seasonality can be reduced with significant price premiums and penalties (Russell, 1967; Sun, Kaiser, and Forker, 1995). However, the price differentials alone cannot offset completely the biological factors in eliminating seasonality in production (Kaiser, Oltenacu, and Smith, 1988; Gao, Spreen, and DeLorenzo, 1992).

In 1993, a seasonal pricing plan was implemented by Florida cooperatives with hopes of cutting the import and export costs by enticing individual farmers to change their dairy's pattern of milk production. The overall objective of the pricing plan was to provide a price premium as an incentive for dairy farmers to produce more milk during deficit fall months and reduce production in the surplus months.

The pricing plan was implemented as follows. Each year, dairy farm owners signed a certification form indicating their intention to participate or not participate in the seasonal pricing program. For each participating farm, production in March, April, and May was summed and divided by the total number of days in those three months. This gave a per day *BASE* production for the high surplus period. The premium was paid in August, September, and October (the deficit period), and only when the average daily production in a month was at least 0.75 of the *BASE*.[2]

Farmers meeting these criteria were paid an average premium price[3] of $3.61, $3.28, and $4.00 per hundredweight (cwt) in 1993, 1994, and 1995, respectively, which was added onto the market price for all milk produced over 0.75 of the *BASE* for the month. Thus by lowering spring production (i.e., the *BASE*) and increasing fall production, participating farmers both increased the likelihood of producing at least 0.75 of the *BASE* and increased the amount produced above 0.75 for the fall months. The Florida cooperatives' seasonal pricing plan was in place from January 1993 through December 1995.

Washington, Lawson, and Kilmer (2000) looked specifically at the effectiveness of the Florida pricing



Source: Florida Dairy Cooperatives

Figure 1. Florida milk production and consumption seasonality index, January 1992 – December 1992

plan in changing the seasonality of milk produced. They compared the seasonal nature of milk production of farms participating in the plan to that of nonparticipating farms. Based on the results for the 68 farms sampled, participating farms decreased seasonality in each year (1993, 1994, and 1995) when compared to 1992 by 19.6%, 6.8%, and 21.8%. In contrast, nonparticipating farms increased seasonality by 5%, 12%, and 35.7% over these years. While the results showed the pricing plan worked for farms that participated, overall the plan was only marginally successful because of the nonparticipating farms. Thus the program was ended in January 1996.

Although the pricing plan was ended, the problem of seasonality remains. As reported by Washington, Lawson, and Kilmer (2000), there were distinct differences in the seasonality of milk production between participating and nonparticipating farms. Consequently, it is likely there were distinct differences in production practices employed by participating farms versus nonparticipating farms, particularly those practices directly affecting production variability.

In an attempt to identify potential production practices that could be employed to reduce seasonal production, this study examines six key variables which directly affect production variability: (*a*) proportion of cows milking (*pm*), (*b*) total number of first lactation animals entering the herd (*efla*), (*c*) total number of cows that left the herd (*clh*), (*d*) average number of days to first breeding after freshening for cows in the current breeding herd

[2] In 1995, 0.75 was changed to 0.70 for August, 0.75 for September, and 0.80 for October.

[3] For the months of August, September, and October, the premiums in 1993 were $3.64, $3.92, and $3.27 per cwt, respectively; in 1994 the premiums were $3.83, $3.00, and $3.00 per cwt; and in 1995 were $4.00 per cwt in each of the three months.

(*adfb*), (*e*) number of calves born (*cb*), and (*f*) milk production per cow (*mppc*). Results should indicate that as production seasonality decreases, the seasonal pattern in production practices should also decrease, and vice versa.

Model and Estimation Procedure

The purpose of the Florida cooperatives' seasonal pricing plan was to provide an incentive for farmers to change the factors of milk production which, in turn, would alter monthly milk production—i.e., reduce seasonality in milk output. To alter milk production, the dairy farmer needs to make adjustments in the number of cows milked in the herd and the amount of milk produced per cow. In a static model, the monthly production of milk produced (q) is simply a function of the levels and combinations of various inputs (x_i). However, because of the biological nature of milk production, the decisions made by the dairy farmer to adjust input use are both sequential and dynamic.

Antle (1983) provides a generalized model to explain the sequential and dynamic nature of production decisions in agriculture. In terms of monthly milk production (q_t), the $T = 12$-month or "stage" production function is specified as:

$$(1)\quad q_t = f(q_{t-1}, \mathbf{X}_t),$$

where t is a particular month of the year and $\mathbf{X}_t$ is the input vector for the various inputs in that month. Therefore, the production in any particular month is not only a function of the input decisions made that month, but also previous input decisions which determined production in q_{t-1}. With input prices $\mathbf{w}_t$, profit is represented by:

$$(2)\quad \pi_t = f(p_t, q_t, \mathbf{X}_t, \mathbf{w}_t).$$

The firm maximizes profit subject to equation (1), where profit maximization means the optimal level of production is determined by the input prices ($\mathbf{w}_t$), the price of milk (p_t), and the dynamic production process. Consequently, it can be argued that the "premium price" received by farmers who participated in the seasonal pricing plan would lead to changes in the inputs used so that the output produced would display less seasonality.

The pounds of milk produced by each cow times the number of cows milked determines the actual amount of milk marketed on a dairy farm for a particular month. Therefore, one fundamental way for a dairy farmer to change the seasonality of milk being produced (q_t) is by altering over time numerous management practices, ranging from adjusting or changing feeding practices to using fans and misters to cool the animals. Altering these practices ultimately translates into changes in the milk produced per cow ($mppc_t$).

The second way to change the amount of milk being produced (q_t) is to change the number of cows being milked. This can be accomplished by altering (*a*) the proportion of cows milking (pm_t), (*b*) the total number of first lactation animals entering the herd ($efla_t$), (*c*) the total number of cows that leave the herd (clh_t), (*d*) the average number of days to first breeding after freshening for cows in the current breeding herd ($adfb_t$), and (*e*) the number of calves born (cb_t) (i.e., the number of cows freshening).

Seasonal changes in each of the production practices for 1993 through 1995 (when the pricing plan was in place) were assessed and comparisons were made between the participating and non-participating farms. Production practice seasonality estimates for 1992–1995 were obtained by using a sine function estimation procedure where the degree of seasonality is measured by the amplitude and phase angle of the sine function.

Makridakis, Wheelwright, and McGee (1983) suggest the following procedure for estimating a sine function:

$$(3)\quad y_t = \hat{A}\sin\left[\left(\frac{f \cdot t}{n}\right)2\pi + \hat{\phi}\right] + \hat{e}_t,$$

where y_t is an index which represents a particular production practice, $\hat{A}$ is the estimated amplitude of the sine wave, f is the known frequency or number of times the sine wave is completed over the span of observations, t denotes time, n is the number of observations, and $\hat{\phi}$ is the estimated phase angle (in radians).

Estimating equation (3) is a nonlinear regression problem and is not easily solved directly. However, by making use of the trigonometric theorem (Makridakis, Wheelwright, and McGee, 1983),

$$(4)\quad A[\sin(U + V)] = A(\sin U)(\cos V) + A(\cos U)(\sin V),$$

equation (3) is linearized and becomes:

$$(5)\quad y_t = \hat{A}\cos\hat{\phi}\sin\left[\left(\frac{f \cdot t}{n}\right)2\pi\right] + \hat{A}\sin\hat{\phi}\cos\left[\left(\frac{f \cdot t}{n}\right)2\pi\right] + \hat{e}_t.$$

By letting $\hat{A}\cos\hat{\phi} = \hat{\beta}_1$ and $\hat{A}\sin\hat{\phi} = \hat{\beta}_2$, equation (5) becomes

$$(6)\quad y_t = \hat{\beta}_1 \sin\left[\left(\frac{f \cdot t}{n}\right)2\pi\right] + \hat{\beta}_2 \cos\left[\left(\frac{f \cdot t}{n}\right)2\pi\right] + \hat{\varepsilon}_t .$$

Equation (6) is sufficient when the intercept is zero or when the dependent variable is equal to zero at the mean. However, the dependent variables in this study are seasonal production practice indexes equal to one at the mean. Therefore, an intercept term is needed. Hence, equation (6) becomes

$$(7)\quad y_t = \hat{\beta}_0 + \hat{\beta}_1 \sin\left[\left(\frac{f \cdot t}{n}\right)2\pi\right] + \hat{\beta}_2 \cos\left[\left(\frac{f \cdot t}{n}\right)2\pi\right] + \hat{\varepsilon}_t ,$$

where $\hat{A}$ (Makridakis, Wheelwright, and McGee, 1983, p. 397) is calculated as:

$$(8)\quad \hat{A} = \sqrt{\hat{\beta}_1^2 + \hat{\beta}_2^2} ,$$

and from equations (5) and (6),

$$(9)\quad \hat{\phi} = \arcsin\left(\frac{\hat{\beta}_2}{\sqrt{\hat{\beta}_1^2 + \hat{\beta}_2^2}}\right).$$

Equation (7) can be estimated using ordinary least squares (OLS), where estimates of $\hat{A}$ and $\hat{\phi}$ are functions of parameter estimates $\hat{\beta}_1$ and $\hat{\beta}_2$.

An amplitude (A) test and phase angle (ϕ) test are used to determine if seasonal variability in production practices significantly changed for the three years in which the pricing plan was in place. Given that $\hat{A}$ and $\hat{\phi}$ are nonlinear functions of $\hat{\beta}_1$ and $\hat{\beta}_2$, the estimated standard errors for $\hat{A}$ and $\hat{\phi}$ are calculated as described by Greene (1997, pp. 360–361). The hypothesis tests of interest are:

$$H_0\colon A_i^y = A_j^y, \qquad H_a\colon A_i^y \gtrless A_j^y;$$

$$H_0\colon \phi_i^y = \phi_j^y, \qquad H_a\colon \phi_i^y \gtrless \phi_j^y,$$

where A_i^y (ϕ_i^y) is the amplitude (phase angle) for year y. This test would determine if the production practice seasonality in year y for the ith-type farms (participating) was significantly different from the seasonality for the jth-type farms (nonparticipating).

Data

As more fully described in Lawson (1997), and in Washington, Lawson, and Kilmer (2000), data sources for our analysis included the Florida Dairy Farmers of America (FDFA), the Tampa Independent Dairy Farmers of America (TIDFA), the Dairy Herd Improvement Association (DHIA), and a survey sent to dairy farmers throughout the state.

In 1992, Florida had 307 dairy farms of which approximately 45% were members of the DHIA. For purposes of our investigation, the need for data from the first three sources reduced the number of Florida dairy farms to 92 (30%). Thus the resulting data set was comprised of 92 farms with production data from January 1992 through October 1995, whether or not they participated in the seasonal pricing plan and/or utilized the production practices examined in this study.

All 92 farmers included in the data set were dairy farmers who produced each month from 1992 through 1995 and were DHIA members (Lawson, 1997).[4] A survey was sent to each of these farmers requesting permission to use their data. Sixty-eight of the 92 dairy producers gave their permission, with this final sample number representing 22% of Florida's 307 dairy farms in 1992.

Washington, Lawson, and Kilmer (2000, p. 117) performed statistical tests to determine if the 68-farm sample was representative of all dairy farms in the state of Florida. Average farm production was statistically the same for the sample and the population in 1993; however, the sample had larger average farm production in 1992, 1994, and 1995. When comparing the amplitude estimates, there was no significant difference between the sample and the population in 1992 and 1994; however, the 68-farm sample was more seasonal in 1993 and 1995. Finally, Washington, Lawson, and Kilmer (2000, pp. 117–118) found the use of 1992 as a base year was justified.

For the years 1992 through 1995, equation (7) was estimated for each of the production practices, using OLS for participating farms and a separate OLS equation for nonparticipating farms. Each regression had 12 observations, one for each month.[5] The index (y_t) was a monthly index of average daily use of each of the production practices where the index was equal to one when the monthly value was equal to the mean.

[4] Farmers not in the DHIA were eliminated because the DHIA data set contained variables not included in the FDFA and TIDFA data sets, such as the production practices analyzed in this study.

[5] The frequency f was equal to 1 because the sine wave was completed once during a given year. The time index t was an index from 1 to 12 for each month, and n was equal to 12, the total number of months. Because the data set ended in October 1995, however, for 1995, $n = 10$, and t is from 1 to 10.

Results and Discussion[6]

All but five (18) of the 72 amplitudes (phase angles) were statistically different from zero (see appendix tables A1 and A2). These findings reveal the presence of seasonality among the production practices before and after the seasonal pricing plan was initiated in January 1993. Furthermore, the phase angle differences indicate that some seasonal production practices do not start at one on January 1, rise to a peak at the end of March, subside to one at the end of June, drop to a low at the end of September, and end at one on December 31. The seasonality (sine curve) shifts to the left when the phase angle is positive and to the right when the phase angle is negative. A shift of ±30 degrees moves the seasonality (sine curve) one month to the left (+) or right (!), thereby changing the degree of seasonality for each month.

Tables 1 and 2, respectively, report the results of testing the null hypotheses that the estimated amplitudes and phase angles are equal for participating and nonparticipating farms during the study period. The amplitudes (phase angles) among the production practices affecting milk production were not statistically different between the participating and nonparticipating farms in 1992 (see the first three rows of tables 1 and 2), with the exceptions of entering first lactation animals (*efla*) in 1992(1993) (table 1), and proportion of cows milking (*pm*) in 1992(1994) and *efla* in 1992(1995) (table 2).

These findings suggest participating and nonparticipating farms had the same production practice seasonality before the seasonal pricing plan was implemented in 1993. However, the last three rows of tables 1and 2 tell a different story after implementation of the seasonal pricing plan in January of 1993.

The amplitude for the proportion of cows milking (*pm*) was 89% higher (table A1) and statistically different (table 1) for nonparticipating farms compared to participating farms in 1993, the year the seasonal pricing plan was initiated (figure 2).[7] This indicates the participating farms were less seasonal relative to the *pm* variable, which would decrease the degree of seasonality in milk production.

In 1993, the participating farm phase angles for entering first lactation animals (*efla*), cows that left the herd (*clh*), and calves born (*cb*) were to the right of those for the nonparticipating farms by 1.9, 1.6, and 0.8 months, respectively (table A2 and figures 3, 4, and 5). This would cause the production of participating farms to be less seasonal than the production of nonparticipating farms. Shifting *efla* and *cb* would increase the number of cows in the higher producing portion of their lactation, which would increase the amount of milk produced from August through November, the deficit milk months. Shifting *clh* would remove cows from the herd in the spring and keep them in the herd during August through November.

In 1994, the respective amplitudes for entering first lactation animals (*efla*) and calves born (*cb*) were 60% and 52% higher (table A1) and statistically different (table 1) for nonparticipating farms compared to participating farms (figures 6 and 7). This means that the cows entering the herd were less seasonal for participating farms, which reduces the degree of seasonality in milk production over the year.

In 1994, the participating farm phase angle for average days to first breeding (*adfb*) was more to the left than the phase angle for nonparticipating farms by 4.2 months (table A2 and figure 8). The *adfb* seasonalities for participating and nonparticipating farms were counter-cyclical to each other, suggesting participating farms were attempting to reduce their seasonal production when compared to nonparticipating farms.

Finally, in 1995, the amplitudes for calves born (*cb*) and milk production per cow (*mppc*) were 37% and 78% higher, respectively (table A1), and statistically different (table 1) for nonparticipating farms compared to participating farms. Furthermore, participating farms had a phase angle for *cb* that was more to the right and a phase angle for *mppc* that was more to the left than nonparticipating farms by 0.6 and 0.7 months (table A2 and figures 9 and 10). The combination of the amplitude and phase angle differences for *cb* and *mppc* reduced the degree of seasonality in milk production for participating farms compared to nonparticipating farms.

In 1995, participating farms had phase angles for entering first lactation animals (*efla*) and average days to first breeding (*adfb*) that were more to the right by 1.2 and 3.4 months, respectively, than those associated with nonparticipating farms (table A2 and figures 11 and 12). Shifting *efla* would increase

[6] A reviewer pointed out that while farmers had time to change seasonal production during the three years of the seasonal pricing plan, the new pricing policy likely had farmers experimenting with ways to change seasonal production.

[7] When the amplitudes (phase angles) were not statistically different between the participating and nonparticipating farms, the same amplitude (phase angle) was used to graph both farm types. The amplitude (phase angle) used was the midpoint between the two amplitudes (phase angles).

Table 1. Results of Testing the Null Hypothesis that the Estimated Amplitudes ($\hat{A}$) Are Equal for Both Participating and Nonparticipating Farms in 1992(y), 1993, 1994, and 1995

	Production Factors (variables)					
Null Hypothesis[a] (H_0)	Proportion Milking (*pm*)	Entering First Lactation Animals (*efla*)	Cows that Left the Herd (*clh*)	Average Days to First Breeding (*adfb*)	Calves Born (*cb*)	Milk Production per Cow (*mppc*)
$A_p^{92(93)} = A_{np}^{92(93)}$	1.732	2.858*	1.238	2.319	0.377	0.363
$A_p^{92(94)} = A_{np}^{92(94)}$	2.240	1.518	0.105	0.690	0.043	0.126
$A_p^{92(95)} = A_{np}^{92(95)}$	0.812	0.486	0.107	0.230	0.005	0.252
$A_p^{93} = A_{np}^{93}$	3.478*	2.412	0.148	1.881	0.743	0.736
$A_p^{94} = A_{np}^{94}$	1.439	5.553**	1.994	0.164	8.786***	0.016
$A_p^{95} = A_{np}^{95}$	0.816	1.707	0.000	0.449	4.582**	8.018***

Notes: *, **, and *** denote significance of the parameters at $\alpha = .10$, $\alpha = .05$, and $\alpha = .01$, respectively. Statistical significance is based on a Wald statistic with a chi-squared distribution and one degree of freedom. (The estimated amplitudes are reported in appendix table A1.)

[a] A = amplitude, p = participating farms, and np = nonparticipating farms. Because farms could participate in the seasonal pricing plan one year and choose not to participate the next year, the amplitude for 1992 was derived separately for participating and nonparticipating farms in each of the three years it was in place [i.e., milk production per cow (*mppc*) in 1992 by farms participating in 1993 ($A_p^{92(93)}$), *mppc* in 1992 by farms not participating in 1993 ($A_{np}^{92(93)}$), *mppc* in 1992 by farms that participated in 1994 ($A_p^{92(94)}$), and *mppc* in 1992 by farms not participating in 1994 ($A_{np}^{92(94)}$), etc.].

Table 2. Results of Testing the Null Hypothesis that the Estimated Phase Angles ($\hat{\text{N}}$) Are Equal for Both Participating and Nonparticipating Farms in 1992(y), 1993, 1994, and 1995

	Production Factors (variables)					
Null Hypothesis[a] (H_0)	Proportion Milking (*pm*)	Entering First Lactation Animals (*efla*)	Cows that Left the Herd (*clh*)	Average Days to First Breeding (*adfb*)	Calves Born (*cb*)	Milk Production per Cow (*mppc*)
$\phi_p^{92(93)} = \phi_{np}^{92(93)}$	0.245	1.116	0.036	0.186	0.428	0.820
$\phi_p^{92(94)} = \phi_{np}^{92(94)}$	3.012*	0.836	0.016	0.006	0.036	0.674
$\phi_p^{92(95)} = \phi_{np}^{92(95)}$	1.763	3.590*	0.058	0.001	0.316	1.098
$\phi_p^{93} = \phi_{np}^{93}$	2.195	22.504***	4.177**	0.047	8.333***	1.048
$\phi_p^{94} = \phi_{np}^{94}$	0.008	0.218	0.439	23.260***	0.358	2.619
$\phi_p^{95} = \phi_{np}^{95}$	2.095	6.567**	0.330	2.760*	3.860**	2.936*

Notes: *, **, and *** denote significance of the parameters at $\alpha = .10$, $\alpha = .05$, and $\alpha = .01$, respectively. Statistical significance is based on a Wald statistic with a chi-squared distribution and one degree of freedom. (The estimated phase angles are reported in appendix table A2.)

[a] ϕ = phase angle, p = participating farms, and np = nonparticipating farms. Because farms could participate in the seasonal pricing plan one year and choose not to participate the next year, the phase angle for 1992 was derived separately for participating and nonparticipating farms in each of the three years it was in place [i.e., milk production per cow (*mppc*) in 1992 by farms participating in 1993 ($\phi_p^{92(93)}$), *mppc* in 1992 by farms not participating in 1993 ($\phi_{np}^{92(93)}$), *mppc* in 1992 by farms that participated in 1994 ($\phi_p^{92(94)}$), and *mppc* in 1992 by farms not participating in 1994 ($\phi_{np}^{92(94)}$), etc.].

the number of cows in the higher producing portion of their lactation, thus increasing the amount of milk produced from August through November, the deficit milk months.

The *adfb* seasonalities for participating and nonparticipating farms were counter-cyclical to each other, suggesting participating farms were attempting to reduce their seasonal production when compared to nonparticipating farms. This would make milk production less seasonal for participating farms and more seasonal for nonparticipating farms.

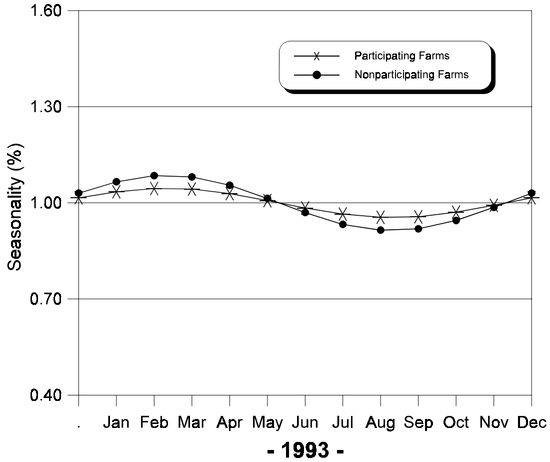


Figure 2. Proportion of cows milking (*pm*), 1993

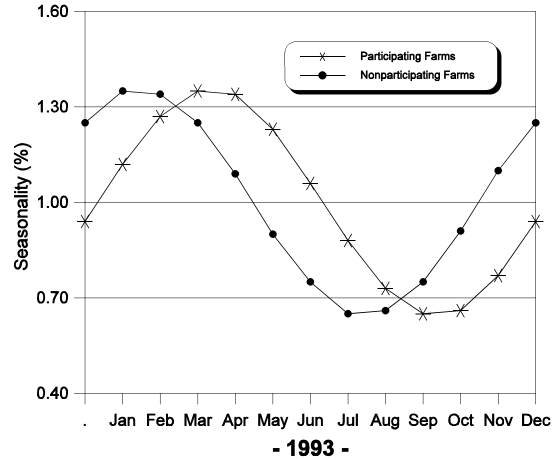


Figure 3. Entering first lactation animals (*efla*), 1993

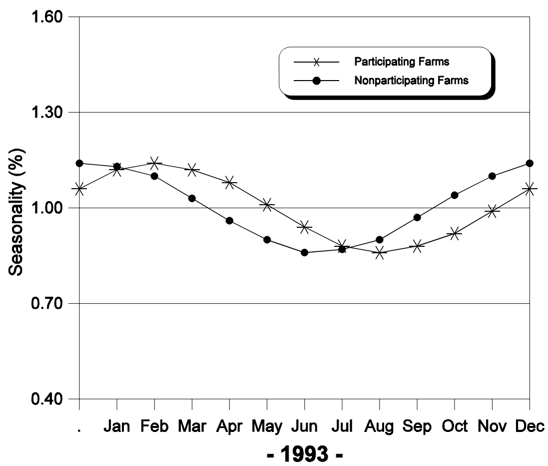


Figure 4. Cows that left the herd (*clh*), 1993

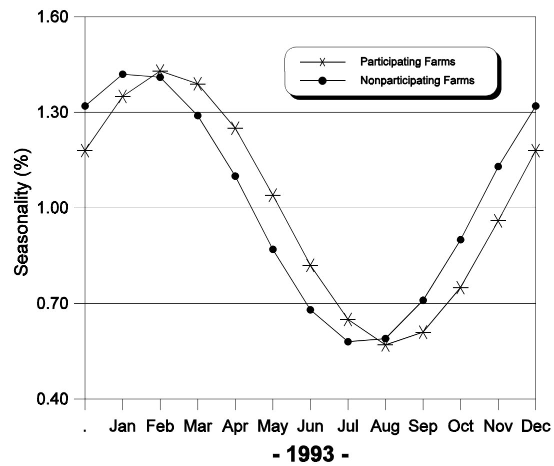


Figure 5. Calves born (*cb*), 1993

Summary and Conclusions

A seasonal pricing plan was implemented in January 1993 by the Florida milk marketing cooperatives in order to change the seasonal production of members. The objective of the seasonal pricing plan was to encourage milk production in the late summer and early fall deficit months and discourage production in the spring surplus months by paying farmers a price premium during the deficit months.

A price premium ranging from $3 to $4 per cwt was paid to farmers who participated in the voluntary seasonal pricing plan. Washington, Lawson, and Kilmer (2000) found production was less seasonal for farms that participated in the seasonal pricing plan than for nonparticipating farms.

The objective of this study was to determine what production practices were used by Florida dairy farmers to change seasonal production. One of the ways for a dairy farmer to change the amount of milk being produced in response to a change in the price of milk is to change the milk production per cow (*mppc*) by altering various management strategies.

A second way to change the amount of milk being produced is to change the number of cows being milked. The number of cows being milked

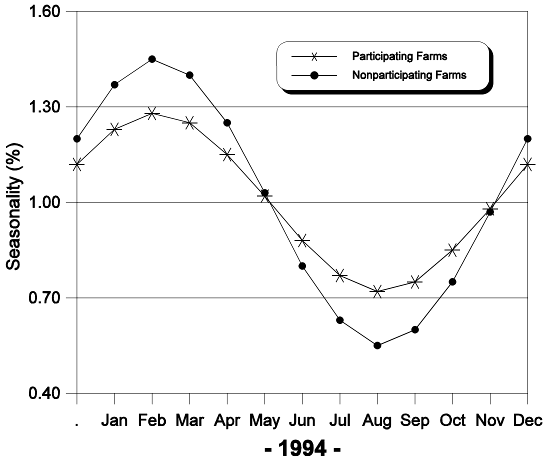


Figure 6. Entering first lactation animals (*efla*), 1994

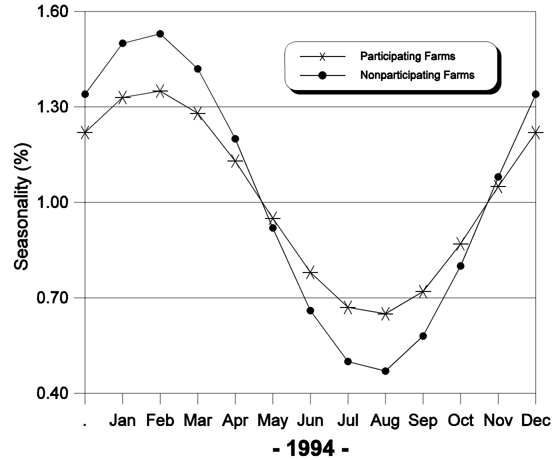


Figure 7. Calves born (*cb*), 1994

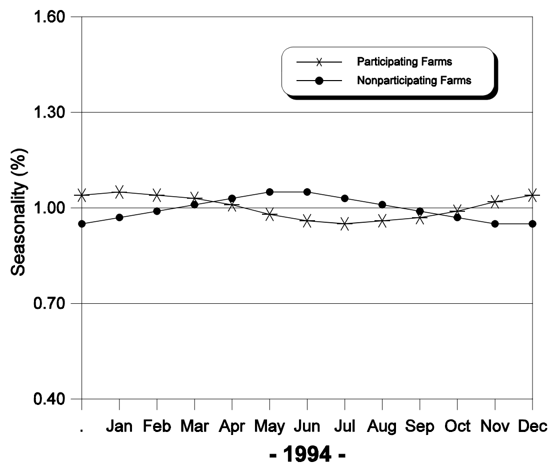


Figure 8. Average days to first breeding (*adfb*), 1994

can be changed by altering (*a*) the proportion of cows milking (*pm*), (*b*) the total number of first lactation animals entering the herd (*efla*), (*c*) the total number of cows that leave the herd (*clh*), (*d*) the average number of days to first breeding after freshening for cows in the current breeding herd (*adfb*), and (*e*) the number of calves born (*cb*) (i.e., the number of cows freshening).

The six production practices examined were seasonal in nature, as virtually all of the sine function amplitudes and phase angles were different from zero. Thus, seasonal production practices were influencing monthly milk production by altering the number of cows milked and the milk production per cow.

Participating and nonparticipating farmers showed no difference in the seasonal use of production practices (magnitude and phase angle) in 1992, the year before the seasonal pricing plan was put in effect. However, a different story emerges after implementation of the seasonal pricing plan in January of 1993.

The seasonality of *pm*, *efla*, *clh*, *adfb*, *cb*, and *mppc* was different for nonparticipating farms compared to participating farms in some years and not others. The *efla* and *cb* variables differed in all three years (1993, 1994, and 1995); *adfb* differed in 1994 and 1995; and *pm*, *clh*, and *mppc* differed in one year. In each case, the magnitude of the seasonal

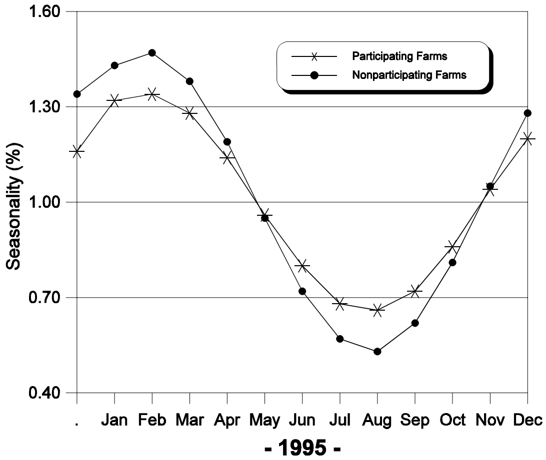


Figure 9. Calves born (*cb*), 1995

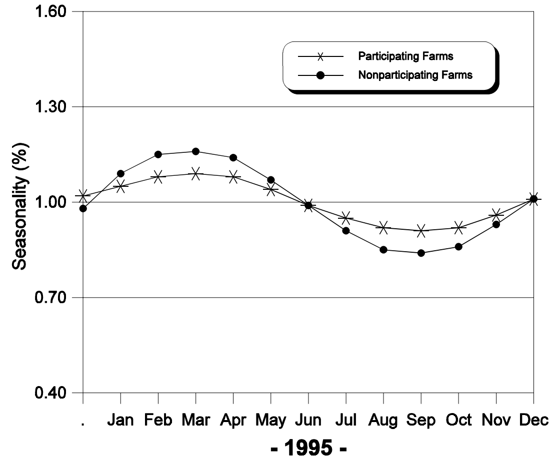


Figure 10. Milk production per cow (*mppc*), 1995

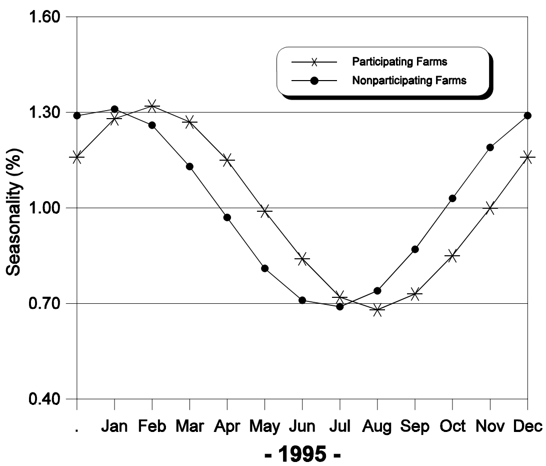


Figure 11. Entering first lactation animals (*efla*), 1995

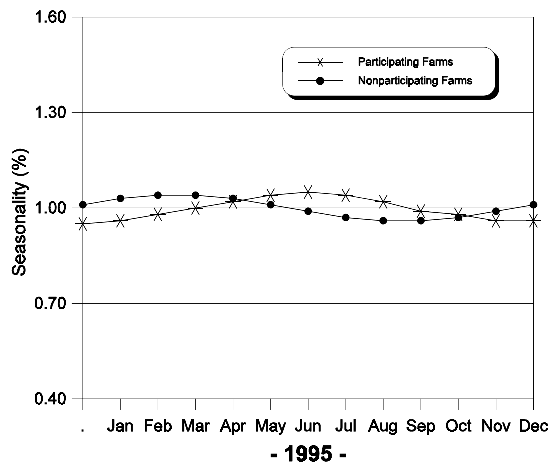


Figure 12. Average days to first breeding (*adfb*), 1995

use of the production practices was less seasonal for participating farms compared to nonparticipating farms. This reduced the degree of seasonality in milk production for participating farms relative to nonparticipating farms.

In conclusion, participating and nonparticipating farms behaved differently during the seasonal pricing plan years. Farms participating in the seasonal pricing plan decreased production practice seasonality in response to price premiums, which caused a decrease in production seasonality as compared to their nonparticipating counterparts. Although participating farms showed a preference for the production practices of adjusting entering first lactation animals and number of calves born, they did make adjustments in other practices as well.

The implications for this study are threefold. First, farmers can reduce seasonal production within one year. Second, all farms must participate in the seasonal pricing plan;[8] otherwise, the success of the plan will be in jeopardy depending on the percentage of participants and nonparticipants. Third, if a large percentage of the dairy industry were to implement a seasonal pricing plan at the same time,

[8] A reviewer noted that reducing seasonality would increase (decrease) the blend price in the surplus (deficit) months. Thus, the overall impact on a farm's annual revenue is not known.

there might not be enough first lactation animals entering the herd (*efla*) available to alter seasonal production; however, other production practices are available to alter seasonal production.

While this study provides strong evidence that a seasonal pricing plan can influence production practices and levels of production, the plan examined here was in place for only three years. Consequently, at the time the plan was terminated, farmers were still learning and experimenting with techniques to change production. Implementation of a seasonal pricing plan for a longer period of time could lead to an even greater reduction in seasonality.

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Appendix:
Estimated Amplitudes and Phase Angles for Participating and Nonparticipating Farms

Table A1. Estimated Amplitudes ($\hat{A}$) for Participating and Nonparticipating Farms: 1992(*y*), 1993, 1994, and 1995

Production Factors	YEARS					
(variables)	1992(93)	1992(94)	1992(95)	1993	1994	1995
A. PARTICIPATING FARMS:						
< Proportion Milking (*pm*)	0.07508*** (0.01149)	0.04874*** (0.01129)	0.05450*** (0.01257)	0.04570*** (0.01350)	0.06625*** (0.01432)	0.05990*** (0.01512)
< Entering First Lactation Animals (*efla*)	0.11587* (0.06072)	0.12594** (0.05668)	0.17531*** (0.06635)	0.41114*** (0.04498)	0.27918*** (0.03720)	0.37235*** (0.07428)
< Cows that Left the Herd (*clh*)	0.05745 (0.07183)	0.07774 (0.05359)	0.08045* (0.04680)	0.15055*** (0.03899)	0.24278*** (0.03103)	0.22893*** (0.07539)
< Average Days to First Breeding (*adfb*)	0.08110*** (0.01782)	0.04684*** (0.01467)	0.04404*** (0.01427)	0.05977** (0.02325)	0.04264*** (0.01266)	0.05955** (0.02813)
< Calves Born (*cb*)	0.40300*** (0.05030)	0.41710*** (0.05547)	0.43093*** (0.06370)	0.40500*** (0.03174)	0.35610*** (0.03257)	0.34440*** (0.05047)
< Milk Production per Cow (*mppc*)	0.10250*** (0.00908)	0.10541*** (0.00897)	0.10434*** (0.01023)	0.09522*** (0.00577)	0.12465*** (0.00524)	0.09213*** (0.01047)

continued . . .

Table A1. Continued

Production Factors (variables)	YEARS					
	1992(93)	1992(94)	1992(95)	1993	1994	1995
B. NONPARTICIPATING FARMS:						
< Proportion Milking (*pm*)	0.05351*** (0.01169)	0.07232*** (0.01098)	0.06923*** (0.01045)	0.08619*** (0.01700)	0.09070*** (0.01449)	0.13674 (0.08373)
< Entering First Lactation Animals (*efla*)	0.27560*** (0.07240)	0.24340*** (0.07665)	0.24015*** (0.06524)	0.30352*** (0.05271)	0.44786*** (0.06116)	0.26070*** (0.04227)
< Cows that Left the Herd (*clh*)	0.15301*** (0.04709)	0.10380* (0.06007)	0.10595* (0.06238)	0.12863*** (0.04149)	0.32201*** (0.04676)	0.22782*** (0.06066)
< Average Days to First Breeding (*adfb*)	0.04482*** (0.01580)	0.03008** (0.01386)	0.03471*** (0.01325)	0.01477 (0.02314)	0.05157*** (0.01804)	0.03271 (0.02851)
< Calves Born (*cb*)	0.45010*** (0.05793)	0.43338*** (0.05494)	0.42552*** (0.04640)	0.45829*** (0.05306)	0.54049*** (0.05300)	0.47324*** (0.3280)
< Milk Production per Cow (*mppc*)	0.11312*** (0.01512)	0.11168*** (0.01519)	0.11345*** (0.01498)	0.10680*** (0.01220)	0.12367*** (0.00561)	0.16393*** (0.02310)

Notes: *, **, and *** denote significance of the parameters at α = .10, α = .05, and α = .01, respectively. Statistical significance is based on a Wald statistic with a chi-squared distribution and one degree of freedom. Numbers in parentheses are standard errors.

Table A2. Estimated Phase Angles (Ñ) in Degrees for Participating and Nonparticipating Farms: 1992(*y*), 1993, 1994, and 1995

Production Factors (variables)	YEARS					
	1992(93)	1992(94)	1992(95)	1993	1994	1995
A. PARTICIPATING FARMS:						
< Proportion Milking (*pm*)	16.361** (8.766)	!6.760 (13.275)	!0.015 (13.213)	35.632** (16.918)	15.239 (12.388)	24.671 (17.826)
< Entering First Lactation Animals (*efla*)	28.306 (30.024)	76.234*** (25.784)	87.320*** (21.684)	!10.297 (6.268)	23.864*** (7.635)	30.899*** (11.351)
< Cows that Left the Herd (*clh*)	52.266 (71.635)	77.285* (39.497)	86.505*** (33.332)	27.072* (14.839)	36.783*** (7.323)	62.386*** (15.441)
< Average Days to First Breeding (*adfb*)	9.185 (12.593)	21.476 (17.946)	21.709 (18.570)	!38.015* (22.292)	53.072*** (17.016)	!87.345*** (22.129)
< Calves Born (*cb*)	37.146*** (7.151)	39.619*** (7.620)	44.299*** (8.469)	24.115*** (4.491)	36.049*** (5.240)	27.188*** (8.579)
< Milk Production per Cow (*mppc*)	10.933** (5.075)	11.638** (4.874)	10.668* (5.618)	8.729** (3.473)	!10.795*** (2.410)	15.055* (8.133)
B. NONPARTICIPATING FARMS:						
< Proportion Milking (*pm*)	8.792 (12.514)	20.785** (8.701)	20.956** (8.651)	5.490 (11.304)	16.574* (9.154)	72.844*** (28.109)
< Entering First Lactation Animals (*efla*)	63.779*** (15.051)	47.465*** (18.044)	36.743** (15.566)	45.485*** (9.949)	28.971*** (7.824)	65.800*** (7.525)
< Cows that Left the Herd (*clh*)	66.260*** (17.635)	83.894** (33.159)	75.131** (33.735)	75.509*** (18.480)	44.125*** (8.320)	73.691*** (12.220)
< Average Days to First Breeding (*adfb*)	19.437 (20.200)	23.969 (26.398)	21.014 (21.863)	!17.946 (89.732)	!73.719*** (20.040)	13.280 (56.378)
< Calves Born (*cb*)	43.870*** (7.374)	41.627*** (7.264)	38.383*** (6.247)	47.240*** (6.634)	40.643*** (5.618)	45.426*** (3.548)
< Milk Production per Cow (*mppc*)	19.250** (7.657)	19.185** (7.795)	20.540*** (7.565)	16.312** (6.544)	!5.059* (2.599)	!6.362 (9.492)

Notes: *, **, and *** denote significance of the parameters at α = .10, α = .05, and α = .01, respectively. Statistical significance is based on a Wald statistic with a chi-squared distribution and one degree of freedom. Numbers in parentheses are standard errors.