PRACTICES USED BY DAIRY FARMERS TO REDUCE SEASONAL PRODUCTION VARIABILITY

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Paper Presented at the 1999 AAEA annual meetings
Nashville, Tennessee

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Introduction

Florida milk production varies throughout the year, with production being highest in the spring and lowest in the late summer. There are two primary reasons for this occurrence. First are biological factors that are affected by moderate temperatures in the spring and hot weather in the summer. Second is the farmer's perception of the profitability of spring production. During the cooler months of the year, more milk per cow is produced at lower input cost levels (Kaiser, Otenacu, and Smith). Additionally, the demand for milk also varies seasonally due to school lunch programs and tourism. However, milk consumption tends to be less volatile than production. These yearly patterns of production and consumption result in supply and demand imbalances that require Florida cooperatives to import and export bulk fluid milk during various times of the year.

Correcting the disequilibrium in seasonal supply and demand is the responsibility of Florida cooperatives because of "full supply" contracts with milk processors. Although these contracts benefit individual farmers as well as processors by facilitating the ease of selling and buying milk, cooperatives are faced with the responsibility of importing and exporting milk at a substantial cost (Lawson).

In an attempt to reduce the variability in seasonal production (seasonality), Florida cooperatives implemented a seasonal pricing plan in January 1993. The overall objective of the pricing plan was to provide an incentive for dairy farmers to produce less milk during the surplus months and more during the deficit months. By achieving this objective, the cost associated with importing and exporting milk would be reduced. The seasonal pricing plan was in place from

January 1993 through December 1995. During the early part of 1996, Florida cooperatives voted to do away with the seasonal pricing plan.

During the years the pricing plan was in place it appeared effective only in the short-run with production seasonality decreasing in 1993. However, in 1994 seasonality increased when compared to 1992, and seasonality in 1995 was the same as 1992 (Lawson).

Washington, Lawson and Kilmer (Washington et al.) assessed the effectiveness of the pricing plan on farms that participated in the pricing plan separately from those that did not. Results indicated that of the 68 farms sampled, those farmers that participated in the seasonal pricing plan were able to reduce seasonality in each year (1993-1995) by as much as 20 percent. For those farms that did not participate, seasonality actually increased in each year by as much as 32 percent. Overall, results indicated that the pricing plan was effective for those farms that participated in the plan and that its apparent lack of success was the result of non-participating farmers increasing seasonality.

The purpose of the seasonal pricing plan was to provide an incentive for farms to change factors of production that could affect production seasonality. There are three ways that the seasonal pattern of production could be changed: (1) buy heifers at particular times of the year in order to increase the herd size and increase total production, (2) change the breeding patterns on the farm so that cows freshen at particular times of the year, (3) or change the average production per cow by changing feeding practices, or technology (Lawson).

Given the purpose of the seasonal pricing plan and Washington et al. results, there should be distinct differences in the factors of production described previously between farms that participated in the pricing plan and those that did not, particularly for those factors that directly affect production variability. The purpose of this study is to assess the seasonal changes in factors

that affect the production of milk that resulted from participation in the seasonal pricing plan. The variables considered are (1) proportion of cows milking, (2) total number of first lactation animals entering the herd, (3) total number of cows that left the herd, (4) average number of days to first breeding for cows in the current breeding herd, (5) number of calves born, and (6) production per cow. Seasonal changes in each factor for the years that the pricing plan was in place are assessed and compared to 1992 for farms that did or did not participated in the seasonal pricing plan. Additionally, seasonality changes in each of the factors for participating farms are compared to changes for non-participating farms. Results should indicate that as production seasonality decreased, the seasonal pattern in factor utilization should also decrease and vice versa.

Estimation Procedure

Production factor seasonality estimates for 1992 through 1995 were obtained using a sine function estimation procedure where the degree of seasonality is measured by the amplitude of the sine function. Makridakis, Wheelwright, and McGee suggests the following procedure for estimating a sine function in which the amplitude is estimated is

$$(1) \qquad y_t = A\sin\left[\left(\frac{f\,t}{n}\right)2\pi + \phi\right] + \varepsilon_t$$

where y_t is the dependent variable; A is the amplitude of the sine waved; f is the frequency or number of times the sine wave is completed over the span of observations; t is a time index; n is the number of observations; and ϕ is the phase angle (in radians)[1].

[1] The amplitude A is the height and depth of the sine function where the maximum and minimum values of the sine function are A and -A respectively. The phase angle is the shift of the sine wave from left to right.

Estimating equation (1) is a nonlinear regression problem that is not easily solved directly. However, making use of the trigonometric theorem

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

equation (1) is linearized and becomes

(3) $$y_t = A\cos\phi \sin\left[\left(\frac{ft}{n}\right)2\pi\right] + A\sin\phi \cos\left[\left(\frac{ft}{n}\right)2\pi\right] + \varepsilon_t .$$

By letting $A \cos \phi = \beta_1$ and $A \sin \phi = \beta_2$, equation (3) becomes

(4) $$y_t = \beta_1 \sin\left[\left(\frac{ft}{n}\right)2\pi\right] + \beta_2 \cos\left[\left(\frac{ft}{n}\right)2\pi\right] + \varepsilon_t .$$

Equation 4 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 article are seasonal production indexes that are equal to 1 at the mean. Therefore an intercept term is needed. Hence equation (4) becomes

(5) $$y_t = \beta_0 + \beta_1 \sin\left[\left(\frac{ft}{n}\right)2\pi\right] + \beta_2 \cos\left[\left(\frac{ft}{n}\right)2\pi\right] + \varepsilon_t$$

where A is

(6) $$A = \sqrt{\beta_1^2 + \beta_2^2} .$$

Equation (5) can be estimated using ordinary least squares (OLS), where estimates of A are functions of parameter estimates $\hat{\beta}_1$ and $\hat{\beta}_2$.

To determine if seasonal variability in production factors significantly changed for the years in which the pricing plan was in place, a test using the amplitude was utilized. Given that $\hat{A}$ is a nonlinear function of $\hat{\beta}_1$ and $\hat{\beta}_2$, the estimated standard error of $\hat{A}$ is calculated as describe

by Green (pp. 360-61). The estimated standard error of $\hat{A}$ is equal to the square root of the variance of $\hat{A}$ which is

$$(7) \qquad Var\,[\hat{A}] \approx \left(\frac{\partial \hat{A}}{\partial \hat{\boldsymbol{\beta}}}\right)' Var\,[\hat{\boldsymbol{\beta}}] \left(\frac{\partial \hat{A}}{\partial \hat{\boldsymbol{\beta}}}\right)$$

where the standard error is

$$(8) \qquad SE\,[\hat{A}] = \sqrt{Var\,[\hat{A}]}\,.$$

The $Var[\hat{\boldsymbol{\beta}}]$ is the OLS estimated variance of $\hat{\boldsymbol{\beta}}$, $s^2(\mathbf{X}'\mathbf{X})^{-1}$.

The hypothesis test of interest is:

$$H_o: A_i^y = A_j^y$$

$$H_a : A_i^y \begin{matrix} > \\ < \end{matrix} A_j^y$$

where A_i^y is the amplitude for year y. The above test would determine if the seasonality in year y for ith type farms was significantly different from jth type farms.[2] Other tests of interest are comparing the amplitude estimates for similar type farms but for different years. This would determine if production factor seasonality changed from year to year given a farm's participation or non-participation in the pricing plan. The hypothesis tests of interest involve the comparison of two random variables. Milton and Arnold (pp. 346-52) describe a test procedure for comparing the mean of two random variables when their variances are equal and unequal.

For participating and non-participating farms alike, the amplitude estimates for the years 1993, 1994, and 1995 were each tested for equality with there corresponding amplitude estimates

[2] The subscripts *i* and *j* indicate participation and non-participation in the seasonal pricing plan respectively.

for 1992. Lastly, a statistical test was used to test the equality of amplitude estimates for participating and non-participating farms for each year.

Data

Data was obtained the Florida Dairy Farmers Association, Tampa Independent Dairy Farmers Association, Dairy Head Improvement Association (DHIA), and a survey sent to dairy farmers throughout the state (Lawson). The resulting data set was 68 farms with production and production factor data from January 1992 through October 1995 and pricing plan participation information.

Statistical tests indicate that in 1994 and 1995, farmers in the data set produced more milk on average than the total population of dairy farmers; therefore, population inference may be questionable for these years. However, for 1993 production, average production by the 68 farms was not significantly different from the total population of dairy farmers.

For the years 1992 through 1995, equation (5) was estimated using OLS for farms that participated in the pricing plan and a separate equation for those that did not for each production factor. The index (y) for those years was divided into two categories, participating and non-participating farmers, where (y) was a monthly index of average daily utilization of each of the production factors. The index for 1992 was derived separately for those farmers that did or did not participate in the pricing plan in any of the three years in which it was in place. Examples are production per cow in 1992 by farmers that participated in 1993, production per cow in 1992 by farmers that did not participated in 1993 (1992(93) Table 1), production per cow in 1992 by farmers that participated in 1994, production per cow in 1992 by farmers that did not participated in 1994 (1992(94) Table 1), etc. This was done for the purpose of comparing amplitude estimates

of participating or non-participating farms for the years the pricing plan was in place with amplitude estimates in 1992. This would determine if farmers increased or decreased seasonally in production factor use by participating or not participating in the seasonal pricing plan.

Results and Discussion

Table 1 shows the Amplitude estimates resulting from the estimation procedure for each of the factors that affect production. For the *proportion of cows milking* all of the amplitude estimates are significant at the .01 significance level (Table 1). Although it is not shown, R^2 calculations for these equations ranged from a low of 56 to as high as 83. Of the twelve equations estimated, eight equations had one parameter estimate not different from zero. However, this did not lead to insignificant amplitude estimates.

For the *total number of first lactation animals entering the herd*, estimates for both pricing plan and non-pricing plan farms were all significant at the .10 alpha level (Table 1). However for both type farms the amplitude estimates for the years the pricing plan was in place are all greater than their estimates in 1992, suggesting that this factor became more seasonal for both type farms. A number of these equations had an R^2 lower than .45 and the F-test indicate that the parameter estimates for three equations were jointly insignificant.

Table 1. Amplitude Estimates (A) for Pricing Plan and Non-Pricing Plan Farms

	Pricing Plan Farms *Years*					
Production Factors	1992(93)	1992(94)	1992(95)	1993	1994	1995
Proportion Milking	.07551 (.01149)[a]***	.04874 (.01129)***	.05450 (.01257)***	.04570 (.01350)***	.06625 (.01432)***	.05990 (.01512)***
Entering First Lactation Animals	.11587 (.06072)*	.12594 (.05668)*	.17531 (.06635)*	.41114 (.04498)***	.27918 (.03720)***	.37235 (.07428)***
Cows that left the Herd	.05745 (.07183)	.07774 (.05359)	.08045 (.04680)	.15055 (.03899)***	.24278 (.03103)***	.22893 (.07539)**
Average Days to First Breeding	.08110 (.01782)***	.04684 (.01467)**	.04404 (.01427)**	.05977 (.02325)*	.04264 (.01266)***	.05955 (.02813)*
Calves Born	.40300 (.05030)***	.41710 (.05547)***	.43093 (.06370)***	.40500 (.03174)***	.35610 (.03257)***	.34440 (.05047)***
Production Per Cow	.10250 (.00908)***	.10541 (.00897)***	.10434 (.01023)***	.09522 (.00577)***	.12465 (.00524)***	.09213 (.01047)***
	Non-Pricing Plan Farms					
Proportion Milking	.05351 (.01169)***	.07232 (.01098)***	.06923 (.01045)***	.08619 (.01700)***	.09070 (.01449)***	.06015 (.01433)***
Entering First Lactation Animals	.27560 (.07240)***	.24340 (.07665)**	.24015 (.06524)***	.30352 (.05271)***	.44786 (.06116)***	.26070 (.04227)***
Cows that left the Herd	.15301 (.04709)***	.10380 (.06007)	.10595 (.06238)	.12863 (.04149)**	.32201 (.04676)***	.22782 (.06066)***
Average Days to First Breeding	.04482 (.01580)**	.03008 (.01386)*	.03471 (.01325)**	.01477 (.02314)	.05157 (.01804)**	.03271 (.02851)
Calves Born	.45010 (.05793)***	.43338 (.05494)***	.42552 (.04640)***	.45829 (.05306)***	.54049 (.05300)***	.47324 (.03280)***
Production Per Cow	.11312 (.01512)***	.11168 (.01519)***	.11345 (.01498)***	.10680 (.01220)***	.12367 (.00561)***	.16393 (.02310)***

[a] Standard errors are in parenthesis

*** Parameters are significant at $\alpha = .01$.

** Parameters are significant at $\alpha = .05$.

* Parameters are significant at $\alpha = .10$

Other factors that did not fit the sine function estimation procedure well were the *number of cows that left the herd* and the *average number of days to first breeding*. Tables 1 shows that five of the amplitude estimates for the number of cows that left the herd were not significantly different from zero, indicating little to no seasonal variability in this variable. Although the amplitude estimates for the average days to first breeding are somewhat better, there is no discernable pattern that supports or refutes the hypothesized relationship between production and this factor.

For the remainder of this paper, the *proportion of cows milking*, the *number of calves born*, and *production per cow* will be the only production factors discussed. Amplitude estimates for each of these variables were all significant at the .01 significance level.

Table 2 shows the results of the hypothesis test that the seasonality estimates in 1993, 1994, and 1995 were not significantly different from their corresponding 1992 estimates (1992(93), 1992(94), and 1992(95)). Pricing plan farms results indicate that there was a reduction in the seasonal variability in the *proportion of cows milking* in 1993 when compared to 1992. However seasonality in this factor significantly increased in 1994 and remained about the same in 1995 when compared to 1992. Results from Lawson and Washington et al. indicated that 1994 was an exceptionally seasonal year for both type firms due to the introduction of BST. Therefore a seasonality increase in this factor in 1994 is not surprising. However, Washington et al. found that in 1995 seasonal variability in production was significantly reduced when compared to 1992. This raises questions about the seasonality in the *proportion of cows milking* in 1995 not being significantly different from 1992.

Table 2. Testing the Hypothesis that the Amplitudes in 1993, 1994, and 1995 did not Change Significantly from the Amplitudes in 1992

H_o:	Pricing Plan Farms *t* statistics			Non-Pricing Plan Farms *t* statistics		
	Proportion Milking	*Calves Born*	*Production Per Cow*	*Proportion Milking*	*Calves Born*	*Production Per Cow*
$A^{93} = A^{92(93)}$	-5.742***	0.117	-2.344**	5.486***	0.361	-1.128
$A^{94} = A^{92(94)}$	3.325***	-3.285***	6.413***	3.527***	5.809***	2.564**
$A^{95} = A^{92(95)}$	0.916	-3.477***	-2.759***	-1.716*	2.729***	5.948***

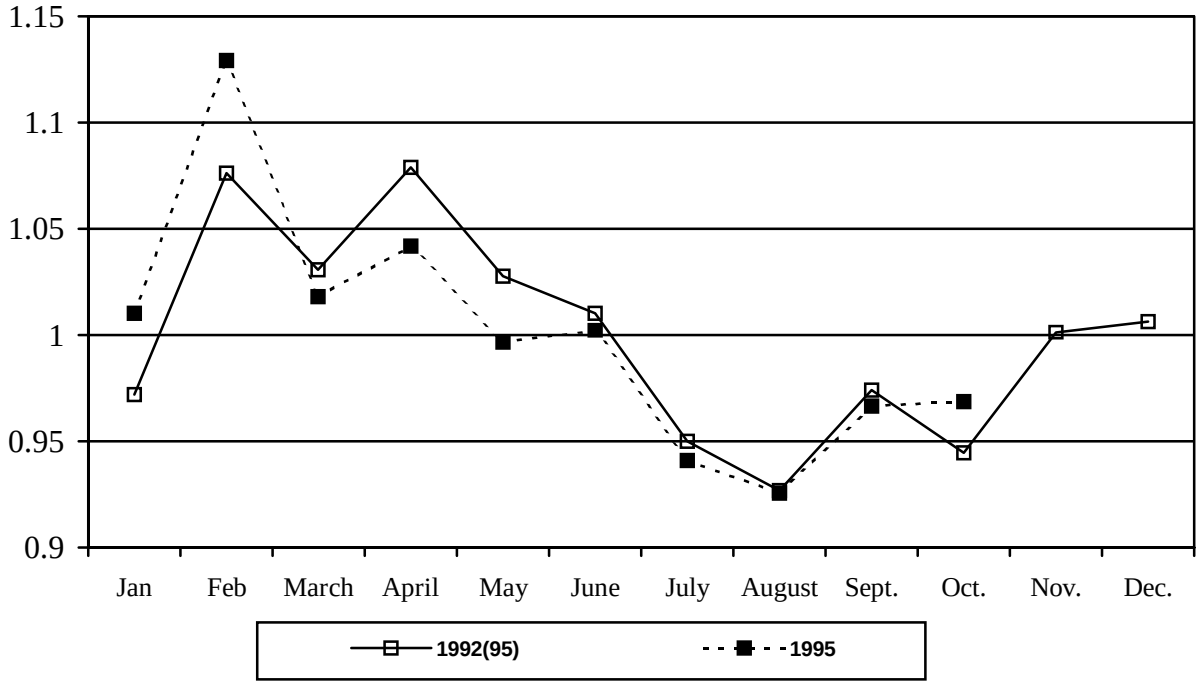
*** Parameters are significant at $\alpha = .01$.
** Parameters are significant at $\alpha = .05$.
* Parameters are significant at $\alpha = .10$

Plots of the actual monthly data for *the proportion of cows milking* (Figure 1) tell a more accurate story of what took place in 1995 for these farms. Although the seasonality estimate indicate that this factor became more seasonal in 1995, Figure 1 shows that during the months where milk surpluses are the highest (March, April, and May), pricing plan farms in 1995 milked a smaller percentage of their total herd in these months when compared to 1992. This suggests that there was an attempt by pricing plan farms to use this factor to reduce production variability in 1995.

Statistical tests also indicate that farmers that participated in the pricing plan in 1994 and 1995 reduced the seasonal variability in the *number of calves born* significantly when compared to 1992 (Table 1). However for farms that participated in the pricing plan in 1993, seasonality for this factor was not significantly different from 1992. One possible reason for this occurrence is

that farms may not have been able to decrease the variability in this factor immediately after the introduction of the pricing plan, but were able to use this factor in the following years.

Figure 1. 1992 and 1995 Monthly Index of Proportion of Cows in Milking for Pricing Plan Farms



When compared to 1992, *production per cow* seasonality estimates for pricing plan farms were significantly smaller in 1993 and 1995, but significantly greater in 1994. As mention, 1994 was an exceptionally seasonal year for both type farms. As mentioned, Lawson and Washington et al. indicated showed that it was the most seasonal year of all the years the pricing plan was in place. However, Washington et al. also indicated that production seasonality in 1994 was still significantly lower when compared to 1992. This raises some questions about the seasonal variability in *production per cow* in 1994 being significantly greater for pricing plan farms.

With the exception of the insignificance difference in seasonality estimates for *calves born* and *production per cow* when comparing 1993 to 1992, non-pricing plan farms increased in seasonality in each year for all factors (Table 2). For the *proportion of cows milking* statistical results indicate that seasonality increased in each year when compare to 1992. This suggests that non-pricing plan farms milked a larger percentage of their herd during the period of excess supply and milked a smaller percentage during the period of excess demand in each of the pricing plan years. In 1993, non-pricing plan farms may not have been able to change the number of calves born or affect the production per cow immediately after the introduction of the pricing plan; however in the following years, seasonal variability significantly increased. Overall, these results support Washington et al. findings that non-pricing plan farms production became more seasonal during the pricing plan years when compare to 1992. Washington et al. also found that production for non-pricing plan farms became more seasonal with each year. The variable that most supports this finding is *production per cow.* The test statistic for this variable became increasingly greater with each year. Percentage changes in amplitude estimates when compared to 1992 indicate a 5 percent reduction in 1993, a 10 percent increase in 1994, and a 44 percent increase in 1995.

Table 3 shows the results of the statistical test equating the seasonality estimates of pricing plan and non-pricing plan farms for the years 1992 through 1995. Farms that participated in the seasonal pricing plan in 1994 and 1995 were significantly less seasonal in the *proportion of cows milking* in 1992 than those farms that did not participate in those years. However, farms that participated in 1993 were significantly more seasonal in 1992 than those that did not participate in the plan that year. During the pricing plan years, in 1993 pricing plan farms become less seasonal in this factor when compare to non-pricing plan farms, which was the direct opposite of what occurred in 1992. Farms that participated in the pricing plan in 1994 remained less seasonal that

those that did not participate that year in term of the percentage of the herd being milked. Although farms that participated in the pricing plan in 1995 were significantly less seasonal than those that did not in 1992, in 1995 there was no significant difference between pricing plan and non-pricing plan farms (Table 3).

With the exception of 1993 participation, the seasonality in the *number of calves born* was not significantly different in 1992 when comparing those farms that participated in the pricing plan in 1994 or 1995 to those that did not. For the years the pricing plan was in place, pricing plan farms in each of the years became less seasonal in this factor than non-pricing plan farms. This indicates that the reduction in seasonality in this factor may be the result of participation in the seasonal pricing plan (Table 3).

With the exception of 1994 participation, farms that participated in the seasonal pricing plan in 1993 and 1995 were significantly less seasonal in *production per cow* in 1992 when compare to those farms that did not participate in those years. Farms that participated in 1994 were not significantly different in 1992 from those that did not participate in 1994. During the pricing plan years farms that participated in the pricing plan remained less seasonal in this factor when compared to those farms that did not participate in 1993 and 1995, and remained not significantly different in 1994. However, in 1993 and 1995 the difference between pricing plan and non-pricing farms became more significant, particularly in 1995 (Table 3). In 1992 the amplitude estimate for farms that participated in 1995 was about 8% smaller than the 1992 estimate for farms that did not participate. However in 1995, the amplitude estimate for farms that participated in the pricing plan was about 45% smaller when compared the amplitude estimate for non-participating farm for that year.

Table 3. Testing the Hypothesis that the Amplitudes are Equal for Pricing Plan and Non-Pricing Plan Farms for the Years 1992, 1993, 1994 and 1995.

	t statistics		
H_o:	*Proportion Milking*	*Calves Born*	*Production Per Cow*
$A_p^{92(93)} = A_{np}^{92(93)}$	4.559***	-2.127**	-2.087**
$A_p^{92(94)} = A_{np}^{92(94)}$	-5.185***	-0.722	-1.230
$A_p^{92(95)} = A_{np}^{92(95)}$	-3.121***	0.238	-1.739**
$A_p^{93} = A_{np}^{93}$	-6.460***	-2.985***	-2.972***
$A_p^{94} = A_{np}^{94}$	-4.156***	-10.268***	0.442
$A_p^{95} = A_{np}^{95}$	-0.038	-6.769***	-8.954***

*** Parameters are significant at $\alpha = .01$.
** Parameters are significant at $\alpha = .05$.

Conclusion

The purpose of this paper was to determine if there were differences in how Florida dairy farms used production factors as a result of participating or not participating in the seasonal pricing plan. As mentioned, Washington et al. indicated that for those farms that participated in the pricing plan, the seasonal variability in production significantly decreased when compared to 1992 by as much as 20 percent and increased by as much as 32 percent for farms that did not participate. He also found that for farms that did not participate in the pricing plan seasonal production variability increased with each year. As follow up, this paper attempted to further prove the point that the seasonal pricing plan was successful in reducing the seasonality in

production for those farms that participated in the plan and that its overall lack of success was the result of nonparticipating farms increasing in seasonality. The latter point of conclusion was adequately proven in this paper. Results indicated that when compared to 1992 farms that did not participated in the seasonal pricing for the most part increased in seasonality in all three factors in all of the years the pricing plan was in place with exception *calves born* and *production per cow* in 1993. This indicates that non-participating farms changed production factors to take advantage of the decrease in production by those farms that were attempting to participate in the plan. Although this point can be argued, it is clear from the results that non-participating become more seasonal in all factors while the pricing plan was in effect.

For farms that participate in the pricing plan results are not as concrete. However, with the exception of 1994, results suggest that pricing plan farms reduced the seasonality in two of the three production factors considered while not changing in the third factor (Table 2). If the hypothesized relationship between the seasonal variability in production and theses factors is correct, then a reduction in the seasonality of two of these factor while the third remained unchanged should lead to a decrease in production seasonality. This would explain the reduction in production seasonality by pricing plan farms in 1993 and 1995. Although BST was introduced in 1994, production seasonality in that year decreased for pricing plan farms; however results indicate that seasonality was only reduced in *calves born* and significantly increased in the *proportion of cows milking* and *production per cow.* Although it can be argues that the effects of *calves born* may have overshadowed the other two factors, this is highly unlikely because

production per cow is the most dominant variable in terms of explaining the variability in production.[3] Why this occurred requires further investigation.

Lastly, farmers that participated in the seasonal pricing plan tended to be less seasonal in production than those that did not participate even prior to the pricing plan; however, the differences between pricing plan and non-pricing farms increased during the pricing plan years (Washington et al.). Results suggest that this occurred with production factors as well, particularly for *calves born* and *production per cow* (Table 3). For the *proportion of cows milking* amplitude estimates for pricing plan farms was significantly smaller than non-pricing plan farms estimates in 1992 with the exception of 1992(93). However for the first year the pricing plan was in place seasonality in this factor was significantly smaller for pricing plan farms when compared to non-pricing plan farms. With each year the difference became less significant with there being no significant difference in 1995. A possible explanation for this occurrence is that the percentage of the total herd being milked can immediately be change while the other factors may require time in order for a change to occur. This is seen in both Table 3 and Table 4 for both type farms. In 1993 when the pricing plan was first introduced, pricing plan farms immediately decreased the seasonal variability in this factor while non-pricing plan farms immediately increased. However, by 1995 the seasonality in the factor was not significantly different for pricing plan farms and only significant at the 10 percent level for non-pricing plan.

Although not overwhelmingly, results of this study further support the effectiveness of the seasonal pricing plan for those farms that participated. This study further showed that Florida Dairy farmer were able to change factors that affect production in order to take advantage of the

[3] Results of regressing production on each of the six production factors considered in this study indicated that *production per cow* explained over 90 percent of the variation in production.

seasonal pricing plan and that farmers that chose not to participate were able to affect factors to increase production seasonality.

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