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The Adoption and Impact of Management Intensive Rotational Grazing (MIRG) on Connecticut Dairy Farms

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Abstract:

Management intensive rotational grazing has garnered a great deal of interest in recent years as a method for returning profitability to Northeastern dairy farms. This work uses a random sample of Connecticut dairy farmers to estimate a binary choice adoption model and then cost, productivity, and profit functions that control for the adoption choice. MIRG adopters are shown to be more educated and have less rented agricultural land (a proxy for lack of access to land within a short distance of the barn). MIRG adoption had no significant effects on costs and productivity, nor did it lower profits, per cow. Evidence was found, however, to suggest that full adopters of the technology had more profitable farms than partial adopters. These results also show the importance of controlling for the different characteristics of adopters when evaluating the returns to animal grazing.

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Introduction:

A centuries old technique, the management of cow grazing, has garnered a great deal of interest in recent years as a method for returning profitability to Northeastern dairy farms. Management intensive rotational grazing (MIRG) incorporates recent advances in the understanding of plant and animal production into an old technology, the management of cow grazing. While most new technologies seek to increase productivity as a means of increasing profits, this one seeks to lower costs per unit of output. Research has shown that MIRG can decrease milk production costs, though generally at the expense of milk production, suggesting that the overall profitability is uncertain.

To date, research on MIRG has concentrated on the productivity and profitability while ignoring the adoption decision farmers make. In addition, many of the current studies have used selected non-representative samples of farmers and have not been able to determine the overall profitability of a farm using MIRG for a full sample of the dairy farm population. This work seeks to go beyond this earlier work by using a random sample of Connecticut dairy farmers to investigate who adopts MIRG and who receives higher farm profits from it. The work estimates a probit binary choice adoption model and then cost, productivity, and profit functions that use predicted values from the adoption choice model to control for the possibility that adoption and cost, productivity, and profit are jointly determined. In other words, adoption decisions may be endogenous to other farm outcomes: the characteristics that influence farmers' decisions to adopt MIRG may also influence cost, productivity, and profit outcomes. In addition, this work estimates the economic returns to different rates of grazing rotations.

A summary of the current literature on grazing sets the context for this work. The econometric estimation methodology is discussed and data description provided. Finally, estimation results of an adoption equation, and cost, production, and profitability equations as well as policy conclusions are presented.

Literature on MIRG:

A growing body of literature has investigated the role modern rotational grazing techniques can play as an alternative to confinement feeding systems. A number of recent simulation studies have demonstrated that from a technical standpoint grazing can be at least as profitable, if not more so, than conventional confinement systems. For example, Elbehri and Ford (1995) did a Monte-Carlo simulation of a Pennsylvania Holstein dairy farm and find lower costs and increased profits from intensive grazing relative to a confinement system. Frank et al. (1996) simulated a whole-farm economic model for different grazing scenarios on typical southwest Wisconsin dairy farms and showed increased profits with grazing.

Other recent studies have used a case study methodology to get a detailed picture of the potential profitability on actual farms. For example, Pillsbury and Burns (1989) looked at Voisin grazing management adoption and daily rotational grazing in a longitudinal study of one Vermont farm and showed lower costs with daily rotation compared to confined feeding and increased benefits with daily rotation compared to extensive grazing. Emmick and Toomer (1991) compared costs before and after intensive pasture adoption on 15 farms in New York to find a reduction of production costs of $153 per cow. Bower-Spence (1995) compared profits from confinement and intensive grazing operation on a single

Pennsylvania farm that switched from one to the other and finds increased profits for grazing.

With an increase in the number of farms using MIRG in many upper-Midwest and Northeastern states, a number of studies report the results of on-farm surveys of farmers adopting grazing. Ford and Hanson (1994) summarized two Pennsylvania studies showing the characteristics of dairy grazier practices that lower feed costs and generate higher profits for grazing farms compared to non-grazers. Jackson-Smith et al. (1996) used two representative surveys to characterize grazing management practices and to analyze economic performance of MIRG users. They showed lower costs for grazers compared to confinement operations, but did not report profitability estimations. The Hanson et al. (1998a) sample of northeastern Pennsylvanian farms showed decreased profits under grazing. Hanson et al. (1998b) combined New York and Pennsylvania dairy farm samples for an empirical analysis that showed lower profit and increased production for extensive grazing and higher profit and increased production for moderately intensive grazing than that for farms that did not graze. Winsten et al. (2000) found decreased productivity, costs, and profits for either extensive or intensive (>75% forage from daily rotation) grazers compared to confinement systems in a sample of Northeastern (PA and VT) dairy farms. However, once other factors had been controlled for, they found that profitability on grazing farms was not significantly different from confinement operations.

This study follows the spirit of the on-farm survey studies. While most of these studies have collected data from a large number of farmers, it is unclear in all but those by Jackson-Smith et al., whether the sample is truly representative of all farmers or just a select few. In addition, while all of these studies have investigated costs and profitability, they do not control for the adoption choices being jointly determined with costs, productivity, and profits. Both the select sample and ignoring that adoption is potentially endogenous to other outcomes will bias the results. In particular, farmers who are most likely to graze should also be those for whom grazing is most likely to increase total farm profits. When comparing profits, one might then overstate the returns to grazing by ignoring this joint determination, or endogeneity. The next section details the econometric procedure used to account for the joint determination of grazing choices.

Methodology:

Using survey data from Connecticut, a model similar to Stefanides and Tauer's 1999 rBST model is used to estimate the effect of MIRG on profits of Connecticut dairy farms. This methodology involves a two step process of estimating the probability that a farmer is a grazier and then using that probability in an estimate of the cost, production, and profit functions. This methodology differs from that used in most of the previous studies on MIRG listed above in that estimates of costs, production, and profits are a function of the farmer's adoption decision. Modeling the joint determination of adoption allows us to control for the fact that the sample of MIRG users is not representative of all farms.

Since the joint determination of adoption is the same for costs, productivity, and profits, we illustrate it only for profits. Assume that profit *(Y)* is a linear function of explanatory variables *(X)* and a MIRG dummy variable *(R)*, so the linear regression equation is:

$$Y = \beta' X + \delta R + e , \qquad (1)$$

where e is a normal random disturbance and R is a 0 or 1 dummy variable for the use of MIRG (R=1 if MIRG is adopted, R=0 otherwise). Note that a farmer's decision to adopt is dependent on many of the same characteristics of farm and farm operator that would also influence profits. Thus, R should be treated as an endogenous, jointly determined variable. An index function (probit) model will be used to estimate the adoption equation:

$$R^* = \gamma' Z + u \qquad (2)$$

where R^* is an unobservable index variable, $\gamma' Z$ is called the index function and Z represents explanatory variables, and u is an error term which $u \sim N(0,1)$. In this case, the observable dummy variable is:

$$R = 1 \quad if \quad R^* > 0 \quad (adopt\ MIRG),$$

$$R = 0 \quad if \quad R^* \leq 0 \quad (not\ adopt\ MIRG).$$

From equation (1) and (2), the expected profit, Y, can be obtained from:

$$(3A) \qquad E[Y] = E[Y/R=1] * prob(R=1) + E[Y/R=0] * prob(R=0)$$

$$(3B) \qquad = \beta' X + \delta \Phi(\gamma' Z)$$

where Φ is cumulative standard normal function. Thus, $\Phi(\gamma' Z)$ serves as the instrumental variable for R in equation (1) to avoid the biases of estimators. Using this framework, the parameters of both the adoption decision and the profit equation are obtained.

In order for $\Phi(\gamma' Z)$ to serve as a valid instrument, we need an exclusion criterion to identify the parameters: some variables that describe the decision to be a grazier that do not influence either costs, productivity, or profits (Greene, 1997, p. 295). The fragmentation of agricultural land in Connecticut and the inability to move cows along roads gives us such a criterion. Only farms with suitable pasture within cow walking distance of their barns can engage in grazing to a serious extent. But this distance between the land base and the barn should have no bearing on the costs, productivity, or profits of farms in general. Thus a reasonable variable to include in *Z* but exclude from *X* would be one that proxies this distance from the barn to the land base.[1]

This work uses this framework to estimate cost, production, and profitability functions with a jointly determined adoption decision. First the adoption equation is estimated, then the predicted probability of adopting is added as a variable in successive estimations of production, cost, and profit equations. [2] [3] In addition, a profitability equation is estimated parameterizing the grazing decision by using the length of grazing rotation as a variable. This last equation is intended to provide some evidence on the profitability of different intensities of rotational grazing.

The Data:

In 1999, the University of Connecticut conducted a survey of dairy farmers in the state. The survey's objectives were to assess the competitiveness of Connecticut dairy farms and the adoption of new technologies including MIRG. All 245 Connecticut dairy farms received a survey, and 124 returned useable information on their dairy farms, representing a 51% response rate.[4] Connecticut dairy farms are relatively small-scale businesses, with more than 60% of farms having less than 100 milk cows. The farmers are

[1] Note that in the increasingly suburban environment of Connecticut the key determinant of getting cows to a pasture is not how far they can walk or how long it takes, but the amount of traffic along the roads that the cows would inevitably have to cross.
[2] Due to significant heteroskedasticity of the error terms, the production, cost, and profit equations were estimated using standard errors corrected with the Huber-White procedure (Greene, 1997, p. 505).
[3] Note that, as suggested by a reviewer, one could estimate the production, cost, and profit equations as a system of equations using for example the seemingly unrelated regression (SUR) framework. Such a framework would be appropriate if the equations had correlated error terms, but estimates of a SUR model with our data showed an insignificant correlation. The Bruesch-Pagan χ^2 test (with 3 degrees of freedom) test of independence of the residuals among the regressed equations = 0.661 with Pr = 0.8822, so we fail to reject the null hypothesis that the residuals of the equations are independent.

on average well educated, productive farmers, with a rolling herd average of 19,800 lbs per cow.

In order to have a definition of being a grazier that is consistent with both practice and the literature, we use one developed by Jackson-Smith et al. A farm is designated as using management intensive rotational grazing if they:

1) rely on pasture for at least part of the forage ration of any milking cows
2) usually move grazing cows to a new paddock at least once a week, and
3) make pasture the primary source of total feed for milking cows during the grazing season.

Using this definition 18% of the sampled farmers were classified as being graziers. A further 20% graze their milking cows to some extent, see Table 1.

The general characteristics and technology differences between MIRG users and non-users are shown in Table 2. Between MIRG adopters and non-adopters, it shows that MIRG users have higher profits on lower productivity and lower costs. These differences are not significantly different at commonly used statistical significance levels (e.g., 1%, 5%, or 10%). Only the number of cows on the farm is statistically different at a five percent level, with MIRG users having on average half the number of cows per farm as non grazers. MIRG users appear to be better educated, with an average level of 2 years of college as compared to one year for non-grazers, although one needs to run the regressions shown below in order to determine whether this is merely an artifact of MIRG users also being younger. MIRG users also are less likely to have freestall housing, although the

[4] An estimate of the sample inclusion probability using a list of all Connecticut dairy farmers and their size, productivity, and location, found no significant parameters.

levels of use of productivity increasing technologies are not statistically different between MIRG users and non-grazers.

Estimations:

Following equation (2) and the literature review, the MIRG adoption equation is hypothesized to have the following form:

(4) $pr(MIRG) = B_0 + B_1\ Owned\ Land + B_2\ Rented\ Land + B_3\ Owner\ Age + B_4\ Owner\ Education + B_5\ \#\ of\ Hires + B_6\ Years\ Farmed.$

As with the adoption of other dairy technologies described in the literature (e.g. Stefanides and Tauer; Foltz and Chang) MIRG adoption is expected to be decreasing in age and increasing in education. The adoption equation uses the acres of owned land, rented land, and how long the family has farmed the land as proxies for how easily a farmer could start grazing. We expect that farms with more owned land, who have farmed the same land for more years, would have more land near their barns and thus would be more likely to graze. We expect the opposite effect with rental land. Since the literature reports many grazers adopting the practice to make use of family labor, adoption probabilities are expected to be decreasing in the number of hired workers.

The production per cow estimation is shown below as equation (5):

(5) $Production/cow = C_0 + C_1\ Farm\ Size\ (cows) + C_2\ Owner\ Age + C_3\ Owner\ Education + C_4\ Technology\ Index + C_5\ pr(MIRG).$

It has variables measuring farm size (the number of cows including dry cows) to control for returns to scale, two proxies for management ability (owner's age and years of formal education, which are weighted by percent ownership in the case of multiple owners), and a general technology measure (the number of the eleven key productivity increasing technologies used on the farm). For the estimations in this study, milk production is defined as average milk production per cow. A last variable, $R*$ from equation (1), measures the MIRG adoption probability. The literature review in the previous section provides conflicting evidence on whether grazing will increase or decrease production per cow. We hypothesize that production per cow will increase in farm size, management ability proxies, and in technology use.

Typically farm costs and profits are estimated as a function of output prices, production levels, and fixed factors (e.g., Chambers). Differences in milk prices within the Connecticut market where a single buyer, Agrimark, purchases most of the milk will primarily be between time periods rather than between farms. In a single year of cross-section data farmers will face very similar input and output prices, and the primary differences between costs and profits across farms can be described as functions of fixed factors, technology adoption, and production choices. The profit and cost equations also include a variable that captures the percent of farm revenues accounted for by milk sales, in order to control for differences between farms which may have other profitable/costly activities and a possible correlation between those activities and being a grazier.

Costs are calculated as total farm expenses per cow including all operating costs and depreciation costs claimed on farmers' taxes while profits are defined on a per cow basis as 1998 total farm receipts (including milk, livestock, crop sales, and all other farm receipts) minus total farm expenses. Note that the cost and profit measures ignore potential changes in inventory, but an analysis of the data on herd size changes on these farms shows no significant relationship between cow inventory changes and the 1998 cost and profit data, suggesting inventory changes do not cause an omitted variable bias to our results. The cost equation estimation is similar to the production equation with the addition of two variables: production per cow and percent of non-milk sales. It has the following form:

(6) $Cost/cow = D_0 + D_1 Production/cow + D_2\ Farm\ Size\ (cows) + D_3\ Owner\ Age + D_4 Owner\ Education + D_5\ Technology\ Index + D_6\ pr(MIRG) + D_7 Pct\ Non\text{-}Milk\ Revenue.$

Following the results reported in the literature (e.g. Stefanides and Tauer; Foltz and Chang) costs are expected to increase in production, age, the percent of non-milk revenues and the technology index; and decrease in education and farm size. The literature on grazing suggests that MIRG should lower costs.

The profit equation shown below in equation (7) will have the same form and variables as the cost equation:

(7) $Profit/cow = E_0 + E_1 Production/cow + E_2\ Farm\ Size\ (cows) + E_3\ Owner\ Age + E_4 Owner\ Education + E_5\ Technology\ Index + E_6\ pr(MIRG) + E_7 Pct\ Non\text{-}Milk\ Revenue.$

Since the average size of Connecticut dairy farms has been increasing for the last decade, we hypothesize that there are increasing returns to scale, so we expect the farm size coefficient (B2) in the profit equation to be positive. Profits are expected to be increasing in management ability and in use of more production increasing technology. The literature provides little guidance on the hypothesized sign for the coefficients on both the percent non-milk revenue and on MIRG.

In addition, because potentially the degree of adoption of MIRG influences farm outcomes, the number of monthly rotations is included in the analysis. Preliminary estimations suggested that the degree of adoption did not significantly influence productivity or cost so only a profit model is presented.[5] A profitability of rotation model is estimated with the following form:

$$(8)\ \textit{Profit/cow} = F_0 + F_1\ \textit{Production/cow} + F_2\ \textit{Farm Size (cows)} + F_3\textit{Owner Age} + F_4\textit{Owner Education} + F_5\ \textit{Technology Index} + F_6\ \textit{Monthly Rotation} + F_7\textit{(Monthly Rotation)}^2 + F_8\ \textit{Pct Non-Milk Revenue.}$$

Following the results of Hanson et. al. (1998), we expect a quadratic relationship between profits and rotation intensity (the most profitable will be either no rotations or high rotations).

Results:

The adoption equation shown in Table 3 demonstrates a number of the hypothesized effects. Farmers with more rented land were less likely to adopt MIRG, probably because of the implied distance from barn to the land. Also farmers with higher education levels were significantly more likely to graze their animals suggesting that education levels were quite important in the management part of rotational grazing.

The production equation, shown in Table 4, has an R^2 of 0.32. Since the coefficient on farm size is not significant, we find no indications of returns to scale in the dairy industry. The technology index has a positive parameter that is significantly different than zero, which may be masking some of the scale effects since larger farms are more likely to adopt new technologies. Surprisingly, given the big, though statistically insignificant differences in average productivity, being a MIRG user has no significant influence on

[5] Results of the productivity and cost estimations using monthly rotation and monthly rotation squared are available from the authors.

productivity. The results suggest very little penalty for being a MIRG user in terms of productivity, when one has controlled for other factors.

Table 5 shows the cost per cow estimates, which produces an R^2 of 0.32 and significant and positive coefficients on production and percent of non-milk revenues. The coefficient on engaging in MIRG is insignificant, though surprisingly positive. One must conclude, as found by Winsten et al., that in the northeast there is not a significant lowering of cost per cow by using MIRG, when one controls for other factors.

Given the insignificant effects of MIRG on both costs and milk per cow productivity, one would expect the same result for profits. Table 6 shows the profit function estimates, which estimate with an R^2 of 0.18. They show that more profitable farms are those with more non-milk revenues and have younger owners. They also show that greater technology use, despite the increases in productivity it yields, produces significantly lower profits. The results on MIRG show no significant effects of being a grazer on overall farm profits.

In order to better specify the effects of grazing on profits, Table 7 reports the relationship between profits and the intensity of rotation as measured by the number of times per month the cows change pastures. Though they are not significant, the results look similar to those using the predict probability, pr(MIRG), with lower profits for MIRG users. There is a suggestion from the quadratic term in these results that farms engaging in grazing but rotating their pasture slowly, have lower profits than either those who do not use rotational grazing at all or those who rotate their cows faster between pastures. These results differ from Hanson et.al. (1998) in that while management intensive rotational grazing is not found to significantly influence milk production, the quadratic form of the influence of increased grazing rotation on total farm profits is significant. This result has important policy implications for extension agents working with potential grazers. The results suggest that profitability from grazing can be found for those who have a rapid rotation of their cows, but that farmers who dabble in grazing may not be improving their bottom line.

Conclusion:

This work has estimated econometric models to show the adoption probabilities and effects on costs, productivity, and profits of Connecticut dairy farms using management intensive rotational grazing. MIRG adopters are shown to have more education and less rented agricultural land (a proxy for lack of access to land within a short distance of the barn). MIRG adoption had no significant effects on costs, productivity, or profits. Evidence was found, however, to suggest that full adopters of the technology had more profitable farms than partial adopters. This finding supports the Hanson et al. (1998) conclusion that farms that employ more intensive rotational grazing practices can have higher returns than forms that use extensive grazing. Equally importantly, non-grazing technology adoption raised costs and production while lowering profits significantly for all types of farms.

Given the difficulty in finding land that is easily accessible to barns in Connecticut, there would seem to be little room for expansion of rotational grazing. The significant negative relationship between rented land as a component of total farmland, a proxy for ease of cow movement, on MIRG adoption suggests such a limit to grazing expansion.

The results do suggest that MIRG technology may be a viable option for some Connecticut dairy farmers, and that it is most profitable with full adoption.. This suggests that extension efforts on grazing might be best directed toward increasing the profitability of those who are currently grazing their animals. With the small average size of grazing farms in Connecticut, an extension effort on increasing MIRG profitability may be one of the better methods to reach the smallest dairy farms and help keep them in business.

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Table 1
Rotation Intensity Categories

Rotation intensity categories

Method 1: 6 categories

Category	Number of rotations per month	% of survey in category
7	0	61.3%
6	0 < > 4	17.7%
5	4	2.4%
4	4 < > 7.5	3.2%
3	10 < > 15	5.7%
2	30	5.7%
1	60	4.0%

Method 2: 3 categories

Category	Number of rotations per month	% of survey in category
None	0	61.3%
Slow	0 < > =4	20.1%
Fast	> 4	18.6%

Table 2
Farm Characteristics

Averages	MIRG users	MIRG non-users
	18.3%	81.7%
Profit per cow	$458.75	$369.01
Production (lbs.) per cow	17,636	20,190
Costs per cow	$2,340.83	$2,737.25
Number of cows**	69.8	144.7
Owner's age (years)	47.9	52.4
Owner's education* (years)	14.0	12.9
Technology use index	6.47	7.49
Use freestall housing for the milking herd*	56.3%	76.9%

Significance levels: * implies 10%, ** 5%, and *** 1%.

Table 3
Adoption Probability Probit Model
log likelihood = -44.443077
Observations = 121

Pr(MIRG)

Variable	Coefficient	standard error
Owned land	-0.000843	0.0013721
Rented land**	-0.0030913	0.0015337
Age	-0.0116459	0.0152558
Education**	0.2033975	0.0842516
Number of hires	-0.0131597	0.0785434
Years farmed	0.0018728	0.0021344
Constant**	-2.819935	1.414532

Significance levels: * implies 10%, ** 5%, and *** 1%.
Percent predicted correctly: 85%

Table 4
Production Equation
$R^2 = 0.32$
Observations = 101

Production/cow (1,000 lbs.):

Variable	Coefficient	standard error
Farm Size (cows)	0.0058659	0.0055775
Age	0.0437567	0.0347566
Education	0.1427541	0.1603475
Technology Index***	0.6237582	0.1576792
Pr(MIRG)	0.8214412	3.168248
Constant***	9.995329	2.854259

Significance levels: * implies 10%, ** 5%, and *** 1%.

Table 5
Cost Equation
$R^2 = 0.32$
Observations = 81

Cost/cow ($):

Variable	Coefficient	standard error
Production per cow***	90.20284	31.35843
Farm Size (cows)	-0.6813033	1.554239
Age	2.032988	9.406923
Education	-10.98245	52.08137
Technology Index	68.03312	49.76473
Pr(MIRG)	619.965	917.7132
% Non-milk revenue*	3110.095	1880.595
Constant	38.23531	522.9367

Significance levels: * implies 10%, ** 5%, and *** 1%.

Table 6
Profit Equation
$R^2 = 0.18$
Observations = 81

Profit/cow ($):

Variable	Coefficient	standard error
Production per cow	13.72707	15.02282
Farm Size (cows)	0.1960464	0.415381
Age**	-7.790699	3.759303
Education	14.12211	21.97333
Technology Index**	-66.32693	25.5455
Pr(MIRG)	71.87377	504.004
% Non-milk revenue**	585.4505	254.1119
Constant**	756.917	327.7958

Significance levels: * implies 10%, ** 5%, and *** 1%.

Table 7
Profit Equation
$R^2 = 0.20$
Observations = 81

Profit/cow ($):

Variable	Coefficient	standard error
Production per cow	11.92145	15.26732
Farm Size (cows)	0.051359	0.04004051
Age	-6.611251	3.933221
Education	19.48925	18.1842
Technology Index***	-71.23166	24.96188
Monthly Rotation	-13.89002	8.499295
$(\text{Monthly Rotation})^2$ **	0.3122173	.1507565
% Non-milk revenue**	606.8594	269.5364
Constant**	735.262	379.4357

Significance levels: * implies 10%, ** 5%, and *** 1%.