Measuring the Risks of New York Dairy Producers

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Abstract

Decomposition methods suggest major contributors to variability in returns to New York dairy farms are purchased feed quantities and milk production; milk price variability contributes substantially less. Decomposing the Gini measure of income inequality indicates that milk revenues and purchased feed expenditures contribute most to farm return inequality over time.

Key Words (variance decomposition, Gini income inequality, dairy farm net returns)

Measuring the Risks of New York Dairy Producers

Recent policy changes in the Federal Agriculture Improvement and Reform Act of 1996 will lead to more market-oriented agricultural production, but may present a riskier environment for U.S. agricultural producers. Dairy production, where farmers historically have been sheltered from extreme market price fluctuations by government purchases of excess production and by Federal Milk Marketing Orders, is a prime example. Provisions in the 1996 Farm Bill, along with the potential changes and/or elimination of marketing orders, could leave dairy producers with little price or income protection through government programs.

The objectives of this paper are to measure the relative significance of the various sources of risk dairy farmers in New York State faced during the past 10 years, and to isolate individual farm characteristics which contribute to these components of risk. Emphasis is focused on identifying the relative contributions of both price and production risk on the variability of dairy farm net returns. Output and input prices may contribute importantly to overall risk, as can variability in milk production and yields for crops used as dairy feed.

Procedure

Two methods are used: the variance in net returns by farm is decomposed, as is the Gini measure of inequality. Both measures of variability are consistent with risk aversion, but provide different perspectives on the relative importance of the sources of risk. While calculation of Gini measures of inequality across firms or households is common in the literature, it has not been used frequently to compare inequality across time for individual producers.

The variance decomposition procedure begins by estimating the variability of net farm income (NFI), including off-farm income, and then isolating the important contributing price and production components. Define NFI and its variance for M outputs and N inputs as:

$$\text{(1)} \quad \text{NFI}(\mathbf{p}, \mathbf{q}, \mathbf{c}, \mathbf{x}) = \sum_{i=1}^{M} p_i q_i - \sum_{j=1}^{N} c_j x_j \quad \text{and}$$

$$\text{(2)} \quad \text{Var}(\text{NFI}) = s^{2}_{\text{NFI}} = \sum_{i=1}^{M} s^{2}_{z_i} + \sum_{j=1}^{N} s^{2}_{y_j} + 2\sum_{i=1}^{M-1}\sum_{k=1}^{M} s_{z_i,z_k} + 2\sum_{j=1}^{N-1}\sum_{l=1}^{N} s_{y_j,y_l} - 2\sum_{i=1}^{M}\sum_{j=1}^{N} s_{z_i,y_j},$$

where $z_i=p_iq_i$, $y_j=c_jx_j$, $i<k$, and $j<l$. If all components of (1) are assumed random, the decomposition of the variance (2) involves variances and covariances among all components and a number of higher-order terms (Bohrnstedt and Goldberger, 1969), but as Burt and Finley (1968) and Boisvert and Bills (1984) point out, a linear approximation is:

$$\begin{aligned}
\text{(3)} \quad \sigma^2_{\text{NFI}} = {} & \sum_{i=1}^{M}\left[E^2(q_i)\sigma^2_{p_i} + E^2(p_i)\sigma^2_{q_i}\right] + \sum_{j=1}^{N}\left[E^2(x_j)\sigma^2_{c_j} + E^2(c_j)\sigma^2_{x_j}\right] \\
& + 2\left[\sum_{i=1}^{M} E(p_i)E(q_i)\sigma_{p_i,q_i} + \sum_{j=1}^{N} E(c_j)E(x_j)\sigma_{c_j,x_j}\right] \\
& + 2\left[\sum_{i=1}^{M-1}\sum_{k=2}^{M}\left(E(q_i)E(q_k)\sigma_{p_i,p_k} + E(q_i)E(p_k)\sigma_{p_i,q_k} + E(p_i)E(q_k)\sigma_{q_i,p_k} + E(p_i)E(p_k)\sigma_{q_i,q_k}\right)\right] \\
& + 2\left[\sum_{j=1}^{N-1}\sum_{l=2}^{N}\left(E(x_j)E(x_l)\sigma_{c_j,c_l} + E(x_j)E(c_l)\sigma_{c_j,x_l} + E(c_j)E(x_l)\sigma_{x_j,c_l} + E(c_j)E(c_l)\sigma_{x_j,x_l}\right)\right] \\
& - 2\left[\sum_{i=1}^{M}\sum_{l=2}^{N}\left(E(q_i)E(x_j)\sigma_{p_i,c_j} + E(q_i)E(c_j)\sigma_{p_i,x_j} + E(p_i)E(x_j)\sigma_{q_i,c_j} + E(p_i)E(c_j)\sigma_{q_i,x_j}\right)\right] \\
& + \sum_{i=1}^{M} RM_{z_i} + \sum_{j=1}^{N} RM_{y_j} + 2\sum_{i=1}^{M-1}\sum_{k=2}^{M} RM_{z_i,z_k} + 2\sum_{j=1}^{N-1}\sum_{l=2}^{N} RM_{y_j,y_l} - 2\sum_{i=1}^{M}\sum_{j=2}^{N} RM_{z_i,y_j},
\end{aligned}$$

where $i<k$, $j<l$, E is the expectation operator, and the σ's are the respective variances and covariances among components. The first line of (3) gives the direct contributions of q_i, p_i, c_j, and x_j, to the variance in net farm income. The next four lines are the first-order interaction effects, while the remainders (RM) include higher-order effects. If these remainders are small, the other terms approximate the variance

decomposition and we can normalize on the total direct contribution to examine the proportions of variability directly attributable to the price and quantity components.

The variation in net returns is also studied using Gini's mean difference, which when used as a measure of risk and combined with the mean provides necessary conditions for second-degree stochastic dominance. Lerman and Yitzhaki (1985) demonstrate that the Gini coefficient can also be derived directly from the formula for Gini's mean difference (A). The Gini ratio (G) is then formed by dividing A by mean income, m_s. Letting $s_1,\ldots,s_K$ be the $K=M+N$ components of net farm income, NFI $= s = \sum_k s_k$, one can use the properties of the covariance of the sum of random variables (Mood *et al*., 1974) to write:

(4) $$A = 2\sum_k \text{cov}[s_k, F(s)],$$

where $F(s)$ is the cumulative distribution of s. Dividing (4) by m_s and multiplying and dividing each component by cov[s_k, $F(s_k)$] and m_k yields the Gini decomposition of net income:

(5) $$G = \sum_k \left[\text{cov}[s_k, F(s)]/\text{cov}[s_k, F(s_k)]\right] \bullet \left[2\,\text{cov}[s_k, F(s_k)]/m_k\right] \bullet \left[m_k/m_s\right] = \sum_k R_k G_k S_k,$$

where R_k is the correlation between s_k and the cumulative distribution of s, G_k is the Gini for s_k, and S_k is s_k's share of s.

To determine the change in inequality due to a marginal change in s_k, Lerman and Yitzhaki (1985) consider a change in income from source k equal to $e_k s_k$, where e_k is close to 1. Then, as proven by Stark *et al*. (1986), the partial derivative of (5) with respect to e_k is:

(6) $\partial G/\partial e_k = S_k(R_k G_k - G)$, and in elasticity terms:

(7) $$[\partial G/\partial e_k]/G = [S_k G_k R_k/G] - S_k.$$

Proportional changes in all sources leave inequality unaffected, so elasticities in (7) sum to zero.

Decomposition Results

Data are from 62 consistent participants in the New York Dairy Farm Business Summary over the past 10 years, and include a wide range of herd sizes, from under 30 to over 2,500 cows. Six sources of income and expenses are identified for decomposition: milk sales, cull cow sales, off-farm income, and expenses for paid labor and purchased and grown feed. The six sources identified here constitute the major components of NFI and its resulting variability. Farm revenue sources were deflated by the U.S. Farm Prices Received Index (1992=100), while farm expenses were deflated by the U.S. Farm Prices Paid Index (1992=100), and off-farm income by the U.S. CPI (1992=100). For the sample farms, net farm returns averaged over $1,200 per cow over the past 10 years, with a standard deviation of $338 (Table 1).

Variance Decomposition Linear approximation of the variance decomposition was relatively accurate, with an average absolute error across all farms of under 14%.[1] Nearly half of the farm decompositions resulted in absolute errors of under 10%, and just under 90% had errors of under 25%. Averaged across all farms, variability in purchased feed quantities per cow accounted for 30% of the variability in net returns per cow, followed closely by milk quantity per cow at 26% (Table 2). However, for some farms these effects were as low as 7% or as high as 65%. Milk price contributed only 12% to overall variability, while purchased feed prices accounted for only 9%. Surprisingly, labor prices and quantities contributed relatively little to the direct variance effects, only 3% and 5%, respectively.

[1] The absolute error measured for each farm is determined by dividing the absolute value of the difference between the approximation and the true variance by the true variance.

While most component covariance effects were small, there are notable exceptions.[2] The positive covariance between milk price and purchased feed price was 7% of total direct effects, while the negative covariances between purchased feed quantity and milk price, milk quantity, and cull cow quantity were 14, 20, and 20% of total direct effects, respectively.

Decomposition of the Gini Measure of Inequality While the variance decomposition above estimates contributions of individual price and production components to net return variability, the decomposition of the Gini measure of inequality for each of the 62 farms over the 10-year sample period may be more informative for policy to reduce farm return inequality. Through the elasticities of inequality by source, one can easily determine the effect of changes in these sources on net return inequality.

From the individual Gini's it is evident that the sources are generally more unequally distributed than is net income itself (Table 3). For example, the average measure of inequality (G_k) for milk receipts was nearly 50% lower than for net income, while the Gini for off-farm income was over 500% higher. Purchased feed expenditures were distributed fairly similarly to net income, while grown feed and labor expenditures were much more unequally distributed. It is only the milk income inequality measure that was consistently below that of the Gini for net income.

The Gini inequality proportions and elasticities depend additionally on the rank correlations of total income and income shares. Not surprisingly, given its large income share relative to the other components, milk receipts explain, on average, 60% of the inequality in net farm returns; cull cow sales (14%) and purchased feed expenditures (10%) are distant seconds indeed. However, these average levels across farms can be misleading. The proportions over all sources must sum to one, but they may

[2] Covariance effects and proportions are not reported here but are available from the authors.

be positive or negative. From the ranges in Table 3, we see that there were farms in the sample for which inequality proportions on any of the components are indeed negative, albeit relatively small.

The final section of Table 3 includes the elasticity of total inequality by source and the number of farms where the elasticities are positive (i.e., increasing total income inequality). With the exception of cull cow sales and off-farm income, the elasticities are of the same sign for nearly all farms. Given the variance decomposition measures in the previous section, we would expect that milk income and purchased feed expenditure variability are major determinants of net income inequality, and indeed this is the case. On average, a 1% increase in milk sales per cow each year would result in nearly a 1.4% reduction in total income inequality. While the magnitude of this elasticity varied considerably, the elasticity was consistently negative for all farms in the sample. These numbers may be of particular interest for supporters of the Northeast Dairy Compact in New York who argue that the Compact will increase producer returns; the results here indicate that an increase in milk revenues would also contribute to stability in net farm returns over time.

Most milk inequality elasticities are below -1, while cull cow elasticities are distributed more uniformly around zero on the interval of [-1, 1], and off-farm income weighs more heavily on [0, 1]. For 29 of the 62 farms, the elasticity of cull cow sales is positive; while 40 farms have positive off-farm income inequality estimates (i.e. for most farms off-farm income contributed to total farm return inequality). This result is somewhat counterintuitive: off-farm income is generally thought to stabilize overall household income. However, this information has only been collected on a consistent basis relatively recently, and it is difficult to know if the data reflect all off-farm income. It most certainly does not include benefits associated with off-farm employment.

All expense source elasticities of inequality, on average, are positive, led by purchased feed expenditures at 0.73, and followed by grown feed costs (0.33) and labor expenses (0.29). While there is a small number of farms where these expenses reduce income inequality at the margin, over 90% of the farm elasticities are positive, and for feed expenditures are often above one. Thus, it is clear that farms that rely heavily on purchased feeds will be more adversely affected during times of volatile market prices for roughages and grain than those farms where a higher proportion of grown crops is fed.

Regression Analysis on Gini Elasticity Estimates

While the average statistics reported in Table 3 provide meaningful insights into income inequality effects of potential policy programs, the distribution of these effects across farms is also important. Though milk elasticity estimates are consistently negative and nearly all purchased feed expenditure elasticities are positive, the range in both elasticities across farms is large. Below we determine if there is any systematic variation in these measures by regressing Gini source elasticities on farm and operator characteristics.

Independent variables hypothesized to affect elasticity measures include: milking system (parlor=1, other=0), milking frequency (3X=1, other=0), BST use (yes=1, no=0), education of lead operator (college=1, other=0), average cow numbers, age of lead operator, cows per worker, and crop acres per cow.[3] An Iterative Seemingly Unrelated Regression (ITSUR) is used to account for correlation of the errors across equations. *A priori* exclusion restrictions are placed on certain equations and allow for an efficiency gain in estimation relative to ordinary least squares (Table 4). Since

[3] The values of the dummy variables for milking system, milking frequency, and college education are based on the last year of data. BST=1 indicates BST use within the last four years, the years for which it was coded in the data. All other continuous variables represent farm sample averages.

the six Gini source elasticities must sum to zero, we drop one equation to avoid singularity in the regressor matrix with no loss of information. Since ITSUR is invariant to which equation is dropped, we drop the "least interesting" cull cow equation. Since all parameters (including the intercept) must sum to zero across equations, the parameter estimates for the omitted equation can easily be derived.

A linear model is estimated with modest success (Table 4).[4] Overall, there seems to be no real consistent systematic effect of farm characteristics on these Gini source elasticities. While the overall explanation of the variation in elasticities is relatively low (R-squares around 0.2), certain significant coefficient estimates are of some interest. Parlor milking systems tend to be related to smaller milk inequality elasticities, while they are associated with higher labor inequality elasticities. Milking frequency has little effect on elasticity measures, with the exception of the elasticities for grown feed expenditures. Here there is a positive relationship (i.e., increase in inequality) with three-times-a-day milking. While BST use was hypothesized to affect all farm elasticity measures, none of the coefficients were statistically different from zero. A college education reduced inequality elasticities for off-farm income, which seems reasonable, and also reduced labor expense elasticities as well. On the other hand, it is somewhat surprising that a college education raises the inequality elasticity for milk income. However, in a regression not reported here, a college education was directly related to 10-year mean farm returns. It could be that while investment in human capital leads to more volatile returns, it also leads to a substantial shift to the right in the distribution as well.

The elasticity estimates also appear invariant to farm size, since average herd size had no significant effect on elasticities in any equation. In addition, operator age was significant in only two equations: milk (negative) and purchased feed expenditures (positive). The numbers of cows per worker reduces the off-farm income elasticities, but in no other equation were the coefficients on this variable statistically different from zero. Finally, crop acres per cow does not seem to affect off-farm income or labor inequality elasticities, but significant coefficient estimates, although opposite in sign, do exist for the purchased and grown feed expenditure equations. It makes sense that grown feed inequality elasticities would increase with the number of crop acres, whereas the elasticity of its purchased feed counterpart would fall.

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[4] Alternative functional forms were evaluated (quadratic, and semi-log), with little or no gain from the linear estimates provided here. Signs and significance of coefficients were generally consistent across specifications.

Conclusions

By decomposing the variance of six major sources of revenue and expenses into their price and quantity components we have shown that variability in net farm returns per cow for New York dairy farms can be attributed largely to variation in purchased feed quantities and milk production. Milk and purchased feed prices also contribute to net return variability, albeit the effects are nearly two orders of magnitude smaller than the effects of the corresponding quantities. While current concern over farm income variability is heightened with more market-oriented pricing policies, the results here suggest farmers may be able to compensate for this additional price risk through management practices, etc. to control the variability in milk production and feed purchases per cow. It is difficult to know if variability in prices will eventually replace variability in production and feed efficiency as the dominant factor in net farm income variability.

The decomposition of the Gini measure of net return inequality tells a similar story. In that decomposition, however, we lose the ability to isolate the separate effects of price and quantity, but we can determine the effects of changes in these sources on overall income inequality. Decomposition of the Gini measure of income inequality across time suggests that milk revenues and purchased feed expenditures have the most substantial effects on net farm return inequality, although the effects are opposite in sign. Policy programs or risk management strategies aimed at increasing milk revenues or reducing purchased feed expenditures would contribute most to reducing net farm return inequality over time.

In trying to isolate any systematic effects of farm characteristics on the elasticity of inequality by income source, there seem to be no clear patterns. These rather inconclusive results may be because this sample of New York farms is fairly homogeneous. Additional analysis with farms from across the country (e.g., Wisconsin, Florida, and California) may provide sufficient variation to identify more clearly the effect of farm characteristics on the elasticities of net income inequality by source.

Table 1. Farm Descriptive Statistics Per Cow[a]

Variable	Units	Mean	Std. Dev.	Minimum	Maximum
Net Returns[1]	$/cow	1,215.87	337.93	304.40	2,193.70
Net Return Components:					
Milk Sales	$/cow	2,322.48	371.70	1,398.77	3,369.85
Milk Quantity	cwt/cow	173.87	26.63	106.14	249.99
Milk Price	$/cwt	13.36	0.73	11.25	16.35
Cull Cow Sales	$/cow	150.27	83.61	7.44	1,156.75
Cull Quantity	cwt/cow	3.69	2.25	0.28	43.48
Cull Price[2]	$/cwt	40.55	6.91	26.61	47.00
Off-farm Income[3]	$/cow	38.93	88.01	0.00	755.50
Labor Expenses	$/cow	257.25	196.08	0.00	705.49
Labor Quantity	months/cow	0.16	0.10	0.00	0.44
Labor Price[4]	$/month	1,518.54	687.42	34.50	6,742.74
Purchased Feed Expenses	$/cow	717.92	214.67	108.02	1,652.13
Purchased Feed Quantity	ton/cow	7.53	2.56	1.26	19.82
Purchased Feed Price[5]	$/ton	97.22	12.11	81.33	126.15
Grown Feed Expenses[3, 6]	$/cow	320.64	124.09	6.40	957.29
Farm Characteristics					
Average Cow Number	head	177.55	303.54	26.00	2,658.00
Cows Per Worker	head/worker	32.78	9.26	10.00	69.00
Crop Acres Per Cow	acres/cow	3.08	1.16	1.04	10.24
Operator Age	years	45.79	9.38	26.00	71.00
Operator Education	College = 1	0.60	0.49	0.00	1.00
Barn Type	Parlor = 1	0.50	0.50	0.00	1.00
Milking Frequency	3X = 1	0.22	0.42	0.00	1.00
BST Use within last 4 years	Yes = 1	0.20	0.40	0.00	1.00

[a] Source: New York Dairy Farm Business Summary, 1988-1997, N=62 farms.

[1] Net returns per cow were calculated as the sum of milk, cull cow, and off-farm income less the sum of labor, purchased feed, and grown feed expenditures. Farm sources are deflated by the U.S. Farm Prices Received and Prices Paid Indecies (1992=100), respectively. Off-farm income is deflated by the U.S. Consumer Price Index (1992=100).

[2] New York average market price.

[3] Nominal price equal to unity.

[4] Implicit price, labor expenses divided by paid labor months.

[5] Weighted average corn grain and alfalfa New York market price.

[6] Grown crop expenses less crop sales.

Table 2. Direct effect variance proportions, averaged across all individual farm decompositions.[1]

Variable	Mean	Std Dev	Minimum	Maximum	CV[2]
<u>Revenue Components</u>					
Prices:					
Milk	0.1230	0.0504	0.0293	0.2241	40.95
Cull Cow	0.0077	0.0045	0.0017	0.0243	58.22
Quantities:					
Milk	0.2589	0.1263	0.0834	0.6582	48.76
Cull Cow	0.0356	0.0805	0.0025	0.5826	226.18
Off-Farm	0.0289	0.0762	0.0000	0.5327	264.01
<u>Expense Components</u>					
Prices:					
Labor	0.0326	0.0327	0.0000	0.1532	100.06
Purch. Feed	0.0942	0.0429	0.0158	0.2386	45.55
Quantities:					
Labor	0.0514	0.0564	0.0000	0.2894	109.75
Purch. Feed	0.2967	0.1425	0.0660	0.6148	48.04
Grown Feed	0.0636	0.0506	0.0056	0.2415	79.60

[1] Since a nominal price=1 for off-farm income and grown feed expenditures was assumed, the proportions are excluded here.
[2] CV = Coefficient of Variation

Table 3. Average rank correlations, income shares, Gini ratios, and elasticities of inequality by source.[1]

Source	Correlation with Rank of Total Income [R_k]	Income Share [S_k]	Gini of Source [G_k]	Share of Inequality Proportion	Elasticity of Total Inequality Mean	Elasticity of Total Inequality No. Positive
Milk Income	0.535 [-0.49, 0.95]	1.984 [1.34, 3.56]	0.044 [0.02, 0.09]	0.602 [-0.28, 1.50]	-1.382 [-2.87, -0.58]	0
Cull Cow Sales	0.404 [-0.56, 0.98]	0.128 [0.06, 0.26]	0.202 [0.08, 0.45]	0.139 [-0.20, 0.86]	0.011 [-0.33, 0.67]	29
Off-farm Income	0.060 [-1.00, 0.95]	0.031 [0.00, 0.25]	0.551 [0.05, 0.90]	0.047 [-0.14, 0.80]	0.016 [-0.17, 0.61]	40
Labor Expenses[2]	0.139 [-0.87, 0.89]	-0.232 [-0.73, -0.01]	-0.253 [-0.84, -0.03]	0.062 [-0.57, 0.59]	0.294 [-0.27, 0.87]	57
Purchased Feed Expenses[2]	0.125 [-0.64, 0.78]	-0.632 [-1.58, -0.19]	-0.097 [-0.27, -0.04]	0.100 [-0.60, 0.92]	0.732 [-0.08, 1.91]	60
Grown Feed Expenses[2]	0.057 [-0.94, 0.90]	-0.280 [-0.65, -0.07]	-0.127 [-0.27, -0.05]	0.049 [-0.46, 0.88]	0.329 [-0.21, 1.23]	58
Total			0.083 [0.04, 0.19]			

[1] The Gini decomposition was completed with a FORTRAN program adapted from Boisvert and Ranney (1991). Ranges of all components across individual farms are listed in brackets.
[2] The Gini's are negative because these source expenses are negative in the net return calculations.

Table 4. Iterative Seemingly Unrelated Regression Results on Gini Inequality Elasticities, Linear Model

	Parameter Estimates, Standard Errors in Parentheses[1]									
Regressor	Milk Income		Off-farm Income		Labor Expense		Purchased Feed Expense		Grown Feed Expense	
Intercept	-0.9159	*	0.3672	**	0.4947		0.2000		-0.2348	
	(0.4612)		(0.1472)		(0.3100)		(0.4015)		(0.3027)	
Milking System	-0.1836	**			0.1630	**				
	(0.0732)				(0.0722)					
Milking Frequency	-0.2854		0.0500		0.0441		0.0967		0.2290	**
	(0.1986)		(0.0423)		(0.0996)		(0.1527)		(0.1016)	
BST Use	0.0148				0.0222		0.0310		-0.0845	
	(0.1550)				(0.0710)		(0.1200)		(0.0790)	
Education	0.1932	**	-0.0673	**	-0.1593	**				
	(0.0764)		(0.0331)		(0.0715)					
Average Cow No.	0.0000		0.0001		0.0002		-0.0001		-0.0001	
	(0.0003)		(0.0001)		(0.0001)		(0.0002)		(0.0002)	
Operator Age	-0.0162	*	-0.0020		-0.0006		0.0150	**	0.0066	
	(0.0086)		(0.0019)		(0.0041)		(0.0068)		(0.0045)	
Cows Per Worker	0.0113		-0.0081	**	-0.0054		0.0009		0.0002	
	(0.0120)		(0.0027)		(0.0059)		(0.0093)		(0.0061)	
Crop Acres Per Cow			0.0050		-0.0152		-0.0782	**	0.0808	**
			(0.0169)		(0.0349)		(0.0370)		(0.0365)	
R-Square	0.2000		0.2107		0.2365		0.1968		0.1199	
RMSE	0.5202		0.1089		0.0544		0.4045		0.2637	

1 To prevent singularity, the cull cow equation is dropped from the estimation. Since the iterative seemingly unrelated regression procedure is
invariant to which equation is dropped, this poses no problems and the parameters can be recovered if necessary. For simplicity, we exclude this equation from the above results.

A SUR Chi Square test (p. 456, Judge et al., 1988) that the error terms across equations were not correlated (H_o: $\sigma_{ij}=0$ for $i \neq j$) was rejected at the 1% significance level. The test statistic, $\lambda = T \cdot \sum_{i=2}^{M} \sum_{j=1}^{i-1} r_{ij}^2 = 63.5$, where r_{ij}^2 is the squared correlation, and under H_o has an asymptotic χ^2 distribution with (M(M-1))/2 degrees of freedom, the critical value $\lambda^* = \chi^2_{(.01,\ 10)}=23.2$.

All exclusion restrictions fail to reject the null that the parameter estimates are zero at the 1% significance level. The t-statistic for the milk equation on crop acres per cow is 0.36 (critical value $t_{(.01,52)}=2.40$). F-tests for the off-farm, purchased feed, and grown feed equations indicate F-values of 0.14, 0.73, and 0.23, respectively; with a critical value $F_{(.01,2,52)}=5.06$

* Significant at the 10% level of Type-I error
** Significant at the 5% level of Type-I error

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