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The Impacts of Farm Financial Structure on Production Efficiency

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Farm financial structure may affect both short- and long-run input usage, thereby affecting farm efficiency. Any inefficiencies arising from the choice of inputs can be magnified over time as credit constraints continue to affect input usage. In a panel of 54 North Dakota crop farms, efficiency and debt structure were related. Intermediate debt was found to be positively related to farm technical efficiency, and short-term debt was negatively associated with technical efficiency. Use of intermediate-term debt was positively associated with farm-scale efficiency, whereas no significant relationship was found between short- and long-term debt and scale efficiency.

Key Words: data envelopment analysis, farm credit, farm efficiency, financial structure

JEL Classifications: Q1, Q12, Q16

Farm financial needs include current-year borrowing to cover production costs; intermediate funds needed for equipment, machinery, and farm-improvement investments; and long-term capital required for investments in land and other real estate. Balancing internal and external sources of funds to cover farm costs may reflect farm financial targets, farm household income, farmer risk attitudes, credit constraints imposed by lenders, or the relative costs of internal versus external funds. The latter two considerations may reflect lender confidence in the payback abilities of the farmer, based on projected farm income or on past experience with the farmer's production efficiency relative to the lender's portfolio of borrowers.

Reliance on external funds can affect farm production decisions. In particular, debt financing can influence factor usage and potentially affect farm costs and efficiency. Greater reliance on short-term credit, which can be costly or constrained by lender limits, may reduce farm expenditures on necessary repairs and maintenance, decreasing the efficiency of owned assets and, consequently, overall farm efficiency. Increasing intermediate- or long-term debt, on the other hand, may increase farm efficiency through adoption of technological innovations embodied in new equipment, buildings, or storage facilities. When input choice is affected by external financing, disparities between input costs and marginal value products may occur, increasing farm costs and, as a consequence, decreasing farm efficiency (Färe, Grosskopf, and Lee).

The objective of this study is to determine the relationship between farm efficiency and farm debt. Annual technical and scale-efficiency measures were determined for a panel of

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54 North Dakota crop farms during the 7-year period 1995–2001. The relationships between external sources of funds for short-, intermediate-, and long-term financial needs and farm production efficiency were determined. Following the approach of Chavas and Aliber, we first calculated farm-efficiency measures, then regressed farm efficiency on short-, intermediate-, and long-term debt ratios, in addition to other specific factors hypothesized to affect farm efficiency. We hypothesized that the source and term of external debt affects farm production decisions and, consequently, efficiency.

Costs, Debt, and Production Efficiency

There is little agreement about the relationship of financial structure, farm costs, and production efficiency. The Fisher separation theorem maintains that, under perfect financial markets, investment and financing decisions are independent (Robinson and Barry). Hence, the optimal capital structure of a firm is solely determined by the leverage ratio where the average cost of debt equals the rate of return on productive investments. First-order conditions for a cost-minimizing firm would thus suggest that allocative efficiency should not depend on capital structure and that there should not be any impact of leverage on technical efficiency. The results from Featherstone, Langemeier, and Ismet and from Rowland et al. support the perfect financial markets hypothesis.

The free cash flow, agency cost, and credit evaluation concepts provide alternative explanations for the relationship between financial leverage and farm-level efficiency (Nasr, Barry, and Ellinger). The free cash flow concept suggests agent obligations may lead to stronger incentive compatibility between principals and borrowers (Jensen). In the agricultural setting, farmers with higher debt obligations should be induced to exert greater efforts on behalf of lenders (Barry and Robinson), which would result in a positive relationship between farm debt and production efficiency.

Alternatively, the higher relative costs of external to internal funds may result in higher costs and induce production inefficiency. Agency cost implies monitoring, bonding, and adverse-incentive costs are largely passed on by lenders to borrowers through interest rate adjustments, origination fees, collateral requirements, and other transfer mechanisms (Ellinger and Barry). These costs, in turn, may reduce the borrower's technical efficiency when compared with farms having less reliance on borrowed funds (Nasr, Barry, and Ellinger). The agency-cost concept implies a negative relationship between technical efficiency and financial leverage.

Support for the agency-cost model comes from Kim and Maksimovic and from Featherstone and Al-Kheraiji. Both articles assume decisions regarding debt load and output precede variable input choices. Estimation of the resulting restricted, variable-cost functions isolates the effects of output and debt load on short-run costs. In the airline industry (Kim and Maksimovic) and in agricultural cooperatives (Featherstone and Al-Kheraiji), debt levels were found to negatively affect short-run variable costs, consistent with the agency-cost model. Interestingly, Featherstone and Al-Kheraiji found a small, positive relationship between debt and total-factor productivity, suggesting differences in the effects of debt and firm efficiency in the shorter versus the longer term.

A single measure of total firm debt was used in these two studies. However, businesses obtain credit to cover short-run needs as well as to finance intermediate- and long-term asset acquisition. Leveraging intermediate- and long-term investments from external funds may affect firm efficiency differently than short-term borrowing. Short-run needs include both purchases of variable inputs anticipated when output and debt decisions are made and responses to shocks arising during the course of a production period, necessitating a greater-than-planned reliance on operating credit. On the other hand, increasing intermediate- and long-term assets through debt financing may positively influence farm efficiency because improvements in equipment and other farm capital facilities can improve farm efficiency.

Credit evaluation considerations may also explain differences in the effects of shorter and longer term debt on firm efficiency. The credit evaluation concept suggests that lenders will prefer to finance more efficient producers. Agricultural bankers often use management and efficiency variables, along with financial variables in evaluating a farmer's creditworthiness (Ellinger, Splett, and Barry). Thus, use of greater financial leverage by some producers could be associated with greater technical efficiency because of increased lender expectations of farm creditworthiness. Although unable to detect significant effects on efficiency from the total debt-to-asset ratio, Nasr, Barry, and Ellinger attributed the positive and significant effects of the current debt-to-asset ratio on technical efficiency to lenders' familiarity with their borrowers, consistent with the credit evaluation concept.

Barry, Baker, and Sanint tested for evidence of the credit evaluation concept in agricultural loans. The authors note that agricultural lenders constrain capital loans more than operating loans because variations in a farmer's recent financial performance are often explained by factors beyond the farmer's control. This, in turn, suggests that the credit evaluation concept implies a positive relationship between intermediate- and long-term financial leverage and technical efficiency, with a weaker relationship between short-term debt and technical efficiency.

The findings of Chavas and Aliber support this hypothesis by identifying a positive and significant relationship between intermediate- and long-term debt-to-asset ratios and the technical efficiency of Wisconsin dairy farms. The positive relationship was attributed to the embodiment of technological innovation in intermediate- and long-run assets. No significant relationship was found between current debt and farm efficiency.

Because of the differences reported in empirical applications, it is difficult to definitively characterize the effects of short-, intermediate-, and longer-term debt financing on firm efficiency. Agency-cost effects would suggest a negative relationship between short-term borrowing and firm efficiency. Conversely, a positive relationship could result under the free cash flow or credit evaluation concepts. Both positive and negative debt effects on farm efficiency have been found in empirical work. Greater consistency appears in the effects of longer-term debt on efficiency. Whether resulting from credit evaluation, free cash flow, or reduced agency costs associated with longer-term borrowing, some evidence indicates that the use of intermediate- and long-term debt can positively affect farm efficiency. Because much innovation in agriculture is embodied in equipment and other acquired inputs that require longer-term financing, a positive effect on efficiency of such borrowing might be expected.

Production Efficiency

Production efficiency for an individual firm is defined relative to the technology available at some time period t. Let S^t be the production technology available at time period t to the firms in an industry:

$$(1) \qquad S^t = [(x, y): x \text{ can produce } y \text{ at time } t],$$

where $x \in \Re^n_+$ is a vector of inputs used to produce outputs, $y \in \Re^m_+$. Assuming that set S^t satisfies standard regularity conditions,[1] the input-distance function D^t_I at time t is defined as:

$$(2) \qquad D^t_I(x^t, y^t) = \left\{\sup\left[\theta: \left(\frac{x^t}{\theta}, y^t\right) \in S^t\right]\right\}.$$

The input-distance function measures the relative distance of a given element of set S^t, (x^t, y^t), representing an individual firm, from the frontier of the production set. The frontier is empirically determined over the set of all firms. We adopt the linear-programming methods of Färe et al. and measure each firm's distance-function value relative to the frontier defined over all firms in each year.

Färe et al. distinguish the measurement of

[1] Regularity conditions include (a) the possibility of inaction (i.e., it is always possible to produce no output), (b) weak disposability of outputs, (c) finite amounts of inputs that can produce finite amounts of outputs, and (d) an output set that is closed.

the distance function under constant (*CRS*) and variable (*VRS*) returns to scale. The overall measure of the distance function derived under *CRS*, $D^t_{I,CRS}$, can be decomposed into technical efficiency under *VRS* and a scale-efficiency score (*SE*) measuring a firm's divergence from the *CRS* efficiency, or

$$D^t_{I,CRS} = D^t_{I,VRS} \times SE^t. \tag{3}$$

Scale efficiency for each firm is determined by dividing $D^t_{I,CRS}$ by $D^t_{I,VRS}$. Scale efficiency is measured relative to the production frontier instead of derived via dual-cost relationships. Scale-efficient farms (i.e., $SE = 1.0$) achieve a maximal, multiple-input average product. Under competitive markets, scale-efficient farms have also selected output levels to achieve minimal average cost (Chavas and Aliber).

Sources of Technical and Scale Efficiency

Farm technical and scale-efficiency estimates are used to estimate the relationship between efficiency and farm characteristics, including farm financial structure:

$$DepVar = f(REGION, YEAR, DARC, DARI, DARL, NFTFIR, YRSFARM, INSUR, GOVT), \tag{4}$$

where the dependent variables are (1) technical efficiency under variable returns to scale (replacing $D^t_{I,VRS}$ with *TE* in future references) and (2) scale efficiency (*SE*). Variables hypothesized to influence farm efficiency include farm location (*REGION*), year (*YEAR*), short-, intermediate- and long-term debt-to-asset ratios (*DARC, DARI,* and *DARL,* respectively), the ratio of nonfarm-to-farm household income (*NFTFIR*), farming experience (*YRSFARM*), and insurance (*INSUR*) and government (*GOVT*) payments to the farm.

The *REGION* and *YEAR* variables test for group and time effects. Regional variation in efficiency measures may arise because of weather conditions or other locally shared factors that influence agricultural production, such as pest outbreak or crop or livestock diseases. Regional differences in efficiency scores may also indicate differences in managerial characteristics across the state. If managerial abilities were uniformly distributed across the state, regional variables might be insignificant. Farmers would make input and output choices based on resource quality, achieving production efficiencies comparable to farms in other regions facing a different quality mix of inputs. Significant regional variation in efficiency values might indicate either variations in managerial ability, differences in input and output qualities that cannot be compensated by increasing (unmeasured) management ability, or failure to accommodate input and output quality differences in the data used in the analyses.

The *YEAR* variable will capture changes in the relative distance of the farms to the production frontier in each year. If the density of farms relative to the frontier remains relatively constant from year to year, the coefficients on *YEAR* should be insignificant. Statistical significance would indicate that, for a particular year, farms were clustered either more closely or farther away from the frontier than they were in the base year (1995 in our case). It should be noted that coefficient estimates do not capture changes in the frontier itself. Additional calculations, such as derivation of the Malmquist total-factor productivity index, are needed to indicate shifts in the frontier over time.

The debt-to-asset ratios measure the impact of financial leverage on efficiency. Debts and assets are classified according to expected duration: 1 year for current debts and assets (*DARC*), from 1 to 10 years for intermediate (*DARI*), and more than 10 years for the long-term (*DARL*). As discussed earlier, earlier empirical work has found both positive and negative relationships between debt structure and farm efficiency. Signs and the significance of the coefficient estimates will support the role of short-, intermediate-, and long-term debt on farm efficiency for the North Dakota farms included in the sample.

The variable *NFTFIR* measures the proportion of household income derived from off-farm sources. As the allocation of family labor to generating off-farm income increases, it is hypothesized that farm production efficiency will decline. Goodwin and Mishra confirm a statistically significant inverse relationship between off-farm employment and farm efficiency. A decline in technical efficiency resulting from an increase in off-farm work would indicate a positive marginal product of family on-farm labor and, consequently, positive opportunity costs associated with off-farm employment.

It is expected that insurance payments received (*INSUR*) will be negatively correlated with farm technical efficiency. Presumably insurance payments are received to offset crop-yield losses. If crop losses occur with no reduction in input levels, the farm's technical efficiency measure should be less than 1.0, indicating the farm lies in the interior of the production set. If covered, crop revenue losses may be offset at least partially by *INSUR*.[2]

Government payments (*GOVT*) are similarly hypothesized to be negatively correlated with technical efficiency, although the correlation is not as straightforward as insurance payments. Were the output measure based only on physical quantities, government payments would only be correlated with programs such as disaster payments for yield losses. Price-support programs would not be correlated with the technical-efficiency values. However, because output is itself an index resulting from an aggregation of the many crops grown on farms in North Dakota, aggregation based on revenues reflects crop-output prices. Thus, government-program payments could be negatively related to efficiency measures because both output quantity and output value reductions could trigger increased government payments.

Because technical and scale-efficiency measures are restricted to the range [0, 1], ordinary least-square estimates are inconsistent (Greene). Use of the tobit model permits data censoring at 1 in our sample. The tobit regressions were estimated by maximum-likelihood procedures using Gauss v. 6.0.

Data

Data were obtained from the North Dakota Farm and Ranch Businoss Management Education (NDFRBME) program. Seven years of data (1995 to 2001) were available for 54 crop farms.[3] Because the data were from records of participants in the state management education program, the farms are not a random sample of North Dakota farms. The results are representative of the types of agricultural enterprises found in the state, but should not be interpreted to represent all of North Dakota crop agriculture.

There were 23 farms from region 1 (the Red River Valley bordering the North Dakota–Minnesota border), 17 farms from region 2 (north-central North Dakota), 11 farms from region 3 (south-central North Dakota), and 3 farms from region 4 (the Missouri Slope of western North Dakota). Farmers in the different regions face different agro-climatic conditions and specialize in different mixes of crop production. For example, Red River Valley farms typically generate higher gross revenues per acre but also employ more farm inputs and face higher costs for fixed farm inputs compared with farms in the other regions.

Whole farm and enterprise data were aggregated to obtain four inputs and one output. The crop-output index was measured by the real monetary value of all crop enterprises. The output-quantity index was calculated as the sum of the market price received by each farmer multiplied by the actual quantity produced. Total revenues received were next aggregated for feed grains, food grains, oil crops,

[2] An alternative hypothesis proposed by a reviewer suggests a role for moral hazard in the efficiency measure. If a farmer is insured, actions taken may lead to a reduction in effort to pursue achievable levels of output knowing insurance would cover any losses. That may lead to a negative relationship between *INSUR* and efficiency, if the drop in outputs exceeds the reduction in farming efforts.

[3] More than 500 farms participate in the NDFRBME program each year. However, data requirements included complete enterprise data for just crop farms for each of the 7 years of the study, resulting in the subsample of 54 farms.

and an aggregate category termed "other." These subtotals were deflated using a prices-received index for North Dakota crops obtained from the Agricultural Statistics Service. Deflating accounted for annual crop-price variations and yielded an index for crop quantities produced. The indices for all four crop categories were summed to represent each farm's annual output.

Aggregation was necessary given that multiple crops are grown on North Dakota farms. More than 50 crops were grown by the 54 farms included in the sample, although more than half of the acreage was in hard red spring wheat, soybeans, hay, corn, and sunflowers. Aggregating various crops using monetary values is a common practice in farm-efficiency analyses (e.g., Chavas and Aliber; Färe, Grosskopf, and Lee; Nin et al.). Adjustments were made in both output and input levels to account for farms producing crops on a share–rent basis.

Inputs consisted of (a) operating expenses, (b) labor, (c) crop acres, and (d) capital. Because data on expenditures for each category of operating expense (e.g., fuel, seed, and chemicals) were not available, it was assumed that all farmers in the sample had a similar mix of operating expenses. Operating expenses were calculated on an accrual basis.

The labor input was measured in work hours per year for paid full-time workers, paid part-time workers, and unpaid operators. Data were incomplete for the amount of unpaid operator labor hours. In those cases, the amount of unpaid operator labor was imputed based on farm enterprise mix and the estimated number of hours necessary for each enterprise.

Crop acres were calculated as total crop acres farmed plus Conservation Reserve Program (CRP) regardless of land tenure. Capital, being an aggregate input, was measured in monetary value. It was calculated as a sum of machinery and equipment, buildings and improvements, and other capital assets. All capital assets were measured on a cost basis and were the simple average of beginning and ending year values.

Table 1 provides summary statistics for farm inputs and outputs as well as the farm-specific variables hypothesized to influence technical efficiency.

Results

Efficiency Scores

Both technical (TE) and scale (SE) efficiency scores were derived for each of the 54 farms in each of the 7 years. Results for TE are reported in Table 2. Individual TE scores ranged from 0.27 to 1.00, with an overall mean of 0.83 and a median of 0.87. For all 7 years, approximately 26% of the observations were on the production frontier (i.e., $TE = 1.0$). The percentage of farms on the frontier ranged from a low of 20% in 1997 and 2000 to a high of 33% in 1998.

Region 1 had the highest mean TE scores for all years except 1998. The efficiency scores for region 1 reflect the highly favorable growing conditions in the Red River Valley. Region 3 had the second-highest TE scores in most years. Region 3 is mixed, with lands equaling the productivity of the Red River Valley in the east but becoming drier and of poorer soils toward the western part of the region. Efficiency scores for the 20 farms in regions 2 and 4 were generally lower than those in the eastern and southeastern areas of the state although comparisons differed by year and distribution measures. None of the three farms in region 4 were on the frontier in any year. An average of about 12% of the farms in region 2 were on the frontier over the period.

Scale efficiency multiplied by the technical efficiency measured under variable returns to scale (TE_{VRS}) equals technical efficiency under an assumption of constant returns to scale (TE_{CRS}). A farm can thus be scale efficient ($SE = 1$) but not lie on the TE_{VRS} or TE_{CRS} efficiency frontiers. Table 3 reports scale efficiency for the 54 farms over time. Differences between TE_{VRS} and scale efficiency do not seem to fit a pattern. The correlation coefficient between technical and scale efficiency is 0.28, indicating only a moderately positive relationship between the two measures. In some cases, mean scale efficiency scores are similar to TE.

Table 1. Descriptive Statistics for Farm Characteristics, 1995–2001 (standard deviations in parentheses)

	1995	1996	1997	1998	1999	2000	2001
Crop output ($)	236,888	234,131	239,343	258,963	301,484	374,266	357,918
	(157,069)	(160,428)	(155,156)	(163,924)	(251,818)	(259,072)	(241,954)
Labor hours	2,822	2,552	2,495	2,707	2,588	2,620	2,699
	(2,586)	(903)	(848)	(958)	(944)	(1,105)	(1,190)
Operating expense ($)	158,882	161,018	177,027	188,431	181,977	223,322	223,362
	(106,712)	(98,178)	(103,992)	(116,126)	(124,755)	(156,137)	(148,877)
Crop acres	1,781	1,841	1,984	1,943	2,211	2,330	2,217
	(963)	(996)	(1,182)	(990)	(1,360)	(1,625)	(1,133)
Capital ($)	248,843	284,612	326,649	340,692	365,711	384,340	407,749
	(184,148)	(193,048)	(231,596)	(209,887)	(229,163)	(237,486)	(245,805)
Return on assets ($)	10.06	13.48	4.95	4.82	10.24	11.35	5.09
	(9.51)	(9.25)	(7.05)	(5.85)	(8.31)	(8.41)	(5.45)
DARC (%)	50.97	55.45	57.16	68.79	63.43	53.56	56.88
	(42.27)	(56.35)	(46.68)	(57.86)	(47.34)	(37.60)	(42.27)
DARI (%)	29.21	28.63	28.51	29.23	30.67	30.46	27.98
	(21.22)	(19.87)	(22.23)	(22.51)	(25.23)	(26.63)	(25.31)
DARL (%)	35.55	38.10	37.73	39.37	38.12	36.71	35.36
	(29.31)	(34.36)	(36.51)	(41.51)	(33.98)	(31.33)	(30.32)
Off-farm income (%)	14.84	18.30	34.16	44.48	74.80	23.03	20.00
	(38.27)	(21.85)	(56.23)	(113.39)	(370.14)	(49.98)	(60.78)
Insurance ($)	8,167	7,981	11,870	11,315	39,185	23,111	26,685
	(14,851)	(13,361)	(18,368)	(28,974)	(47,886)	(29,552)	(35,385)
Government payment ($)	10,630	21,259	17,500	40,278	74,704	108,500	82,093
	(7,537)	(14,193)	(10,131)	(21,689)	(52,731)	(60,675)	(42,616)
Years farming	16.70	17.69	18.69	19.69	20.69	21.69	22.69
	(6.89)	(6.89)	(6.89)	(6.89)	(6.89)	(6.89)	(6.89)

Table 2. Technical Efficiency Scores by Region: Variable Return to Scale Input Orientation

		1995	1996	1997	1998	1999	2000	2001
Region 1	Mean	.90	.93	.91	.93	.92	.89	.90
(n = 23)	Median	.98	.96	.96	.90	.92	.93	.93
	Minimum	.66	.58	.62	.80	.78	.66	.65
	No. 1's	11	10	8	10	10	5	7
Region 2	Mean	.75	.72	.74	.78	.60	.71	.78
(n = 17)	Median	.68	.72	.71	.81	.59	.65	.83
	Minimum	.48	.46	.44	.43	.27	.52	.50
	No. 1's	2	3	2	2	2	2	3
Region 3	Mean	.71	.85	.84	.97	.90	.89	.86
(n = 11)	Median	.69	.81	.87	1.00	.98	.93	.84
	Minimum	.51	.71	.60	.85	.57	.72	.63
	No. 1's	2	2	2	7	4	5	5
Region 4	Mean	.72	.72	.80	.75	.56	.70	.71
(n = 3)	Median	.70	.76	.87	.65	.56	.67	.79
	Minimum	.68	.63	.63	.59	.54	.61	.54
	No. 1's	0	0	0	0	0	0	0
All Regions (n = 54)								
Mean		.80	.84	.84	.88	.79	.82	.84
Median		.78	.88	.87	.90	.84	.81	.87
Minimum		.48	.46	.44	.43	.27	.52	.50
No. 1's		15	15	12	19	16	12	15

Table 3. Scale Efficiency Scores by Region

		1995	1996	1997	1998	1999	2000	2001
Region 1	Mean	.96	.91	.93	.93	.95	.92	.96
(n = 23)	Median	.99	.97	.96	.97	.96	.94	.99
	Minimum	.82	.71	.74	.67	.84	.76	.85
	No. 1's	9	8	4	6	5	3	5
Region 2	Mean	.87	.77	.82	.88	.57	.83	.85
(n = 17)	Median	.90	.76	.81	.86	.56	.89	.90
	Minimum	.66	.56	.56	.69	.08	.40	.55
	No. 1's	0	0	0	0	0	0	0
Region 3	Mean	.81	.79	.79	.90	.82	.81	.87
(n = 11)	Median	.81	.78	.80	.99	.92	.83	.90
	Minimum	.42	.49	.24	.44	.28	.51	.43
	No. 1's	0	1	0	5	2	2	2
Region 4	Mean	.90	.80	.83	.85	.56	.88	.93
(n = 3)	Median	.89	.82	.86	.85	.62	.86	1.00
	Minimum	.85	.75	.71	.83	.34	.81	.79
	No. 1's	0	0	0	0	0	0	0
All Regions	Mean	.90	.84	.86	.90	.78	.87	.90
(n = 54)	Median	.93	.86	.89	.93	.90	.89	.94
	Minimum	.42	.49	.24	.44	.08	.40	.43
	No. 1's	9	9	4	11	7	5	7

Table 4. Relationship between Technical Efficiency (Variable Return to Scale) and Farm Characteristics, Tobit Model

Explanatory Variable	Estimate (Standard Error)	Explanatory Variable	Estimate (Standard Error)
Intercept	0.9465***	*DARC*	−0.0904**
	(0.0366)		(0.0215)
Region 2	−0.2004**	*DARI*	0.1295**
	(0.0211)		(0.0455)
Region 3	−0.0428	*DARL*	−0.0091
	(0.0250)		(0.0290)
Region 4	−0.2297**	*NFTFIR*	0.0009
	(0.0395)		(0.0069)
Year 1996	0.0380	*YRSFARM*	−0.0005
	(0.0324)		(0.0013)
Year 1967	0.0431	*INSUR*	−0.0019**
	(0.0324)		(0.0003)
Year 1998	0.1035**	*GOVT*	0.0004
	(0.0342)		(0.0004)
Year 1999	0.0405	σ	0.0259**
	(0.0375)		(0.0023)
Year 2000	0.0101		
	(0.0412)		
Year 2001	0.0562		
	(0.0379)		

DARC is short-term debt-to-asset ratio; *DARI* is intermediate term; and *DARL* is long-term.
NFTFIR is nonfarm-to-farm income ratio; *YRSFARM* is farming experience; *INSUR* is insurance payments; and *GOVT* is government payments.

Farms in Regions 2 and 4, on the other hand, lie below the technically efficient frontier, yet higher scale-efficiency scores in these two regions indicate that the scale of resources employed in the farms is closer to farms in the other parts of the state. However, even though mean and median scale-efficiency scores are higher than the technical-efficiency scores in regions 2 and 4, none of the farms achieved scale-efficiency scores equal to 1.0.

Farm Efficiency and Farm-Specific Factors

Table 4 reports the results of the tobit analysis used to estimate the relationships between technical efficiency and selected farm-specific characteristics. Results indicate that regional effects are significant. The χ^2 (3) value derived from a likelihood-ratio test equaled 97.10, rejecting the null of no regional effects on the results. *TE* scores for farms in region 1 were higher than farms in the other regions. The regional effects were significant at the 1% level for regions 2 and 4. The effect was also negative for region 3 although not statistically significant at acceptable levels of confidence. These results provide the statistical basis for the observed levels of *TE* in Table 3.

Time effects were not significant for any years except for 1998. The null of no time effect could not be rejected (χ^2 (6) = 12.163). As seen in Table 2, both mean and median *TE* measures in 1998 exceeded all other years. In addition, a higher proportion of farms were on the production frontier in 1998. However, even though not statistically significant, parameter estimates were positive in each year following the 1995 base. The positive coefficients on *YEAR* do not, however, indicate technological progress, but rather indicate a tighter clustering of farms relative to each year's frontier.

Leverage variables *DARC* and *DARI* (current and intermediate-term debt-to-asset ratios) were statistically significant at the 1% level, whereas variable *DARL* (long-term debt-to-asset ratio) was not significant. Current debt-to-asset ratios (*DARC*) had a negative influence on *TE*. The result supports the existence of agency costs. Technically inefficient farmers may not be able to generate internal financial resources to cover operating expenses so are forced to increase borrowing. At the same time, lenders may impose a higher proportion of bonding (collateral) and adverse incentive costs (higher interest rates, servicing fees) on those producers, which, in turn, increases their operating costs and lowers their *TE*. *TE* would, therefore, fall, and current debt would rise, explaining the negative coefficient.

Variable *DARI* has a positive influence on *TE*. This relationship is consistent with the credit-evaluation concept, indicating that bankers may prefer to extend intermediate-term capital to more-efficient farmers. It is also consistent with the liquidity-preference theory of credit use in agriculture, developed by Baker and extended by Barry, Baker, and Sanint. The liquidity-preference theory suggests that lenders are more willing to finance and provide more favorable financing terms to producers with high-repayment capacity. Consistent with the increasing willingness of lenders to lend to more-efficient producers, increasing levels of *DARI* might indicate increased acquisition of capital equipment. Our results are similar to those of Chavas and Aliber, who attributed their finding of a positive relationship between intermediate-debt and efficiency to the embodiment of technological innovation in capital equipment.

There was no significant relationship between the long-term debt-to-asset ratio, *DARL*, and farm efficiency. Use of long-term debt may affect the farm scale or change the composition of long-term assets. Neither impact was found to influence annual farm technical efficiency.

Only one nonfinancial farm factors (insurance payments) had a significant effect on technical efficiency. The off-farm to farm-income ratio (*NFTFIR*) had no significant impact on *TE*, indicating part-time farmers were neither less nor more efficient in using the measured inputs than their full-time peers. This result is consistent with the findings of Chavas and Aliber that no significant relationship existed between *NFTFIR* and Wisconsin dairy-farm efficiency.

Farming experience (*YRSFARM*) also had no significant effect on farm efficiency. Older producers may have more experience, which might positively influence efficiency, yet may be more conservative or more reluctant to adopt innovating practices as they near retirement.

Insurance payments received (*INSUR*) is negatively correlated with *TE* and is significant at the 1% level. This supports the hypothesis that adverse conditions resulting in lower farm efficiency may be offset by compensating insurance payments.

Variable *GOVT* was not statistically significant. Earlier discussion concluded that the effects of *GOVT* on technical efficiency were *a priori* indeterminate because the program composition of payments was uncertain. Our results indicated that government payments had no effect on farm efficiency for the farms analyzed during the 1995–2001 period in spite of the large increase in government payments over that period (Table 1).

Tobit results from regressing scale efficiency on farm characteristics are reported in Table 5. Total regional effects were significant (χ^2 (3) = 73.54). Similar to the effects on technical efficiency, regional effects were significant (and negative) for all regions when compared with the Red River Valley (region 1). Annual effects were also significant in explaining scale efficiency (χ^2 (6) = 51.61), with more farms being scale inefficient in 1996, 1999, 2000, and 2001. In addition, the farm-specific variables *NFTFIR, INSUR,* and *GOVT* exhibit greater influence on scale than on technical efficiency. Scale efficiency increases as the proportion of off-farm contributions to household income falls, indicating a tendency for full-time farm operators to operate closer to the constant returns to scale frontier.

Increasing insurance payments have a significant negative impact on scale efficiency. Not only do insurance payments negatively affect technical efficiency, as discussed earlier, but they tend to be associated with farms not operating at the most efficient scale.

Table 5. Relationship between Scale Efficiency and Farm Characteristics, Tobit Model (Maximum-likelihood estimate and standard errors in parentheses)

Explanatory Variable	All Observations $n = 378$	SE_{DRTS} $n = 205$	SE_{IRTS} $n = 94$
Intercept	0.9836**	0.9149**	1.0024**
	(0.0297)	(0.0382)	(0.0552)
Region 2	−0.1436**	−0.0750	−0.0875**
	(0.0173)	(0.0409)	(0.0338)
Region 3	−0.1261**	0.0187	0.0169
	(0.0204)	(0.0343)	(0.0506)
Region 4	−0.0989**	−0.0085	0.0493
	(0.0328)	(0.0370)	(0.0457)
Year 1996	−0.0858**	−0.1226**	−0.1073*
	(0.0267)	(0.0412)	(0.0510)
Year 1997	−0.0490	−0.996*	−0.1332
	(0.0266)	(0.0454)	(0.0840)
Year 1998	−0.0295	−0.0481	−0.0004
	(0.0279)	(0.0438)	(0.0547)
Year 1999	−0.1769**	−0.1176**	−0.0560
	(0.0307)	(0.0220)**	(0.0306)
Year 2000	−0.1887**	−0.1390	−0.0320
	(0.0340)	(0.0273)	(0.0345)
Year 2001	−0.0910**	−0.0650	−0.0624
	(0.0313)	(0.0392)	(0.0469)
DARC	−0.0258	−0.0073	−0.0783**
	(0.0177)	(0.0234)	(0.0286)
DARI	0.0742*	−0.0195	0.0366
	(0.0368)	(0.0516)	(0.0658)
DARL	0.0129	0.0250	0.0882
	(0.0237)	(0.0299)	(0.0536)
NFTFIR	−0.0167**	−0.0123*	−0.0197
	(0.0048)	(0.0047)	(0.0324)
YRSFARM	−0.0004	−0.0015	−0.0017
	(0.0011)	(0.0013)	(0.0021)
INSUR	−0.0016**	−0.0024**	−0.0013**
	(0.0003)	(0.0004)	(0.0003)
GOVT	0.0018**	0.0021**	0.0008*
	(0.0002)	(0.0004)	(0.0004)
σ	0.0180**	0.0156**	0.0095**
	(0.0014)	(0.0015)	(0.0014)

SE_{DRTS} includes farms exhibiting decreasing returns to scale; and SE_{IRTS} includes those farm observations with increasing returns to scale.
DARC is short-term debt-to-asset ratio; *DARI* is intermediate term; and *DARL* is long-term.
NFTFIR is nonfarm-to-farm income ratio; *YRSFARM* is farming experience; *INSUR* is insurance payments; and *GOVT* is government payments.
* indicates significance at the 5% level; ** indicates significance at the 1% level.

Government payments, on the other hand, are positively related to scale efficiency. Because the effect was positive and significant for all of the observations, as well as for additional analyses concentrating just on those farms that are operating in the region of increasing (or decreasing) returns to scale (Table 5), no conclusions can be drawn about the role of government payments on farm size. The results show government payments are greater for farms clustered on or close to the constant returns to scale frontier.

DARC and *DARL* do not have significant impacts on scale efficiency. However, increased borrowing for intermediate-assets does have a positive effect on scale efficiency. This suggests that attaining scale economies may be enhanced by increasing the use of intermediate-term debt for equipment and other intermediate-term assets. This may be especially true in this sample in which more than two thirds of the farmed land was rented from other owners.

The relationship between financial structure and scale efficiency may depend on whether farms exhibit decreasing or increasing returns to scale. Chavas and Aliber, for example, found no statistically significant relationship between debt structure and scale efficiency for farms operating under decreasing returns to scale. Conversely, for farms exhibiting increasing returns to scale, they found a significant negative relationship between intermediate debt and a positive relationship between long-term debt and scale efficiency.

Table 5 presents tobit results for the effects of farm-specific factors on scale efficiency for farms, depending upon whether they exhibited increasing or decreasing returns to scale. Similar to the results found by Chavas and Aliber, no statistically significant relationship existed between debt structure and scale efficiency for the 205 observations[4] exhibiting decreasing returns to scale. This suggests that the financial structure of the larger farms does not affect scale efficiency. For the 94 observations characterized by increasing returns to scale, there was also no statistically significant relationship between intermediate- or long-term debt and scale efficiency. Assumption of multiyear debt, therefore, does not appear to improve the smaller farms' tendency towards scale efficiency. However, current debt-to-asset ratio was negatively related to scale efficiency. This may indicate that short-run capital needs disadvantage smaller farms from attaining scale-efficient operations.

Summary and Conclusions

Efficiency analyses were conducted for 54 farms participating in the NDFRBME program between 1995 and 2001. Results indicate farms are heterogeneous in their efficiencies in combining inputs to produce crop outputs. Across all regions and all years, about one quarter of the observations lay on the *VRS*-efficient frontier.

Farm technical efficiency was found to be influenced by debt structure. A significant negative relationship was found between technical efficiency and the current debt-to-asset ratio. Two nonexclusive rationales may explain the nature of these impacts. First, the negative relationship supports the agency-cost concept, in which the higher costs of external to internal funds result in input misallocation. An alternative explanation, especially in a state subject to adverse weather events during the production year, may be increased reliance on operating loans to compensate for production shocks during the year. Increased borrowing may be necessary to cover costs required to bring in a crop or, alternatively, localized crop damage may reduce output levels below those attainable for the level and composition of farm inputs, including operating loans, employed.

The positive relationship between the intermediate debt-to-asset ratio and technical efficiency supports both the credit-evaluation theory and liquidity preference. Lenders are presumed to finance more-efficient farmers having a high probability of repayment. With respect to intermediate-term debt, lenders may be willing to finance acquisition of assets they perceive to positively affect production efficiency.

The different effects of current and intermediate debt on farm technical efficiency are

[4] A total of 378 observations resulted from estimating scale-efficiency measures for the 54 farms in each of the 7 years. Of these 378 observations, a total of 299 were not scale efficient. Two hundred and four of the observations exhibited decreasing returns to scale, and 94 observations exhibited increasing returns to scale. Seventy nine observations over the 7 years were scale efficient, lying on the production frontier defined under an assumption of constant returns to scale.

not contradictory. Differential transaction costs between current and intermediate debt, as well as the lenders' preference for more-efficient farmers seeking financing for capital equipment, are consistent with the findings. The findings do, however, run counter to the Fisher separation hypothesis in which capital structure and investment and expenditure decisions are separable and no relationship between debt and efficiency would be expected.

Few farms operated at an efficient scale. On average, slightly more than 7 of the 54 farms were operating at an efficient scale. Scale efficiency was attained primarily by farms in region 1. Farms in other regions, even if technically efficient, appeared not to operate at the same level of efficiency. Greater reliance on intermediate-term debt was positively and significantly associated with scale efficiency for all the farms, perhaps indicating the importance of equipment (and other intermediate assets) in achieving efficient scale.

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