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STAFF PAPER

SYSTEMATIC AND UNSYSTEMATIC RISK COSTS

FOR SOUTHEASTERN KANSAS FARM ENTERPRISES

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Systematic and Unsystematic Risk Costs for Southeastern Kansas Farm Enterprises

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Systematic and Unsystematic Risk Costs for Southeastern Kansas Farm Enterprises

Abstract

Six measures of farm returns are used to estimate the most "appropriate" market index for southeastern Kansas farms. Systematic and nonsystematic risks and risk costs are estimated for farm planning. Results suggest that regional indices are more appropriate for use as the market index than state indices.

Keywords: Single Index Model, systematic risk, risk costs

Systematic and Unsystematic Risk Costs

for Southeastern Kansas Farm Enterprises

Farm income variability is a problem farm businesses in the Great Plains deal with each year. Farm diversification is one method that can be used to reduce this variability. However, understanding and planning for income risk is a difficult task because of the various risk sources and the difficulty farm managers have relating to risk-return trade-offs based upon correlations, means, standard deviations, and risk aversion coefficients. Mean-variance techniques used to derive efficient diversification strategies usually do not consider an individual enterprise's contribution to the risk of the farm. Providing improved information about risk associated with individual farm enterprises is necessary for a farmer to make decisions more wisely. Including risk cost information in enterprise budgets will allow farmers to begin to see some of the risk-return trade-offs that occur when considering alternative enterprises.

The objective of this study is to determine the levels of systematic and nonsystematic risk and the corresponding costs for alternative farm enterprises in southeastern Kansas using enterprise budgets from actual farm data. Nonsystematic risk is reduced as a farm diversifies, whereas systematic risk is not. If a farm is fully diversified, nonsystematic risk is zero. A risk cost can be estimated from systematic and nonsystematic risks of an enterprise and can be subtracted from the budgeted returns. Estimates of the risk costs of different enterprises can be used by farm managers in selecting efficient portfolios.

The single index model (SIM) has been used in finance and agriculture as an alternative to the more complex quadratic programming model to provide estimates of risk that represent the variance-covariance structure of enterprise returns. Several studies have used the SIM either to provide risk information and derive optimal enterprise combinations or to determine the risk costs (Collins and Barry; Turvey and Driver; Turvey et al.; Gempesaw et al.; Sharpe and Baker). The problem of index choice has been considered in the SIM application in agriculture using state enterprise extension budgets. Most of the research above studied enterprises at a state level using average state returns as a proxy for the market index. However, the SIM has not been applied to data collected on actual farms for a smaller geographic area. This type of data would likely be more appropriate for extension economists and farm managers to use in decision making.

The manuscript is organized as follows. First, six farm indices are considered as the index needed for the application of the SIM. The farm enterprise data represent the average returns of farms that are members of the Kansas Farm Management Association. The quality of the market index is determined using the Lagrange Multiplier test. Systematic and nonsystematic risks and the corresponding costs are estimated for undiversified individual enterprises using the "best" indices.

Analytical Framework

The basic assumption underlying the SIM is that enterprise returns are correlated to a market index, m, as follows:

(1) $R_i = \alpha_i + \beta_i R_m + e_i, i = 1, ..., n$

where R_i is the net return of the i^{th} enterprise, R_m is the return of the market index m, α_i is the fixed component of R_i that is independent of R_m; β_i is a measure of responsiveness of the net returns from enterprise i to a change in R_m, and e_i is a random factor with mean zero and variance σ_{ei}^2 (Sharpe). Further assumptions that characterize the SIM approximation of the variance covariance structure are (a) the error term is uncorrelated with the index return, $Cov(e_i,R_m)=0$, and (b) the error terms are not correlated across equations, $Cov(e_i,e_j)=0$ for $i \neq j$.

Enterprise and portfolio variances are derived as follows, based on the single index model assumptions:

(2) $$\sigma_i^2 = \beta_i^2 \sigma_m^2 + \sigma_{ei}^2$$

(3) $$\sigma_p^2 = (\sum_{i=1}^{n} x_i\beta_i)^2\sigma_m^2 + \sum_{i=1}^{n} x_i^2\sigma_{ei}^2$$

where σ_p^2 is the farm portfolio variance, and σ_m^2 is the variance associated with the return of the market index. In a well-diversified farm portfolio, the nonsystematic portion of the variance (second terms in equations 2 and 3) is negligible. Portfolio standard deviation can be obtained by taking the square root of equation 3.

Marginal standard deviation as the i[th] enterprise is added to the portfolio for a well-diversified portfolio (nonsystematic risk = 0) is:

(4) $$\frac{\partial \sigma_p}{\partial x_i} = \beta_i\sigma_m$$

which is the systematic risk of the i[th] enterprise. If the portfolio is not well diversified, the addition of a marginal unit of one enterprise increases the portfolio risk by its standard deviation (σ_i), which has a systematic ($\beta_i\sigma_m$) and nonsystematic (σ_i^{NS}) component.

(5) $$\frac{\partial \sigma_p}{\partial x_i} = \sigma_i = \beta_i\sigma_m + \sigma_i^{NS}$$

The variable σ_i^{NS} depends on the degree of diversification and can be defined as the difference between total enterprise risk and its systematic component:

(6) $$\sigma_i^{NS} = \sigma_i - \beta_i\sigma_m$$

Derivation of the Risk Costs

The mean-standard deviation model often used in portfolio selection is formulated as follows:

$$\text{Max } Z = \sum_{i=1}^{n} x_i R_i - \Theta\sigma_p$$

where Z is the utility function, Θ is the risk aversion coefficient, and $\Theta\sigma_p$ is the portfolio risk cost. Sharpe and Baker have shown that the addition of a marginal unit of enterprise, i, changes the utility function as much as $(R_i - \Theta\sigma_i)$, the first derivative of Z with respect to x_i. From equation (5):

(7) $$\Theta\sigma_i = \Theta\beta_i\sigma_m + \Theta\sigma_i^{NS}$$

where $\Theta\sigma_i$ represents the total risk cost for enterprise i, $\Theta\beta_i\sigma_m$ is the systematic risk cost, and $\Theta\sigma_i^{NS}$ is the nonsystematic risk cost. Thus, by multiplying the risk by the risk aversion coefficient, the risk is converted into a certainty equivalent value.

The LM Test

The Lagrange Multiplier (LM) test can be used to test the SIM most crucial assumption of uncorrelated error terms across equations (Sharpe and Baker). Given Ω, the variance-covariance matrix between the error terms e_i and e_j, the hypothesis to be tested is that H_o: Ω is a diagonal matrix against the alternative that the off-diagonal elements of Ω are different from zero. The LM statistic is constructed as follows:

$$LM = N \sum_{i=1}^{k} \sum_{j=1}^{i-1} r_{ij}^2$$

with: $r_{ij} = N^{-1} (\sigma_{ei}^2 \sigma_{ej}^2)^{-1/2} (E_i' E_j)$

where σ_{ei}^2 is the estimated variance of e_i, E_i is a vector of error terms e_i, K is the number of enterprises, and N is the number of observations. The LM statistic is distributed as Chi-Square with (K/2)(K-1) degrees of freedom (Breusch and Pagan). Indices that violate the assumptions of the single index model are not appropriate for use in single index applications.

Data

The net returns to operator's unpaid labor and management are collected for nine enterprises from 1976 through 1988. Crop net returns are gross income from the operator's share of the production plus government payments and other incomes, minus the total costs. Total costs include all cash expenses; depreciation on equipment, buildings, and storage facilities; real estate taxes; an interest charge on capital; and rental rate. Livestock returns are obtained by subtracting total costs from the gross income; gross income from livestock is the value of livestock sales income minus purchase costs plus miscellaneous income. The return on the farmland ownership enterprise is the residual obtained by subtracting property taxes from the cash rent of land, after adjusting for the changes in land price. All the returns on the farm enterprises are measured in 1988 constant dollars. Crop returns are those of southeast Kansas; livestock and owned farmland returns are state averages (table 1). The mean returns to all enterprises except the beef cow and the beef finishing enterprises were positive from 1976 to 1988, based on actual farm records. The returns to the dairy and sow & litter enterprises were the least variable, based upon the coefficient of variations.

The following six variables were selected as possible market indices (m): 1) Kansas gross farm income per farm before inventory adjustment: GFI; 2)

Kansas net income per farm after inventory adjustment: NFI; 3) total state net farm income in Kansas: TFI; 4) net farm income for southeast Kansas Farm Management Association farms: NFIS; 5) rate of return on net worth for southeast Kansas Farm Management Association farms: RNWS; and 6) gross farm income for southeast Kansas Farm Management Association farms: GFIS (table 2).

Estimation Procedures

Real returns, R_i of the i^{th} farm activity, are regressed separately on each one of the six farm indices included in this study. Given the nine enterprises included in this study, the number of degrees of freedom for the LM test is 36. Two indices, GFIS and NFIS, equally satisfied the LM-test results. These indices are used to derive systematic and nonsystematic risk components. Nonsystematic risk is obtained by subtracting estimated systematic risk from the total risk for each enterprise. Brink and McCarl estimated an average risk coefficient of 0.23 with a range from 0 to 1.28 for a group of cornbelt farmers. These values are used as an approximation of Kansas farmer's risk preferences to derive the risk costs when multiplying the risk aversion coefficient by the respective risks.

Results

Systematic risk is a component of the total risk of an enterprise return when the corresponding beta coefficient is significantly different from zero. Total risk is diversifiable, if the beta coefficient is not different from zero. Results differ by index as to whether systematic risk is part of or none of the total risk of the farm enterprises (table 3). The NFI and TFI indices suggest that the risks on all enterprise returns are nonsystematic. The GFIS and NFIS indices suggest a large systematic risk component for most enterprises. The GFI and RNWS indices imply that few enterprises have systematic risk and, thus, the risk on most enterprises is diversifiable. The choice of index determines the risk components of enterprise total risks.

Results of the Lagrange Multiplier Test indicate correlated error terms across equations with the GFI, NFI, and TFI indices. The null hypothesis of zero correlation of error terms is not rejected at 0.01%, 0.31%, and 0.38%, respectively, with the RNWS, NFIS, and GFIS indices (table 3). The NFIS and GFIS indices are selected for the estimation of systematic and nonsystematic risk costs, based on the LM results.

The error correlation matrix for the gross farm income for southeast Kansas farm index is presented in table 4. This matrix was constructed by taking the errors from each of the estimated regressions. This matrix is useful for further interpreting the LM test results. Those correlations that are signficantly different from zero at the 5 percent level will negatively affect the LM results. Using the estimates of systematic and nonsystematic risk to compare enterprises for which the correlation is significantly different from zero from a statistical standpoint is probably not advisable.

Systematic risks generated by the GFIS for most enterprises are greater than those generated by the NFIS for the same enterprises. Systematic risk is consistently greater than nonsystematic risk for all enterprises studied, except sow and litter and swine fattening, with both indices (table 5). The choice of index has a small impact on estimated risk measures because the LM results were approximately the same for both indices. The rankings of enterprises by systematic risk do not change with the use of either index.

Risk Costs and the Gain to Diversification

Risk cost information is important for choosing among alternative production possibilities in order to maximize farm income while reducing risk. Systematic risk costs are a function of the farm sector index. Farmers can do nothing to reduce them. These costs are inherent to farming and occur whether each enterprise is produced separately or in combination with others. Nonsystematic risk costs can be reduced by diversifying into alternative enterprises. Systematic and nonsystematic risk costs are derived for each enterprise under alternative risk aversion levels, assuming that there is no diversification (table 6). These costs are proportional to the risk components, and the proportion of systematic and nonsystematic risks are maintained with respect to the costs. The risk costs are larger for more risk-averse farmers.

A farmer in southeastern Kansas having average risk preferences (θ = 0.23)[1] has a systematic cost of \$8.19 per acre and a nonsytematic cost of \$3.31 per acre for growing sorghum (table 6). Nonsystematic risk cost can be partially reduced or totally eliminated, depending on the degree of diversification. For each farm enterprise, this cost should be added to the systematic risk cost when that enterprise is produced individually, but represents the potential gain from an efficient combination with other enterprises in a portfolio. If a farmer is more risk averse (θ = 1.25)[2], the systematic risk cost for grain sorghum production is \$44.53 per acre, whereas the nonsystematic risk cost is \$18.00 per acre. If a farmer is less risk

[1] The average risk aversion coefficient for a group of Cornbelt farmers was 0.23 (Brink and McCarl).

[2] A maximum risk aversion coefficent of 1.28 was observed in the Brink and McCarl study.

averse ($\theta = 0.01$), the systematic and unsystematic risk costs are \$0.36 and \$0.14, respectively.

For all enterprises with a mean return greater than zero, the sum of the systematic and nonsystematic risk costs is less than the mean, if the risk aversion coefficient is 0.01 or 0.23. If the risk aversion coefficient is 1.25, the sum of the nonsystematic and systematic risk costs is greater than the mean return in all cases. In this case, the certainty equivalent is negative and, therefore, doing nothing is preferred to specialized farming. However, the systematic risk costs of the dairy, the sow & litter, and the swine fattening enterprises are less than the mean return, indicating that combinations of these enterprises in a diversified portfolio are appropriate choices for the more risk-averse farmer.

Systematic cropping risk costs are greatest for sorghum and are lowest for wheat. Soybeans are the most profitable crop after considering systematic risk costs for low (\$25.21/acre) and average (\$17.89) risk-averse farmers. Sorghum is the second most profitable crop (\$18.21/acre), after considering systematic risk costs for the low risk-averse farmer, whereas wheat is the second most profitable crop (\$12.30) for the average risk-averse farmer. These examples illustrate some of the trade-offs that may occur when risk costs are considered in enterprise budgets.

Conclusion

Six farm indices were tested in this study for use in estimating systematic and nonsystematic risks for southeast Kansas farm enterprises. Using the Lagrange Multiplier test and compared to statewise indices, the southeast gross farm income and southeast net farm income indices better approximate the SIM assumptions. Results suggest that localized farm indices are more appropriate for the market index than are statewide indices.

These indices are used to derive the risk components. Systematic risks are larger than nonsystematic risks for seven of the nine enterprises studied. Similarly, systematic risk costs are greater than nonsystematic risk costs for most enterprises. In southeastern Kansas, systematic risk costs are less than the mean return to farmer's unpaid labor and management for dairy, sow & litter, and swine fattening enterprises for even the most risk-averse farmers. Systematic cropping risk costs are greatest for grain sorghum and smallest for wheat. Some changes in the ranking of crop enterprises occur when systematic risk costs are considered for alternative risk aversion levels. The single index model is a promising tool to illustrate risk-return trade-offs for enterprise analysis.

Table 1. Real Enterprise Income for Southeast Kansas Farm Enterprises, 1976-1988[1]

Year	Sorghum	Wheat	Soybeans	Beef cow	Beef finishing	Dairy	Sow & Litter	Swine fattening	Land ownership
	acre[a]	acre[a]	acre[a]	head[a]	head[a]	head[a]	head[a]	head[a]	acre[b]
1976	122.25	-7.84	75.00	-68.01	-80.17	382.01	31.99	13.48	108.39
1977	54.80	32.25	91.19	-15.86	2.75	575.16	54.60	16.42	159.97
1978	15.90	30.66	91.09	333.82	186.99	887.28	82.04	21.18	195.10
1979	76.06	95.01	60.84	136.01	40.87	817.93	3.77	-10.58	198.49
1980	-32.69	62.09	-1.80	-42.03	-52.78	707.10	10.00	-16.12	85.62
1981	-2.58	5.72	24.95	-220.47	-104.09	222.86	10.37	-0.12	67.65
1982	13.99	-6.63	-7.67	-167.66	-0.40	61.01	53.98	17.01	-9.95
1983	-44.32	7.49	7.14	-195.81	-28.55	22.05	5.77	0.21	-1.31
1984	-52.02	1.08	-67.34	-152.58	-8.73	41.56	15.62	4.56	-123.38
1985	7.97	-18.42	-3.99	-177.04	-90.80	-125.83	16.14	-0.45	-68.51
1986	2.16	-32.85	6.91	-92.79	-18.88	267.91	42.99	12.70	-26.91
1987	14.32	10.59	3.84	34.47	72.66	441.74	37.23	114.15	60.35
1988	65.58	51.78	51.83	56.48	28.88	407.57	10.14	-2.35	52.20
Mean	18.57	17.76	25.54	-43.96	-4.02	362.18	28.82	5.39	53.67
St.D.	50.02	35.55	46.09	156.56	77.51	320.44	24.06	11.44	98.48
C.V.(%)	269.36	200.17	180.46	-356.14	-1928.11	88.48	83.48	212.25	183.49

Source: [a]Historical Returns to farm operator's unpaid labor and management, Kansas Farm Management Association reports, Department of Agricultural Economics, Cooperative Extension Service, Kansas State University.
[b]Economic Statistics, Kansas Farm Facts, Kansas State Board of Agriculture.

[1]Measured in 1988 constant dollars.

Table 2. Six Possible Choices for the Market Index, 1976-1988[1]

Year	GFI[a]	NFI[a]	TFI[a]	NFIS[b]	RNWS[b]	GFIS[b]
	$	$	$ million	$	%	$
1976	99,501.19	12,327.79	961.60	25,027.71	-5.33	188,046.3
1977	105,134.68	11,213.08	863.46	45,374.33	-7.46	207,285.9
1978	109,148.79	10,121.11	769.20	51,266.44	-4.42	201,491.3
1979	143,005.39	17,295.63	1297.21	63,859.32	-2.84	234,070.0
1980	118,494.99	-2,563.66	-192.27	-1,084.41	-15.83	159,183.1
1981	109,263.92	4,264.57	319.84	3,531.11	-14.73	169,990.8
1982	113,062.82	12,994.67	974.60	14,262.17	-11.46	179,623.3
1983	105,990.24	5,747.44	431.09	7,147.11	-11.57	155,615.3
1984	111,799.43	12,637.25	935.13	763.32	-13.31	158,977.6
1985	107,008.76	17,746.87	1,277.73	410.06	-14.84	151,747.7
1986	105,022.22	22,600.54	1,582.01	20,388.08	-7.24	164,218.9
1987	107,932.39	24,986.52	1,755.91	48,438.41	-0.74	188,663.4
1988	106,161.00	23,025.00	1,588.70	57,076.00	2.47	201,818.0
Mean	110,886.60	13,261.29	966.48	25,881.51	-8.25	181,594.70
St.D.	10,257.83	7,644.23	533.03	23,158.15	5.65	23,745.72
C.V.(%)	9.25	57.64	55.15	89.48	-68.49	13.08

Sources: [a]Economic Statistics, Kansas Farm Facts, Kansas State Board of Agriculture.
[b]Historical Data, Kansas Farm Management Associations reports, Department of Agricultural Economics, Cooperation and Extension Service, Kansas State University.

[1]Estimates are in 1988 constant dollars.
GFI: Kansas gross farm income before inventory adjustment
NFI: Kansas net farm income after inventory adjustment
TFI: Kansas total net farm income
NFIS: Net farm income for southeast Kansas Farm Management Association
RNWS: Rate of return on southeast Kansas farm net worth
GFIS: Gross farm income for southeast Kansas Farm Management Association

Table 3. Estimated Beta Coefficients for Individual Enterprises Using Alternative Market Indices[1].

Enterprise	GFI	NFI	TFI	NFIS	RNWS	GFIS
Sorghum	0.0002	0.0024	0.0370	0.0013*	5.452*	0.0015*
Wheat	0.0024*	-0.0008	-0.0117	0.0008*	2.025	0.0010*
Soybeans	-0.00002	0.0001	0.0040	0.0013*	4.290*	0.0014*
Beef cow	0.0044	0.0042	0.0625	0.0052*	17.932*	0.0046*
Beef finish	0.0014	0.0029	0.0423	0.0023*	8.079*	0.0018*
Dairy	0.0130	-0.0044	-0.0580	0.0090*	26.285	0.0093*
Sow & lit.	-0.0007	0.0004	0.0068	0.0003	0.924	0.0002
Swine fat.	-0.0006*	0.0005	0.0072	0.0001	0.525	0.0001
Farmland	0.0031	-0.0019	-0.0233	0.0028*	7.892	0.0032*
LM-statistic	106.54	102.32	102.13	63.58	76.06	62.74
LM-probability[2]	0.00	0.00	0.00	0.31	0.01	0.38

*indicates the coefficient is significantly different from zero at 5% confidence level with the t-test.

[1] GFI: Kansas gross farm income before inventory adjustment
NFI: Kansas net farm income after inventory adjustment
TFI: Kansas total net farm income
NFIS: Net farm income for southeast Kansas Farm Management Association
RNWS: Rate of return on southeast Kansas farm net worth
GFIS: Gross farm income for southeast Kansas Farm Management Association

[2] The probability that the calculated statistic is less than the theoretical value, that is, the confidence level at which the null hypothesis of zero correlation among error terms is not rejected (%).

Table 4. Error Correlation Matrix for the GFIS Index[1].

Enterprise	Sorghum	Wheat	Soybeans	Beef cow	Beef fin.	Dairy	Sow litt.	Swine Fat.	Farmland
Sorghum	1.00	-0.46	0.46	-0.29	-0.58*	-0.28	-0.02	0.15	0.01
Wheat		1.00	0.18	0.19	-0.02	0.51	-0.58*	-0.85*	0.30
Soybeans			1.00	0.21	-0.11	0.29	0.33	0.24	0.71*
Beef cow				1.00	0.79*	0.70*	0.43	0.13	0.37
Beef finish					1.00	0.34	0.57*	0.41	0.01
Dairy						1.00	0.18	-0.20	0.75*
Sow-litter							1.00	0.87*	0.18
Swine fat.								1.00	-0.09
Farmland									1.00

*Significant at the 5% level of confidence.
[1]GFIS: Gross Farm Income for Southeast Kansas Association farms.

Table 5. Systematic and Nonsystematic Risk Measured in Standard Deviation for Southeast Kansas Enterprises by Index[1].

	Systematic Risk ($\beta_i \sigma_m$)		Nonsystematic Risk (σ_i^{NS})	
Enterprise	GFIS	NFIS	GFIS	NFIS
Sorghum	$35.62	$30.11	$14.40	$19.91
Wheat	23.75	18.53	11.80	17.02
Soybeans	33.24	30.11	12.85	15.98
Beef cow	109.23	120.42	47.33	36.14
Beef finishing	42.74	53.26	34.77	24.25
Dairy	220.84	208.42	99.60	112.02
Sow & litter	5.70	6.95	18.36	17.11
Swine fattening	2.37	2.32	9.07	9.12
Land ownership	75.99	64.84	22.49	33.64

[1] NFIS: Net farm income for southeast Kansas Farm Management Association
GFIS: Gross farm income for southeast Kansas Farm Management Association

Table 6. Systematic and Nonsystematic Risk Costs at Various Risk Aversion Levels

Enterprise	Risk Aversion Coefficient					
	0.01		0.23		1.25	
	Syst	Nonsyst	Syst	Nonsyst	Syst	Nonsyst
Sorghum ($/acre)	0.36	0.14	8.19	3.31	44.53	18.00
Wheat ($/acre)	0.24	0.12	5.46	2.71	29.69	14.75
Soybeans ($/acre)	0.33	0.13	7.65	2.96	41.55	16.06
Beef cow ($/head)	1.09	0.47	25.12	10.89	136.54	59.16
Beef finishing ($/head)	0.43	0.35	9.83	8.00	53.43	43.46
Dairy ($/head)	2.21	1.00	50.79	22.91	276.05	124.50
Sow & litter ($/head)	0.06	0.18	1.31	4.22	7.13	22.95
Swine fattening ($/head)	0.02	0.09	0.55	2.09	2.96	11.34
Land Ownership ($/head)	0.76	0.22	17.48	5.17	95.00	28.11

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