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DIVERSIFICATION OPPERTUNITIES FOR HOG PRODUCERS: A SINGLE-INDEX MODEL APPLICATION*

by

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Swine

Abstract

DIVERSIFICATION OPPORTUNITIES FOR HOG PRODUCERS:
A SINGLE-INDEX MODEL APPLICATION.

The risk of alternative management strategies for midwestern hog enterprises is quantified using results from a single-index model. Results suggest that combining farrowing and finishing may not always be the best strategy for hog producers. Diversification into feed production, cash crops, and nonfarm investments may be better in some situations.

DIVERSIFICATION OPPORTUNITIES FOR HOG PRODUCERS: A SINGLE INDEX MODEL APPLICATION

Introduction

Diversification is one of the most important risk management strategies for hog producers, but the actual benefits of alternative strategies have not been well quantified. Hog producers often diversify by including both farrowing and finishing pigs within a single farming operation. Hog producers have also diversified into both feed and cash crop production. Other strategies include production of other types of livestock, such as beef, and off-farm investments such as common stocks.

The purpose of this study is to quantify the potential of each of these diversification strategies for risk reduction. The specific objectives are: 1) to determine the effectiveness of on-farm diversification opportunities for hog enterprises; and 2) to identify the potential for risk reduction in hog enterprises through off-farm investments. The analysis is based on a single index model of portfolio selection developed by Sharpe in 1963. The single index model provides, with relatively low information requirements, the partitioning of an activity's variability into its systematic (non-diversifiable) and non-systematic (diversifiable) components.

This study has some special characteristics. First, it is based on monthly budgeted rates of return. This characteristic potentially yields more information on variability of returns than the annual average returns used in similar studies (Turvey and Driver, Collins and Barry). Second, the study used firm level data, usually assumed in the theoretical development, as opposed to aggregate data. Third, it focuses on hog production and enterprises often combined with it. The results are potentially of interest to farmers, their lenders, and those who advise them.

The remainder of the paper first briefly reviews portfolio model applications in agriculture. The theoretical framework is then described and

the methodology and data sources outlined. Finally the results of the analysis are presented.

Previous Research on Portfolio Models in Agriculture

As early as 1967, Johnson recognized the applicability of the results of portfolio analysis research to studying farm diversification since "...the problem of selecting combinations of enterprises for farms is similar in nature to the portfolio problem of the investor...". In 1980 Barry applied the capital asset pricing model (CAPM) to estimate the premium required to hold farm real estate in a well diversified market portfolio. His results suggested that farm real estate is a good candidate for diversification as the systematic risk associated with it is very low. He also found that farm real estate offers premiums above those for systematic risk.

Shurley analyzed data for West-Central Indiana farms for the period 1965-1979. He found that, by making changes in crop combinations, the variability of gross margins could be reduced by 30%, with a reduction in gross margins of only 5%. More recently, Turvey and Driver examined the potential for diversification of many agricultural production activities in Canada. They constructed a farm sector portfolio composed of 28 activities including feed and cash crops, vegetables, and livestock. They found that agricultural activities carry high levels of systematic risk and suggest that farmers may be better off by diversifying into non-farm investments. Collins and Barry recently adapted a single-index portfolio model to a farm diversification problem. They concluded that when the single-index measures are used in a simplified quadratic programming (QP) model (the diagonal model), the computational work required is significantly reduced compared to a full variance-covariance model, but that it gives only an approximate, although relatively accurate, solution to the constraint set.

Theoretical Framework: The Single Index Model

The single index model of portfolio selection was developed by Sharpe in 1963. He built on the portfolio selection concepts advanced earlier by Markowitz. The single index model relates the rate of return of a given asset to the variability (risk) of some common element. This common element, as defined by Sharpe, should be an index representing the most important factor that explains the variability of the returns on the assets under consideration. The index is often chosen to be the average of the returns on a group of investments, but this is not required. The return on each asset (r_i) is linearly related to the index (r_m) and to some random component (ξ_i):

$$(1) \qquad r_i = \alpha_i + \beta_i r_m + \xi_i, \quad i=1,2,..,n$$

where r_i is the i^{th} asset's return, α_i is the intercept, β_i is the response of r_i to a change in the index (r_m), and ξ_i is the random error term. Equation (1) is usually estimated by regressing historical asset returns on the index.

The single index model is closely related to, yet different from, the CAPM. The most important difference is the restrictive assumption in the CAPM that the capital markets are in equilibrium, implying that all investors will hold only one portfolio, the market portfolio. The single-index model requires no such assumption and, when used in a diagonal QP model, it yields a set of optimal investments based on the risk preferences of the decision maker and the asset choices available to the decision maker.

The index used in the model is assumed to capture the covariance of returns between all pairs of assets in the portfolio. Therefore, the return on the assets are related only through the common relationship with the index. If this assumption holds, the random error terms between any two assets will be uncorrelated ($\text{cov}(\xi_i,\xi_j) = 0$ for all $j \neq i$) and $\text{cov}(r_i,r_j) =$

$\beta_i\beta_j\sigma_m^2$. This greatly reduces number of parameters necessary to derive the expected value-variance efficient frontier (EV) in the following diagonal QP model:

$$\max \Psi = [x'\alpha + \bar{R}_m (x'\beta)] - \lambda[x'\Omega x + x'\beta\sigma_m^2] \tag{2}$$

$$\text{s.t. } Ax \leq b, \tag{3}$$

where x is a vector representing the proportion the assets in the portfolio, $\bar{R}_m$ and σ_m^2 are the mean and variance of the index, respectively, α and β are the vectors of intercept and slope coefficients from the single-index model, respectively, Ω is a diagonal matrix of the $\sigma_{\xi i}^2$ estimated from the regression errors, A is a matrix of resource use coefficients, b is a vector of available resources, and λ is a risk aversion coefficient.

The variance of the returns on asset i (σ_i^2) is:

$$\sigma_i^2 = \beta_i^2\sigma_m^2 + \sigma_{\xi i}^2, \tag{4}$$

where σ_m^2 and $\sigma_{\xi i}^2$ are the variance of the index returns and the error term, respectively. As equation (4) shows, the variance of an asset has two components. The first component represents the inherent variability common to all activities ($\beta_i^2\sigma_m^2$). This is called the systematic risk of the asset. The second component ($\sigma_{\xi i}^2$) is the portion of the asset's variability that is uncorrelated with the index, and is called non-systematic risk.

If the chosen index is a weighted average of the activities being considered, the assets in a portfolio can be easily classified according to the magnitude of their beta coefficients. Assets with betas greater than one are considered aggressive since their returns will change more than proportionately with a unit change in the index. The reverse is true for assets with betas less than one and they are classified as defensive assets.

Assets with beta values of one will, on the average, be as variable as the index which, by the construction of the model, also has a beta of one.

The variance of returns for a portfolio of activities expressed in summation notation is:

$$(5) \qquad \sigma_p^2 = [\sum_{i=1}^{n} x_i \beta_i]^2 \sigma_m^2 + \sum_{i=1}^{n} x_i^2 \sigma_{\xi i}^2.$$

The choice of investments will sometimes involve a trade-off between portfolio systematic and non-systematic risk, as well as the well known risk-return trade-off. This can be seen by examining equation (5), which is the sum of two parts. The first part contains the sum of activity betas weighted by the level of the activities; this is called the portfolio beta. The portfolio beta squared and multiplied by the variance of the index is the portfolio systematic risk. The second term is the sum of the activity non-systematic risks weighted by the square of the activity levels.

If the non-systematic risk is about the same for the various activities, then diversifying by investing a relatively small amount in each would reduce the portfolio non-systematic risk, since the x_i^2's decrease at an increasing rate. However, portfolio systematic risk can be reduced by concentrating investment in assets with low beta coefficients. Thus, there may be a trade-off between diversification (lower non-systematic risk) and specialization in assets with low betas. It should be mentioned, however, that the selection of low beta activities may also result in a lower expected return on the portfolio, depending on the intercept coefficient. The total variability in the portfolio, therefore, can be reduced by choosing activities with low betas and/or low non-systematic risk, although it seems difficult to find assets with both characteristics. The more likely situation will be a trade-off between low betas and low portfolio systematic risk. The final choice, of course, will also depend on the decision maker's attitude toward risk (the λ coefficient in equation (2)).

IV Data and Procedures

The general approach of this study was to budget monthly rates of return to a range of midwestern farm enterprises and to use these returns to estimate Betas, systematic and nonsystematic risks, and expected returns based on the single index model results. The activities considered included 3 hog operations (farrowing, farrow to finish, and finishing hogs); 2 beef operations (finishing chioce yearling steers and finishing choice steer calves); 3 crops (corn, soybeans, and wheat); and 1 non-farm investment (S&P 500 common stock index). Operational and fixed costs and revenues were estimated on a monthly basis for all the activities for the period from January 1974 through December 1985. The rate of return to management, capital and risk was then budgeted for each activity and for one crop or production cycle. These rates of return per growth period were converted to annual equivalents through compounding and used as the basis for the analysis.

The data on the beef and hog operations came from the Cooperative Extension Service at Iowa State University (Futrell). The crop data were drawn from several sources including the Indiana Crop and Livestock Statistics; the Corn, Soybean, and Wheat issues of USDA's Background for 1985 Farm legislation; and Estimated Production Costs from the Purdue Crop Guide. Data on the S&P 500 index returns were obtained from Standard and Poor's Daily Stock Price Record and The Outlook. The data on 3-month U.S. Treasury bills came from the Annual Statistical Digest of the Federal Reserve System.

The budgeted returns used here omit some transaction costs and "friction" for which little data is available. For example, The hog finishing budget did not include the search cost for finding appropriate feeder pigs or the slow growth and increased disease problems that can occur when moving feeder pigs. The results are obtained here for a typical midwestern producer; inferences about other regions or producers with higher

or lower management levels should be approached with caution. Also, although not all the data used correspond to a single state, it was assumed that the differences between Iowa and Indiana regarding agricultural practices and prices are small enough to allow comparable return estimates to be generated. By using monthly data seasonal variability of returns was retained, thereby making the results more comparable to real world situations. It should also be mentioned that the factor of land renting versus owning was not considered in the study, and that the crops were assumed to be stored until the month of marketing. Also, the returns on the crop activities do not include possible government program payments.

The index was constructed by obtaining a weighted average of all the activities. The weights emphasized the hog activities and were: 1/6 for the Farrow, farrow to finish, finishing pigs, and corn operations; 1/9 for soybeans; and 1/18 for the calves, yearlings, wheat, and stock activities. Using the monthly rates of return on each activity and on the index, the Beta coefficients were obtained by regressing each activity's returns on the index and solving the characteristic equation. Finally, the total variability in each activity was broken down into its two components (systematic and nonsystematic) to analyze the potential gain to be obtained if the activity is undertaken as a part of the overall portfolio.

V Results

The estimated Betas ranged from a low of -0.056 for corn to a high of 3.60 for the farrow operation (table 1). Two of the hog operations (farrow and farrow to finish) contribute the most to the variability in the index, indicated by a high level of systematic risk. On the other hand, activities like stocks and all three crops showed very low Beta coefficients, suggesting the presence of low systematic risk. The remaining activities' Betas were also relatively low.

The variability of the farm activities is much higher than that of the non-farm activity (table 1). This is as expected because the S&P 500 reflects a broad portfolio of stocks and virtually all of its variability is systematic risk. The farrowing operation has the highest variability of the enterprises considered, and the beef enterprises have the lowest variability of all the farm activities.

The activities with the highest proportion of non-systematic risk are the crops. Of the three hog operations, only finishing hogs shows a significant amount of non-systematic risk (about 55% of the total risk); for a farrow or farrow-to-finish operation most of the risk is systematic and, therefore, nondiversifiable. The mean rate of return varied from -22.99% for the wheat to 51.69% for the farrowing enterprise (table 1). The information contained in table 1 is all that is necessary to derive the E-V efficient frontier of activity portfolios in a diagonal QP model. The availability of a risk free asset will complete the analysis and provide the optimum enterprise mix.

When some simplifying assumptions are made, the single-index model reduces to the specific case of the CAPM. The most important assumptions are the existence of a risk-free interest rate for borrowing and lending, homogeneity of expectations among investors, and equilibrium in the capital markets. Under these assumptions, the intercept of the characteristic equation is expected to be equal to the risk-free asset's return. The intercept values of the estimated equations are shown in table 2. As the table shows, if the risk-free rate is estimated by be the return on 3-month treasury bills, with a mean return of 8.53% and standard deviation of 2.91%, the intercepts were significantly different from the risk-free asset return at the 5% level for the farrow, calves, yearlings, wheat, and stocks activities. In all these cases the intercept was lower than the risk-free return. For the rest of the enterprises the intercept was not significantly different from the risk free rate. The CAPM interpretation to intercept

values lower than the risk-free return is that enterprises with these intercept values offer returns that are lower than the expected equilibrium return. Alpha values different from the risk-free return have also been found in other studies in which the CAPM has been applied in agriculture (see for example Barry). This indicates that the CAPM assumptions may not hold in the agricultural sector and that care should be taken when it is used to analyze optimal farm enterprise mix.

To test the sensitivity of the results to changes in the index, a new index was formed as the unweighted average of the enterprises and the parameters were reestimated. The estimates follow the same pattern as when the weights emphasizing hog enterprises are used . The estimated Beta coefficients were: farrow 4.57, farrow/finish 1.62, finishing hogs 1.07, calves 0.39, yearlings 0.51, corn 0.24, soybeans 0.18, wheat 0.41, and common stocks 0.006. The farrowing activity is again identified as having the most systematic risk. Farrow to finish and finishing pigs also have relatively large amounts of systematic risk, and the crop activities and the common stock asset show low systematic risk. The choice of weights obviously affects the estimated Betas but the relative ranking of activities by systematic risk apears to be robust. This finding supports the view that the choice of weights to form the index is not crucial.

Table 3 shows the expected returns and variances of several portfolios that can be constructed from the coefficients in table 1. The portfolios considered in table 3 emphasize or deemphasize the hog activities. Portfolio 1 is the base portfolio; portfolio 2 assumes equal weights for all enterprises. Portfolios 3 and 4 represent hog operations that are diversified through vertical integration and into crops and stocks (horizontal integration), respectively. Portfolio 5 is composed of those activities with relatively low betas ($\beta < 1$).

As table 3 shows, the final return and variability of a portfolio can be tailored to specific preferences by choosing activities with low

systematic risk and/or low beta coefficients. Portfolio 3, for example, has a return of 18.6% and standard deviation of 23.6%. This portfolio clearly dominates portfolios 1 and 2 since it yields a higher return at lower risk. From portfolios 3 and 4 we see that the expected return for the vertically integrated operation (portfolio 3) is 20% higher than that for the horizontally integrated enterprise (portfolio 4). However, it also shows a 136% increase in variability. Portfolio 5 also shows a significant increase in return from portfolio 4, but its variability increases dramatically (an 85% increase in return for a 1152% increase in variability).

IV Conclusions

The estimated Betas and the returns and standard deviations of the portfolios considered indicate that the combination of farrowing and finishing into one operation may not be the best risk reduction alternative for hog producers. The estimates indicate that all the hog operations are relatively high in systematic risk. Combining one hog activity with either an off farm investment or crops can be more beneficial in stabilizing income than vertically integrating, say, farrow to finish with a finishing hog operation. Operating various stages of hog production as one enterprise may be profitable because of synergism, but it may be difficult to justify from a purely risk management point of view.

With a Beta of around zero, the common stock appears to be a good candidate for inclusion in the farm portfolio. With government programs reducing the variability of output prices, however, the systematic risk level of the crop activities is not much higher than that of the common stock. Synergism between hog and crop activities (especially corn) may offset the slight advantage for risk reduction offered by the off-farm investment. For example, swine wastes can be an important fertilizer source that is unused if the hog operation does not include crop activities.

Table 1. Beta Coefficients, Expected Rates of Return, Systematic, and Nonsystematic Risk for Alternative Enterprises.

Activities	Betas (β_i)	Mean Return[b]	Total Risk (σ_i^2)	System. Risk $(\beta_i \sigma_m)^2$	Nonsys. Risk[c] ($\sigma_{\xi i}^2$)
		--%---	----------(%)^2----------		
Farrow	3.602	51.69	18062.02	16485.76	1576.26
Farrow/Finish	1.265	31.56	2470.09	2033.31	436.78
Finish Hogs	0.899	24.96	2251.12	1026.93	1224.19
Calves	0.302	0.57	323.71	115.89	207.82
Yearlings	0.401	-0.06	581.00	204.32	376.68
Corn	-0.056	3.55	1354.46	3.99	1350.47
Soybeans	-0.021	11.75	984.33	0.56	983.77
Wheat	0.037	-22.99	1756.78	1.74	1755.04
Stocks	0.005	4.81	43.98	0.03	43.95
Index[a]	1.000	18.36	1270.64	1270.64	0.00

[a]The proportions of each activity in the index are: Farrow, farrow/finish, finish hogs, and corn, 1/6 each; soybeans, 1/9; calves, yearlings, wheat, and stocks, 1/18 each.

[b]The mean return for each activity is obtained by solving the regression equation at the mean of the index. It is also the same as the sample mean.

[c]Nonsystematic risk is also equal to (total risk - sytematic risk).

Table 2. Alpha Values from Regression Estimates.

Activities	Alpha Value	t-value
Farrow	-14.441	37.756**
Farrow to finish	8.347	0.008
Finishing hogs	8.451	0.005
Calves	-4.972	98.885**
Yearlings	-7.420	76.110**
Corn	4.576	1.304
Soybeans	12.141	1.499
Wheat	-23.675	66.675**
Stocks	4.715	37.281**

** Denotes significant at 1% for the t test: H_o: α_i - 8.525 = 0

Table 3. Expected Return and Risk of Alternative Portfolios.

Portfolio[a]	Expected Return (%)	Risk (σ_p^2)
1	18.36	1270.64
2	11.76	748.30
3	18.62	555.91
4	15.55	235.15
5	28.76	2944.74

[a] Portfolio1 = Farrow, farrow/finish, finish hogs, and corn, 1/6 each; soybeans, 1/9; calves, yearlings, wheat, and stocks, 1/18 each. (Base Portfolio)

Portfolio2 = Equal weights for all activities (1/9).

Portfolio3 = Farrow to finish, 40%; finishing hogs, and corn, 15% each; calves, soybeans, and stocks, 10% each.

Portfolio4 = Finishing hogs, 50%; corn, 20%; soybeans 15%; and stocks, 5%.

Portfolio5 = Finishing hogs, 50%; Farrow, 30%; corn, 15%; and stocks, 5%.

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