Returns to Limited Crop Diversification

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This study suggests a new single index model (SIM) application procedure which enables users to more easily assess the risk/return tradeoff among crop portfolios. A decision criterion is presented, based on a new crop portfolio performance measure derived here. The new procedure aids in reducing problems of data sensitivity often faced when using quadratic programming or standard SIM techniques.

Key words: crops, portfolios, performance measure, risk.

Selecting which crops to produce is one of the most important decisions faced by farmers. Prospective growers must know how to use risk management strategies to select the crops that best suit their needs (Weimar and Hallam; Reid and Tew; Weisensel and Schoney; Seale and Shonkwiler). One of the most popular approaches to managing risk is to reduce risk exposure through diversification (Barry; Irwin, Forster, and Sherrick). For many agricultural producers this strategy leads to growing a number of crops that differ in their production and/or marketing characteristics. However, methods which lower risk generally reduce expected net returns. Thus, it is important to account for the risk/return tradeoff when designing risk management strategies (King and Lybecker; McSweeny, Kenyon, and Kramer; Walker and Lin; Pyle and Turnovsky). In particular, growers often need to decide "how much diversification is enough" to capture most of the potential gains from expanding their enterprise mix.

The effects of diversification, reflected in the relationship between absolute risk levels and the number of crops included in a portfolio, are expected to be similar to those for stock market portfolios; risk is reduced significantly at first as additional securities are added to a one-product portfolio, but the rate of decline in risk levels declines as the portfolio grows (Jacob and Pettit, p. 188). In other words, most possible risk reduction is achieved by including a few products in a portfolio. This means that adding another crop to an existing rotation or creating an entirely new portfolio may or may not be an effective risk management strategy.

Previous studies most often have used linear or nonlinear programming procedures to identify optimal crop portfolios for a particular case. Although risk programming approaches lead to theoretically optimal portfolios, there are practical limitations to the use of these methods by agricultural producers.[1] Collins and Barry proposed using a single index model (SIM) as a computationally simpler technique which offers a more general risk measure that may provide better representation of future risk measures than the full variance-covariance matrix. However, applications of the SIM in agriculture have not overcome two limitations currently facing producers when using the method to select a portfolio of crops. The first problem is the SIM's reliance on a crop risk measure ("beta," defined later) which is unstable over time, creating potential measurement error in portfolio risk and return forecasts. Second, no decision criterion has been specified to aid in evaluating the risk/return tradeoff among portfolios. These problems may discourage growers and/or extension personnel from using SIM techniques.

The objective of this study is to suggest a new SIM application approach which enables users to assess more easily the risk/return tradeoff among crop portfolios. A decision criterion is presented, based on a new measure

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This is Giannini Foundation Research Paper No. 946.

[1] For example, farmers cannot do this kind of analysis easily due to time, skill, and data requirements, as described by Collins and Barry.

Western Journal of Agricultural Economics, 15(2): 204–212

which indicates a portfolio's return/risk performance relative to that of the market's fully diversified crop portfolio. The new performance measure's specification makes it stable over time enabling virtually any data to be used in its calculation, thus raising its potential value to (and use by) growers and/or extension personnel.

Portfolio Approach to Risk Reduction

The standard Markowitz mean-variance approach to developing portfolios implies that adding more crops to the enterprise mix reduces risk. Portfolio risk is measured using the full covariance model of returns for n enterprises. In quadratic programming (QP) applications the Markowitz model often is specified as

$$\text{(1)}\quad \text{Minimize } \sigma^2(R_p) = \sum_{i=1}^{n}\sum_{j=1}^{n} x_i x_j \operatorname{Cov}(R_i, R_j),$$

$$\text{subject to } \sum_{i=1}^{n} x_i E(R_i),\ x_{i,j} \geq 0,$$

where $\sigma^2(R_p)$ is the variance in returns of the portfolio, x_i and x_j are the portfolio proportions of crops i and j, $\operatorname{Cov}(R_i, R_j)$ is the covariance between crops, and $E(R_i)$ is the expected return for enterprise i (Jacob and Pettit, p. 201).[2] Portfolio risk is reduced most by including enterprises which are negatively or weakly positively correlated with the current enterprise (Mac Minn). Therefore, one strategy for portfolio creation is to start with the highest returning crop then continue to add crops or other enterprises with returns that have the greatest amount of negative correlation with the first product and/or the portfolio.

The SIM generates risk measures which are consistent with traditional QP risk measures, making it a good alternative to the Markowitz approach to portfolio choice (Sharpe; Collins and Barry; Turvey, Driver, and Baker). The SIM most often used is

$$\text{(2)}\qquad R_i = \alpha_i + \beta_i R_m + \epsilon_i,$$

where the return to enterprise i (R_i) is linearly related to the market's return (R_m), β is the risk measure,[3] α is a constant, and ϵ is an error term. The variance of returns for an enterprise is

$$\text{(3)}\qquad \sigma^2(R_i) = [\beta_i \sigma(R_m)]^2 + \sigma^2(\epsilon_i).$$

The SIM assumes that part of variance is due to the single factor of "the market," and a second component of variance comes from random factors unique to the enterprise. The β coefficient reflects the "systematic" risk from the market. This risk is nondiversifiable. The $\sigma^2(\epsilon_i)$ portion of variance is "nonsystematic" or diversifiable risk which can be eliminated by diversifying totally.

In this study, the β coefficients are adjusted to reflect risk in expected returns, above the level required to produce a crop, by subtracting the risk-free rate (R_f) from equation (2) giving $E(R_i) - R_f = \alpha_i + \beta_i[E(R_m) - R_f] + \epsilon_i$, or

$$\text{(4)}\quad E(R_i) = \alpha_i + R_f + \beta_i[E(R_m) - R_f] + \epsilon_i.$$

As suggested by Collins and Barry, the risk-free rate is defined as the return from leasing land. The expected values of α_i and ϵ_i are zero. As explained by Collins in his reply to Hutchinson and McKillop, the SIM in equation (4) appears similar to, but is quite different from, the standard capital asset pricing model (CAPM).[4]

Single index portfolio models have been used recently to assess diversification in agriculture. For example, Lopez-Pereira, Lowenberg-DeBoer, and Baker used a single index market model to study diversification opportunities for hog producers. Using Canadian gross revenue data, Turvey and Driver concluded that opportunities for diversification are limited due to the large degree of systematic risk within agriculture. Using net returns data, Collins and Barry found a large degree of nonsystematic risk in California markets. Gempesaw et al. showed that contrasting results such as these indicate the importance of data measurement and estimating techniques. Therefore, it is argued here that net returns data are more rel-

[2] Additional constraints may be needed to reflect productive, financial, and/or management limitations faced by individual farmers when selecting their product mix.

[3] Beta, β, is a standard measure used in the finance literature to indicate the relationship between a product or portfolio and the "market." It is defined as the ratio of a security's covariance with the market's variance,

$$\beta \equiv \frac{\operatorname{Cov}(R_i, R_m)}{[\sigma(R_m)]^2}.$$

[4] The CAPM is an equilibrium, one-period model; the SIM is not. Although the two equations have some common parameters, the meaning and significance of those parameters differ dramatically.

evant in farm planning and are used here in a way aimed at reducing the sensitivity of results to the estimation process.

Restrictions on a grower's use of the portfolio approach to crop selection are mostly internal rather than external. Internal restrictions are those specific to an individual producer, such as a grower's knowledge of production techniques, scale economies of production, and financial requirements. First, a successful portfolio can include only crops which can be grown efficiently with the available resources and management skills. Second, the number of crops a grower can produce profitably at one time may be constrained as diversification limits each crop's scale of production, thereby raising cost levels. Finally, capital requirements may grow along with the number of crops produced, forcing a grower to restrict the level of diversification achieved to the degree which can be financed.[5] The only significant external restrictions faced by growers are agronomic limitations on the list of crops which can be chosen. These limitations concern the productive capabilities of resources at the location, specifically, what crops can be grown efficiently and what crops must be grown to maintain resource productivity. For example, crops such as alfalfa often are included in traditional rotations because they have positive effects on soil quality.

Portfolio Performance Measures

A primary goal of diversification is risk reduction. However, it is expected that absolute levels of risk and return are positively related, so diversification reduces returns as well as risk. As a result, crops included in a portfolio should be evaluated in terms of their effects on relative risk and return levels of the portfolio.

Performance measures are designed to assess a portfolio's risk/return relationship and the effects of diversification on that relationship. Therefore, such measures may offer useful information to managers making cropping decisions. Two different performance indexes will be calculated here, one from the finance literature and one derived for this study. Their use as decision tools will be illustrated with an empirical example.

The first index to be calculated is the commonly used Treynor-Black appraisal ratio. It is a performance measure that divides the alphas by the residual standard deviations (nonsystematic risk),

$$(5) \qquad \frac{\alpha}{\sigma(\epsilon)}'$$

from the temporal Jensen Performance Index equation,

$$(6) \qquad R_{it} - R_{ft} = \alpha_i + \beta_i(R_{mt} - R_{ft}) + \epsilon_{it}.$$

In the appraisal ratio, α is a measure of an individual crop's or portfolio's performance (positive or negative) relative to expected values at time t. Dividing alpha by $\sigma(\epsilon)$ enables relative performance ranking of crops or portfolios with the highest ratio being ranked first (assuming constant-absolute-risk-aversion) (Lehmann and Modest).

The new index specifies the sources of deviations from expected returns by identifying the risk/return tradeoffs faced when considering alternate crop portfolios. By evaluating relative risk-adjusted returns in more detail, this index makes it easier to rank portfolios of crops. The index measures returns to limited diversification. For any portfolio p, these returns are expected to be a function of two factors: the cost and revenue from limited diversification.[6]

The first factor is the cost of limited diversification (CLD). To begin, a portfolio's risk measure needs to be adjusted when not fully diversified. By definition, the SIM market reference portfolio is fully diversified (it includes all crops grown in the region) and has no nonsystematic risk remaining; its total risk equals

[5] For example, some crops may require special equipment which cannot be used in producing other crops, thus increasing the total capital requirements beyond the borrowing capacity of the operation.

[6] A third factor expected to affect the benefits of diversifying crop portfolios is scale costs (SC). It is expected that economies of scale in production and marketing will be lost as a grower includes additional crops in the enterprise mix. For portfolio p,

$$SC_p = \sum_{i=1}^{k} (AVC_{ip} - AVC_i^*) + \sum_{i=1}^{k} (MTC_{ip} - MTC_i^*),$$

where AVC_{ip} is the average variable costs of product i in portfolio p, AVC_i^* is the average variable costs if product i is a one-product portfolio, MTC_{ip} is the marketing transaction costs of product i in portfolio p, MTC_i^* is the marketing transaction costs if product i is a one-product portfolio, and k is the number of crops in portfolio p (and $k \leq n$). If k equals one, SC_p will equal zero. SC_p cannot be estimated without data from a cross section of farmers. These data are unavailable currently. Therefore, although scale costs are expected to exist, their effects on diversification strategies must be addressed in future research.

its systematic risk. Any portfolio p that does not include all the crops in the reference portfolio is not fully diversified and its producer is exposed to some diversifiable risk. This means β_p will not precisely measure that portfolio's total risk. An adjustment to account for this voluntary change in total risk is to divide beta by the correlation coefficient between returns for portfolio p and the market portfolio, r_{pm} (Jacob and Pettit, pp. 674–75). This makes the portfolio's total risk-adjusted expected returns

$$(7) \qquad E(R_p) = R_f + \frac{\beta_p}{r_{pm}} [E(R_m) - R_f].$$

The cost of limiting the degree of diversification, therefore, is the difference between the total risk-adjusted and unadjusted equations:

$$(8) \qquad CLD = \left\{R_f + \frac{\beta_p}{r_{pm}} [E(R_m) - R_f]\right\} - \{R_f + \beta_p[E(R_m) - R_f]\}.$$

The second factor is the revenue from limited diversification (RLD). A portfolio's returns are expected to change (increase) when its contents become more selective (i.e., not all crops are included). This means the revenue from limiting the degree of diversification equals the difference between actual returns on portfolio p and the total risk-adjusted expected returns:

$$(9) \qquad RLD = R_p - \left\{R_f + \frac{\beta_p}{r_{pm}} [E(R_m) - R_f]\right\}.$$

By subtracting the expected revenues calculated with a total risk-adjusted beta from actual returns, RLD more accurately measures the benefits portion of a portfolio's performance.

Subtracting the cost from the revenue gives the returns to limited diversification[7]: $\pi_{D_p} = RLD_p - CLD_p$. Substituting equations (8) and (9) and combining terms gives

$$(10) \qquad \pi_{Dp} \equiv R_p - R_f - 2\left(\frac{\beta_p}{r_{pm}}\right) \cdot [E(R_m) - R_f] + \beta_p[E(R_m) - R_f].$$

The decision criterion normally is to select the portfolio with the highest π_D. Also, any number of portfolios can be ranked relative to their π_D values. This facilitates comparisons among portfolios of different size which have large differences in their absolute levels of return and risk.

Empirical Methods and Results

To illustrate the benefits of this new approach to using SIM, three issues will be highlighted: the value of a simple alternative to QP analysis, the ability to reduce problems caused by unstable crop betas, and the robustness of π_D as a performance measure. Empirical results are presented for Yolo County, in the delta of northern California, as a sample from a large study covering each of California's 58 counties.

Data used in the study are annual observations reported by county extension staff from 1958 to 1986 for every product grown there commercially. Average values for yield per acre (Y) and price per ton (P) are combined with average cost estimates to calculate average real net returns per acre for each product.[8] Costs per acre (C) are reported in Extension Service budgets published for each crop by county. Therefore, for each crop i average net returns per acre at time t is

$$(11) \qquad R_{it} = [(PY) - C]_{it}.$$

Leasing rate data are from Reed and Horel.

Net income data for Yolo County are presented in table 1 as an example of the range of outcomes facing growers in the 58 counties. The high absolute levels of risk evident in the data imply a need for, and potential gains from, diversifying into a variety of crops.

Figure 1 illustrates this potential by presenting the average relationship between the number of crops in a portfolio and the level of risk for all 58 counties. The portfolios used in the calculations were derived as examples only by starting with the single most profitable crop in each county and adding the second

[7] Risk preference parameters (exponents) can be placed on each of the factors (*RLD, CLD,* and *SC,* if used). Estimating these parameters is beyond the scope of this article. Therefore, all preference parameters are assumed to equal one and, hence, are excluded.

[8] An inflationary trend existed over the data period, so the price and cost series were adjusted into "real" terms (1986 dollars) by using the index of farm prices received reported in the *Economic Report of the President, 1988.* Also, using county average data obviously understates variance faced by individual firms but is useful in illustrating the concepts in this article.

most profitable crop to form an equally weighted two-product portfolio, then adding the next most profitable crop, and so forth. Standard deviations of each portfolio from each county were converted into percentage terms with the one-crop value being 100. The standard deviations from all portfolios comprised of the same number of crops were then averaged to get the values in figure 1. For 12-crop portfolios, for example, the average standard deviation was only 27% of the average standard deviation for one-crop portfolios, implying that at least 73% of original risk can be diversified away.

QP's Volatile Results

To illustrate the value of a simple alternative to QP analysis, a sample of portfolios are derived for Yolo County using a programming model. Using crop mean and variance-covariance data, the quadratic programming model, called GAMS/MINOS (Kendrick and Meeraus), uses equation (1) to estimate the optimal (minimum variance) portfolio, given a target return per acre and the constraint that $x_{i,j} \geq 0$. By repeating the calculations with different target returns, the expected value-variance frontier for the market can be developed.

The portfolios presented in table 2 demonstrate how volatile QP-derived crop rotations can be in terms of their scope (the number of crops included)[9] and their return/risk performance. For example, moving along the Yolo County efficient frontier from portfolio A to D involves shifting from a two-crop to a five-crop rotation and back again. This volatile composition does not facilitate analysis of the marginal effects of a one-crop change to an existing rotation—a common situation considered by growers. Also, the relative return/risk performances of those portfolios shifts up and down. Although portfolios A through D in table 2 are each "optimal" for the target return levels, they are not equal in their relative return/risk tradeoff.

A SIM approach to crop portfolio assessment facilitates marginal analysis of rotations and their return/risk tradeoff and, therefore, may provide a simple alternative to QP in some situations. If QP is used, a portfolio performance measure such as π_D can be applied as well, aiding in the portfolio selection process.[10] Also, SIM techniques enable the scope of rotations to be manipulated directly, if desired.

Another reason commonly cited for using SIM as a substitute for QP methods is to reduce application difficulties caused by data requirements. QP is data intensive and the crop rotations recommended by QP models are data sensitive—they may change if different temporal data are used. Yet, standard SIM methods also have problems with data sensitivity which require adjustments, as described below.

Table 1. Net Income Mean and Standard Deviation for Crops Grown Profitably in Yolo County ($/acre)

Crop	Mean	Standard Deviation	Leasing Rate
Alfalfa hay	73.94	139.79	97
Beans, dry	49.50	192.84	87
Corn, field	147.25	135.34	105
Grain sorghum	39.65	160.96	62
Pears	497.45	1,885.13	590
Rice	201.34	221.01	176
Safflower	71.61	94.46	56
Sugar beets	234.52	263.72	130
Tomatoes, process	582.22	483.21	222
Wheat	111.33	54.58	68

Note: All amounts are in real 1986 dollars. Crops grown in the county but which had negative mean returns for the data period are not listed.

SIM Beta Instability

In the finance literature studies have indicated that a security's beta (its measure of risk relative to R_m) should vary through time given changes in the micro and macro environments (Bos and Newbold). Hutchinson and McKillop and Gempesaw et al. raised the same issue in applying the SIM in agriculture. It is unlikely that betas for individual crops are stable over the 29-year data period used here. However, it is expected that betas for portfolios of crops will be increasingly stable as the portfolio becomes more diversified. By definition, a fully

[9] No application of a programming model with a constraint on the number of securities in the portfolio could be found in the literature. In a stock market study, Sutcliffe and Board constrained each security's portfolio proportion to be below a particular positive value, thereby forcing additional diversification.

[10] Portfolio selections made by individual investors (growers) depend upon their attitudes toward risk and return. Evaluating the selection process is beyond the scope of this article, so sample portfolios are presented here to illustrate the performance measures only.

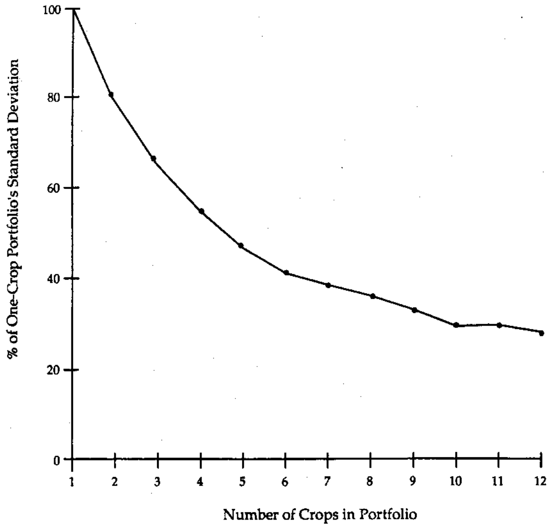

Figure 1. Diversification of risk (average for all California counties)

Table 2. Sample Crop Portfolios on the Efficient Frontier, Yolo County

Crops	A $134/ 63	B $158/ 158	C $234/ 176	D $275/ 183
	Portfolio and Target Return/Standard Deviation[a]			
Alfalfa hay	.0	.0	.0	.0
Beans, dry	.0	.339	.168	.0
Corn, field	.0	.0	.0	.0
Grain sorghum	.0	.0	.0	.0
Pears	.0	.014	.0	.0
Rice	.0	.0	.0	.0
Safflower	.0	.0	.0	.0
Sugar beets	.0	.054	.005	.0
Tomatoes, process	.048	.118	.281	.347
Wheat	.952	.475	.546	.653

[a] The values listed under each portfolio letter represent the proportion of that portfolio allocated to the relevant crop. These portfolios are derived so as to generate the arbitrarily selected target returns listed. The standard deviation for the portfolio is listed also.

diversified portfolio always will have a beta of 1.0, regardless of what data period is used in its calculation. Therefore, the π_D procedure of using portfolio betas helps reduce data sensitivity.

To determine whether the relative measure of systematic risk is stationary over time, separate portfolio betas are estimated using Yolo County data from 1958–86 and 1977–86 and compared for equality based on a Chow test.[11] This comparison for a range of partially diversified portfolios illustrates the effect of diversification on parameter stability. If β_p varies through time, its value in equation (10) cannot be calculated using the entire data set; it must reflect only data considered relevant to the period being evaluated.[12]

Table 3 presents results for the Yolo County sample portfolios. Of interest first are the two columns of betas. The columns labeled "29 year" and "10 year," respectively, include each portfolio's beta calculated using data from 1958–86 and 1977–86. The two betas prove to be significantly different only for portfolios of up to three crops. This supports the hypotheses that betas for individual crops (one-crop portfolios) will vary through time and that increased diversification will create increasingly stable betas for portfolios. The implications of these results are that diversified portfolio betas are not sensitive to data used in their calculation (making their use less restrictive than crop betas), which means that they may better represent future risk levels than do measures using crop betas.

The portfolios used here to illustrate the π_D procedure were derived as examples only by starting with the single most profitable crop in each county and adding the second most profitable crop to form an equally weighted two-product portfolio then adding the next most profitable crop and so forth. This analysis is done on a per-acre basis, which facilitates assessments of simultaneous production of any number of different crops on portions of total farm acreage without being bound by a particular farm size.[13]

[11] Chow tests comparing betas from 1967–76 and 1977–86 were conducted also, but produced virtually identical results to those for the 29-year versus 10-year test. Therefore, only one set of results is reported in table 3.

[12] The choice of relevant data is an empirical question; no general guidelines exist. Examples of approaches range from this study's use of a moving 10-year period to Gempesaw et al.'s use of all available data with a stochastic coefficients regression method.

[13] Previous assessments of cropping decisions (such as that by Carter and Dean) have identified and evaluated "traditional" cropping rotations within counties or regions. The analysis often focused on a representative farm consisting of some fixed total acreage. The rotations usually were evaluated as a unit over the number of years required to complete the cycle. That approach specifically recognizes the need to maintain soil quality by including crops such as alfalfa in rotations, despite their low level of profitability. Here it is assumed that efforts to maintain soil quality must be ongoing, therefore, crops included in traditional rotations for that purpose can be excluded from decisions concerning how to allocate land which is not undergoing conditioning.

Table 3. Diversification Analysis of Crop Portfolios from Yolo County

Portfolio[a]	Mean Return	r_{pi}[b]	Beta[c] 29 yr	Beta[c] 10 yr	$\frac{\alpha}{\sigma(\epsilon)}$[d]	π_{Dp} 29 yr	π_{Dp} 10 yr
1. Tomatoes, process	582	.800	2.58	2.88*	1.04	5.70	−58.54
2. Sugar beets	408	.921	1.98	2.11*	0.95	52.57	30.53
3. Rice	339	.966	1.71	1.84*	1.27	52.45	33.06
4. Corn, field	291	.982	1.46	1.51	1.97	49.85	
5. Wheat	255	.986	1.19	1.26	3.16	54.96	
6. Alfalfa hay	225	.991	1.12	1.16	3.15	37.81	
7. Safflower	203	.987	1.02	1.07	2.33	28.38	
8. Beans, dry	184	.998	1.08	1.05	11.34	4.46	
9. Grain sorghum	168	1.0	1.0	1.0	—	0	

[a] The portfolio number indicates how many crops are included. The crops in a portfolio are those listed from 1 down to the portfolio number. All crops included are equally weighted in each portfolio.
[b] This is the correlation coefficient between the portfolio listed and the market portfolio for the county made up of all crops listed in this table.
[c] These portfolio betas are calculated using data from 1958–86 and 1977–86, respectively. Asterisks indicate that the 10-year beta is significantly different than the 29-year beta according to a Chow test.
[d] This is the Treynor-Black index, as described in the text.

Collins and Barry used the average of net returns to all crops produced in the county studied as the SIM market proxy (for R_m). The same is done here, although crops with negative average returns are excluded because farmers would not knowingly include them in a profit-maximizing strategy. Therefore, R_m is calculated for each year using Yolo County data from all profitable crops.

In this study the Prais-Winsten (P-W) generalization of the Cochrane-Orcutt procedure is used to estimate SIM betas for portfolios of crops. Previous studies have used varied estimation methods. Collins and Barry and Turvey and Driver used ordinary least squares; Irwin, Forster, and Sherrick and Barry used the Cochrane-Orcutt approach to correct for autocorrelation; and Gempesaw et al. used the P-W and stochastic coefficients regression methods. However, all earlier studies estimated betas for crops not portfolios, so betas from this study are not comparable to those reported elsewhere.

Performance Measure Results

Performance results for the sample portfolios also are presented in table 3. Those results provide evidence of the weakness of the standard Treynor-Black index compared to the new index in evaluating the risk/return tradeoffs among crop portfolios. Using the Treynor-Black index to rank and select from among the portfolios leads to greater levels of diversification than that indicated using π_D as the decision criterion. The Treynor-Black index assumes only a small percentage of assets in the market portfolio are held by an investor. As a result, it breaks down as a performance measure because it will have an increasingly smaller denominator and eventually become undefined, as portfolios diversify to become more similar in composition to the market index portfolio. This means it is biased in favor of more diversified portfolios. This situation illustrates the need for a more robust index when making cropping decisions. The π_D index is such a measure because it is specified so as to avoid biases related to portfolio scope.

To demonstrate the usefulness of π_D as an addition to standard SIM procedures, its application in Yolo County is considered. Index values for sample portfolios are presented in the last two columns of table 3.

The new performance measure is intended as a tool for ranking any number of portfolios based on their return/risk tradeoff. The column of index values calculated with the entire 29-year data set lead to portfolios 5, 2, and 3 being ranked first, second, and third, respectively. However, portfolios 1–3 have betas which are unstable over time. As a result, new betas reflecting "current" risk levels are calculated using the most recent 10 years of data. Substituting the 10-year π_D values for the 29-year values leads to a change in the relative rankings of these sample portfolios; portfolios 2 and 3 become ranked fifth and fourth, respectively. Also of interest, portfolio 1's π_D value becomes negative when shifting from the

29-year to the 10-year index, indicating that recent return/risk performance of that portfolio has not been good.

Summary and Conclusions

This study suggests a new SIM application approach which enables growers and/or extension personnel to more accurately assess the return/risk tradeoff among crop portfolios. A new performance measure is derived from the SIM to aid in ranking crop portfolios based on that tradeoff.

It is shown that the new performance measure and its application can be a useful addition to, or substitute for, more complicated methods. For example, the π_D index provides a criterion by which crop rotations derived using a QP model can be ranked. This method also aids in avoiding data sensitivity problems of both QP and standard SIM procedures. In particular, using betas for portfolios, rather than for crops, may give more accurate results when establishing rankings. Crop betas vary through time, but betas become increasingly stable for more diversified portfolios. In the example presented, betas became stationary for portfolios of at least four crops.

Finally, it is shown that the new index derived in this study is superior to the standard Treynor-Black appraisal ratio when ranking crop portfolios. Performance measures from the finance literature, such as the Treynor-Black ratio, are likely to fail when evaluating agricultural markets because they are based on the assumption that portfolios always will be composed of a small percentage of the assets in a market. To apply the SIM in agriculture, small (county?) regions must be used as the market proxy to produce results relevant to individual decision makers. Yet, this means that actual crop rotations may include a high percentage of enterprises in the market proxy. The π_D index is designed to be a robust measure of performance in any agricultural market.

[*Received September 1989; final revision received July 1990.*]

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