The Robustness of Single Index Models in Crop Markets: A Multiple Index Model Test

Steven C. Blank

The single index model (SIM), developed for analysis of financial assets, is assessed as a tool for evaluating the risk-return tradeoff faced in agricultural enterprise selection. This study tests whether some of the hypotheses underlying the SIM are valid when the SIM is used in agricultural cropping decisions. Empirical evidence from county-level data does not support SIM hypotheses, indicating that more robust results might come from multiple index models.

Key words: cropping decisions, index models, risk.

Single index models (SIM) are increasingly being used to assess the risk-return tradeoff faced in planning farmland use (Gempesaw et al.; Turvey and Driver). Due to its simplicity relative to other portfolio choice models, Collins and Barry argued that a SIM approach could be used by farmers in making crop selections. However, McDonald and Lee noted there is a growing body of finance literature which cites limitations of the SIM and its necessary assumptions. Yet, the recent literature favoring applications of the SIM in agriculture have not formally dealt with the criticisms raised in studies of securities markets. If empirical results from agricultural markets do not support the SIM's theoretical assumptions, its application may be misleading. On the other hand, if those assumptions prove to be valid, abandoning the simple SIM for more complex models derived from portfolio theory may not be justified in many cases.

Therefore, the objective of this study is to test whether some of the assumptions underlying the SIM are valid when the SIM is used to evaluate risks in agricultural cropping decisions.

SIM Theory

The SIM model is a returns-generating process which describes the risk-return relationship for an asset (which can be securities, real property, agricultural enterprises, etc.). The SIM most often used is

$$R_i = \alpha_i + \beta_i(R_m) + \epsilon_i, \tag{1}$$

where R_i is the return on crop i, R_m is the return on an appropriate market index, α_i is a constant, and ϵ_i is an error term. Beta, β, is a standard measure used to indicate the relationship between a crop (or portfolio) and the index, R_m. Beta is defined as the ratio of a product's covariance with the index to the index's variance,

$$\beta_i \equiv \frac{\mathrm{Cov}(R_i, R_m)}{\sigma^2(R_m)}. \tag{2}$$

Beta is also referred to as a measure of a crop's systematic risk relative to the index. Therefore, the beta for the index itself is defined to equal one. The total variance in returns from equation (1) can be expressed as

$$\sigma^2(R_i) = [\beta_i\sigma(R_m)]^2 + \sigma^2(\epsilon_i), \tag{3}$$

where the first component is systematic risk and the product's unsystematic (diversifiable) risk is the second component $[\sigma^2(\epsilon_i)]$.

In this study, the β coefficients are adjusted to reflect risk in required returns ($/acre) by

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subtracting the risk-free rate from equation (1) giving

$$R_i - R_f = \alpha_i + \beta_i(R_m - R_f) + \epsilon_i, \tag{4}$$

where the intercept is Jensen's performance measure. In this study, a risk-free return (R_f) available to farmers is defined as the return from cash leasing land to others, as suggested by Collins and Barry. The expected values of α_i and ϵ_i are zero (Jensen; Haugen, pp. 284–87).[1] As explained by Collins, the SIM in equation (4) appears similar to, but is quite different than, the standard Capital Asset Pricing Model.[2]

The SIM provides a simplified method for establishing a mean-variance opportunity set, often called a Markowitz efficient frontier (EF). The EF of portfolios available to a decision maker identifies the portfolio with the lowest level of risk for each level of return available under current market conditions. If a risk-free investment exists, borrowing and lending can occur and the EF becomes linear. That is, cash-lease transactions transform the EF into a linear opportunity schedule (OS). The OS created by linear combinations of cash rent activities and the optimal crop portfolio is the new EF available to individual decision makers. Therefore, the SIM can be used to test specific hypotheses implied by portfolio theory.

SIM Assumptions and Their Validity for Crop Markets

Use of the SIM requires making several assumptions and raises some hypotheses. Three necessary and two implied hypotheses are tested in this study of SIM applications in crop markets. The first three hypotheses to be examined relate to common assumptions used in SIM portfolio models.

Hypothesis (*a*). The relationship between returns, R_i, and risk, β_i, is linear.

Hypothesis (*b*). The intercept of the SIM [α_i in equation (1)] equals the risk-free (cash-leasing) return. [This is equivalent to $E(\alpha_i) = 0$ for equation (4), the regression model used to estimate the SIM.]

Hypothesis (*c*). An enterprise's residual (diversifiable) variability, ϵ_i, does not affect its ranking among alternate investments.

Hypothesis (*d*). The SIM, expressed in equation (1), implies that only the macro factor, R_m, influences returns for individual agricultural crops, no micro factors are significant.

Hypothesis (*e*). There is one geographic "market" affecting all crops, thus enabling use of a single, aggregate measure of risk across local markets.

Hypothesis (*a*), that a market's risk-return relationship is linear, implies that market participants are able to lease land, in or out, in order to hedge their risk exposure. Papers by Feder, Just, and Schmitz; and Meyer and Robison develop theoretical commodity hedging models and recognize the similarity between their models and a portfolio model with a riskless asset. However, efficient hedging in this sense can only occur if there is an active, competitive market for leased land.[3] Without perfect hedging opportunities, the nonlinear EF will not be transformed into the linear OS postulated by the SIM. Therefore, empirical tests of the linear OS assumption have implications concerning land leasing opportunities in the market being studied.

Hypothesis (*b*) follows from hypothesis (*a*) and is found through simple mathematical manipulation of the SIM. The intercept term should reflect the return required of an enterprise (or portfolio) with a β of zero, which in equation (1) is expected to equal the risk-free rental rate. This hypothesis is likely to be supported only in regions with a highly efficient, competitive market for leased land. Whereas these markets may be efficient in the aggregate, disaggregated local markets are more likely to show signs of inefficiency in the allocation of leased land, resulting in an EF which is not perfectly "efficient" in a mean-variance sense.

Hypothesis (*c*), that an enterprise's diversi-

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[1] The observed values of α_i will not always be zero, of course, because R_f is negotiated before production is undertaken and R_i and R_m are found after crop production and marketing are completed. However, the weighted sum of all α_i values across all i must equal zero.

[2] The Capital Asset Pricing Model 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.

[3] Hedging the returns to owning land can only be accomplished through leasing portions of land available. Hedging using forward and futures contracts reduces price risk, but net returns will still vary due to production risk. Therefore, to adjust the level of total risk exposure, owners can cash lease land to replace varying returns per acre with "fixed" returns on the desired portion of acreage owned.

fiable risk level does not affect its relative attractiveness, is central to the validity of the SIM. Portfolio theory argues that residual variability can be reduced through diversification, therefore, it is not a form of risk which investors need to consider when ranking investments. Although diversification can be accomplished easily and with little or no cost to investors in securities markets, there are physical and financial limitations on crop diversification efforts of producers which may affect their crop selections and expose them to diversifiable risk (Blank).[4] Also, diversifiable (or unsystematic) risk derives from factors unique to the enterprise which are not explained by movements of the general index, meaning that if diversifiable risk is significant, multiple (rather than a single) factors are needed to model it (Levinsohn and MacKie-Mason). This is necessary because the SIM estimate of an enterprise's risk, β, will be over- (under-) stated if residuals of alternative enterprises are negatively (positively) correlated rather than uncorrelated as assumed by the SIM. In agriculture, unsystematic risk has often been found to be large compared to systematic risk (Collins and Barry; Gempesaw et al.),[5] casting doubt on the assumption that it can always be ignored.

Nonetheless, using the SIM implies that only the macroeconomic factor of systematic risk, β_i, is relevant to decision makers when comparing investments (Haugen, pp. 153–54). The SIM's focus on beta is based on the hypothesis that all crop activities are related to the same factor, R_m, and differ only in their degree of covariance to this index. This implies that no microeconomic factors unique to the product or firm will significantly alter estimates of risk for that particular enterprise. For example, the relative size of a firm (or local production region) is often expected to alter both the level and distribution of returns (Haugen, pp. 184–85). The significance of such micro factors has not been tested in an agricultural index model framework. Therefore, hypothesis (*d*) is designed to do so. If the hypothesis is supported, it can be argued that multiple, rather than single, index models may be more appropriate in agriculture.

All SIM studies have implicitly used the hypothesis of a single OS. Yet, Collins and Barry define a competitive market for crops as "a region of homogeneous land" and choose a county to represent such a market. This implies that regions of heterogeneous land are expected to have different profit levels relative to risk levels faced, giving them different opportunity schedules. A single national (or international) market may exist for financial securities, but that is not the case for agricultural commodities. Whereas, perfectly "storable" securities have insignificant transactions costs associated with their transfer, production costs and prices for perishable crops both vary across time and space (Weisensel and Schoney; Weimar and Hallam). As a result, farmers' risks differ by location, making the SIM hypothesis of an aggregate risk measure across geographic regions inappropriate in many cases. Thus, the SIM should be based on the smallest economic unit definable (a firm, county, state, etc.) for which the hypothesis of a single OS is realistic.

Testing SIM Robustness

Many authors (such as Banz, and Stambaugh) have outlined difficulties in testing index models. Therefore, this article does not claim to test the validity of the SIM generally, it considers only the robustness of results generated when the SIM is applied in geographically disaggregated agricultural markets. To do this, a two-step process is used following that of Levinsohn and MacKie-Mason. First, disaggregated time-series data are used to estimate betas for individual crops. To test the fourth hypothesis across time, the beta for each crop *i* in each county is estimated at time *t* from equation (4) modified here for this purpose:

$$(5) \qquad R_{it} - R_f = \alpha_{it} + \beta_{it} R_{mt} + \Omega_{it} S_{it} + \epsilon_{it},$$

where S_{it} is a proxy for the micro factor "production region importance," measured as the county's *i*th product's relative market share (percentage of total acreage of crop *i* in the state which is accounted for by producers in the relevant county at time *t*), and ϵ_{it} is a residual. If this "size" or "share" variable does not have a significant effect on crop returns, equation

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[4] Of course, crop producers may diversify in many ways, such as holding financial assets, besides holding various crop enterprises.

[5] The relative level and significance of diversifiable risk are two different issues. As noted by Gempesaw et al., and Turvey, the relative sizes of an asset's systematic and unsystematic risk may be influenced by data definition (such as gross versus net income). In this study, the concern is whether unsystematic risk is significant in explaining crop returns regardless of the relative amount of that risk.

(5) is identical to the SIM. If size is significant, multiple factors may be needed to accurately estimate risk levels.

The second step is to use the results from step one in a single cross-sectional analysis of all crops from all geographic regions. The SIM is expanded into a multiple index model (MIM) by including variables enabling tests of all five hypotheses previously listed. The MIM is specified as:

$$(6) \qquad R_i - R_f = \alpha + \Phi\beta_i - \tau\beta_i^2 + \phi\epsilon_i + \Theta S_i + \delta_s D_{si} + \delta_n D_{ni} + u,$$

where S_i is now the average of crop i's state market share over the data period, u is an error term, and the other variables are described below. Equation (6) is an expanded version of the SIM expressed in terms of excess returns in equation (4). A SIM understates diversifiable variances if residuals are correlated; using a MIM reduces the correlation (Haugen, pp. 168–69). The SIM hypotheses lead to these expected values for the coefficients in equation (6): $E(\alpha, \tau, \phi, \Theta, \delta) = 0 < \Phi$. The tests associated with these variables are explained below.

Hypothesis (*a*) is tested by adding a nonlinear risk variable, β^2, as an independent variable in the cross-sectional model in equation (6). It is the square of the beta estimated in the time-series stage of analysis. If its coefficient, τ, is negative, it implies that lower increases in returns are demanded as risk is increased. This is consistent with decreasing absolute risk aversion and operating along the concave EF, rather than the linear OS.

The test for hypothesis (*b*) requires determining whether the intercept of equation (6) is zero. If it is not, the SIM intercept does not equal the risk-free rate. The intercept term used here is Jensen's performance measure. As Jensen explains, a significantly positive (or negative) intercept is a measure of bias in the asset's returns relative to the returns required of it given its risk level. For a grower, a significant intercept would partially represent returns to the variability in the market for leased land.

Hypothesis (*c*) is tested by adding the error term, ϵ_i, expressed as the standard error of the regression (SER) from time-series regression on equation (5) for each crop as a factor in the cross-sectional analysis in equation (6). A significantly positive coefficient, ϕ, implies that diversifiable variability is important in ranking alternative cropping enterprises. If this test, or the others, rejects the relevant hypothesis, the robustness of SIM betas is questioned and MIMs may provide more accurate estimates of crop risk levels.

To test hypothesis (*d*) across crops, a market-share proxy variable is included in equation (6). Statewide market share is specific to crop *i*, so it reduces unsystematic risk (measured using SER) if it is a significant factor. If the market-size variable is significant in explaining R_i, it supports the hypothesis that micro factors affect product returns, suggesting that MIMs may be superior to SIMs in agricultural applications.

Finally, hypothesis (*e*) is tested by including dummy variables in equation (6) for two local markets to determine whether individual county returns differ from more aggregate (e.g., state) returns.[6] If the dummy for the southern desert county, D_{si}, or the northern delta county, D_{ni}, is significantly different than zero, then this would indicate that risk profiles vary by regions. This would bring into question the efficacy of a single aggregate risk measure and provide support for the conjecture that betas should be defined at the smallest economic unit (e.g., farm or county level).

There is some debate over the choice of proxies for R_m and R_f. Collins and Barry say the choice of R_m is not critical and quote Sharpe (p. 281) saying that R_m should be "any . . . factor thought to be the most important single influence on returns. . . ." As a result, they use average (equally weighted) net returns from all crops in a county as their index and suggest leasing rates as a proxy for R_f. Blank, and Gempesaw et al. do the same, but Blank shows the sensitivity of beta estimates to the length of data sets used. Therefore, it is understandable that beta estimates varied when Turvey used indices comprised of equally weighted and acreage-weighted crop portfolios.[7]

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[6] A large volume of work exists in the literature concerning spatial integration of commodity markets (see Faminow and Benson, for example). Most of that work focuses on the degree of temporal correlation in prices of one product in different spatial markets or of different forms of a single product in one market. In this study, the focus is on net returns of different products in different local markets. Although the two research agendas have some common themes, results generated are not directly comparable.

[7] A reviewer raised the issue of using a "complex" index of market returns. This point may become important in SIM studies. The index used here represents actual average returns per acre received in a county from the crop portfolio produced that year. Any other indexing method would give distorted estimates of actual average returns, therefore, a complex index is inappropriate in this case. In this study the composition of the index changes very little each year, and the total amount of change has been small over the three decades studied (see sample data below). Never-

It is argued here that geographically disaggregated data should be used when evaluating cash market opportunities facing individual crop producers. Farmers need to know what their market is offering in terms of returns and risk. Betas estimated using national or state (average) data are not relevant to a producer who cannot sell in national or statewide markets. By definition, highly aggregated market data cannot be perfectly correlated with each of the specific local markets in which decision makers operate. The low degree of correlation between local and aggregate markets generates betas which understate actual risk levels faced by farmers and may alter the relative attractiveness of alternate crops.

In contrast, the county-specific indices in this study are computed from the average of net returns from all crops grown in the county, weighted according to each crop's proportion of total acreage in crop production. If hypothesis (*e*) is valid, risk-return relationships (OSs) in each county will not be statistically different, despite betas being estimated from different indices. If counties have different OSs, as argued earlier, betas estimated using a disaggregated index will be more efficient and will cause the county dummy variables in equation (6) to be significant.

Time-series data used in this study are annual observations from 1958 to 1986 reported by extension staff in each of California's 58 counties for every commercially grown product. 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* are

$$R_{it} = [(PY) - C]_{it}. \quad (7)$$

The technique used to estimate betas has most often been ordinary least squares (OLS) (Collins and Barry; Turvey and Driver), but Barry; Irwin, Forster, and Sherrick; and Blank used the Cochrane-Orcutt (CO) iterative method to reduce effects of autocorrelation.[9] In this study, autocorrelation is present in some of the time series, therefore, the CO method is used to estimate equation (5). The cross-sectional MIM is estimated using ordinary least squares.[10]

Empirical Results and Implications

Three California counties are chosen to illustrate the relationship between crop returns and risk. Fresno, Imperial, and Yolo counties represent different geographical regions in the state: respectively, the central valley, southern desert, and northern valley/delta regions. The list of crops for Fresno county is divided into two groups: trees and vines (those crops requiring a long-term commitment) and field and horticultural crops (those requiring a commitment of only one year or less). Separate results are reported for each group to facilitate comparison.

Tables 1–3 summarize the time-series data and results for the three sample counties. The first three columns of each table present historical data, while the last two columns list the betas and standard errors of the regressions from estimations of equation (5) for each crop. The third column presents actual average cash-leasing rates, adjusted from Reed and Horel, which are used as the risk-free return for the relevant crop. It is noted that the disaggregated betas in the three tables prove to be significant more often than those in other studies (such as Gempesaw et al.) using aggregated data. This implies disaggregated data may produce more efficient estimates of relevant risk levels.

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theless, stock market studies and Blank's crop market study have shown that betas change over time, whether the composition of an index changes or not. This means complex indexing efforts will not eliminate the need to reestimate beta coefficients over time.

Sample data: The coefficient of variation for the market share data for 1958–86 in Yolo County is: alfalfa, .388; beans, .896; corn, .343; sorghum, .635; pears, .311; rice, .181; safflower, .380; sugar beets, .418; tomatoes, .225; and wheat, .634. This low level of variation indicates the continuity in cropland allocation over the study period.

[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 growers but is helpful in illustrating the issues here.

[9] A reviewer noted that agricultural SIM studies need to consider whether single-equation or system estimation techniques should be used. For example, seemingly unrelated regression (SUR) could be used if production decisions are joint over time. In this study, the vast majority of crops studied are annuals so each year's cropping pattern can be independent of previous patterns. Studies involving more perennials and/or livestock enterprises may need to use SUR.

[10] As noted by a reviewer, the possibility of heteroskedasticity exists between the betas and the error terms. Therefore a Goldfeld-Quant test was performed on those two series. The hypothesis of homoskedasticity could not be rejected at the 95% confidence level, so OLS estimation could be used.

The second column of each table presents the average share of total state acreage of the crop accounted for by acreage in that county. Market share proved to be significant when estimating equation (5) for 22 of 41 crops reported in the three tables. Of those crops with a significant market share factor, all had a negative sign except alfalfa, plums, silage, and strawberries in Fresno County, carrots in Imperial County, and sorghum in Yolo County. These results indicate that a MIM may be useful in some crop markets, but further research is necessary to explain the effects of market share on enterprise returns.

The time-series results are pooled into a cross section and used to estimate the MIM. The results, with t-statistics in parentheses, follow:

$$\begin{aligned} R_i - R_f = {} & \underset{(12.94)}{-175.46} + \underset{(2.71)}{58.3183\beta_i} \\ & \underset{(-1.72)}{-\,32.3699\beta_i^2} + \underset{(9.81)}{2.0805\epsilon_i} \\ & \underset{(-.82)}{-\,15.9093S_i} - \underset{(-42.48)}{652.04D_{si}} \\ & \underset{(-7.68)}{-\,326.29D_{ni}}. \end{aligned} \tag{8}$$

The R^2 of equation (8) is .67. As expected in the SIM, beta is a significant factor in equation (8).

The hypothesis of a linear OS can be rejected, although the results are not strong. The coefficient for β^2 is negative and significant at the 90% confidence level, but it is insignificant at the 95% level. Nonlinearity is consistent with decreasing absolute risk aversion and a concave OS. Implications are that there may be some variance in real leasing rates or that individual growers may have limited opportunities to hedge through leasing land which, in turn, affects the validity of other SIM hypotheses, as noted below.

The intercept of equation (8) is negative and significantly different than zero, contrary to the SIM hypothesis. For a particular enterprise, such a result is normally interpreted as an indication of poor performance (Jensen). For a specific region, it might indicate that growers do not receive the full risk-free rate for leased land. However, if the OS is nonlinear (concave), negative intercepts are expected from a regression on excess returns. If growers cannot efficiently hedge returns by leasing land, or if growers are unaware of current leasing rate levels, there is no reason for the SIM intercept to be the risk-free rate [or zero when expressed as equation (8)].

The factor of residual (diversifiable) variability is positive and significant in equation (8). This provides strong evidence to reject SIM hypothesis (*c*) for these crop markets. This result may reflect growers' concerns over limits in their ability to diversify away all residual risk. If there were no apparent limits to hedging opportunities (the OS was linear), residual risk might not be significant. In general, this result is quite a blow to the validity of applying the SIM in agricultural enterprise analysis. Clearly, some enterprise-specific factors significantly influence the return-generating process, requiring use of a MIM to avoid specification error.

Results for hypothesis (*d*) indicate that despite many significant results in the time-series analysis of individual crops, market share is not generally a significant factor in these county crop markets. These cross-sectional results indicate that the search for micro variables to include in MIMs may be more productive if firm-level factors are used, rather than industry or regional factors. The regional market-share variable used here may be too aggregated to be of use. This issue may be a fruitful area for future research.

General hypothesis (*e*) that there is a single, aggregate geographic market is not supported by the empirical results. The fact that the dummy variables in equation (8) for Imperial, D_s, and Yolo, D_n, were both statistically different than zero and each other indicates county OSs differ significantly. Therefore, county markets should be evaluated separately, which requires data disaggregated to that unit level or smaller (town- or firm-level data, for example).

Conclusions

In summary, none of the five hypotheses of the SIM tested here are strongly supported by the empirical results. The findings of the study support the following conclusions. First, at a weak (90%) level of confidence the hypothesis of a linear opportunity schedule could be rejected. A nonlinear OS implies that farmers are not always able to efficiently leverage revenue risk through cash leasing land. Second, there is a strong indication that cash leasing land cannot, in general, be considered risk free.

Table 1. Returns and Risk for Crops Grown Profitably in Fresno County, 1958–86

Crop	Mean Return	Average Mkt. Share	Lease Rate	Beta	SER[a]
	($/acre)	(%)	($/acre)		
Field and Horticulture Crops:					
Alfalfa hay	61.31	8.60**	150	.031	74.59
Alfalfa seed	46.81	3.43*	150	.333***	114.57
Beans, dry	27.94	.72*	119	.226***	96.40
Corn, field	50.78	1.10	95	.033	55.69
Cotton	258.24	20.50	180	.136	137.10
Lettuce	860.44	.47	150	.419	787.06
Onions, dry	1,934.83	.22**	710	.775	768.62
Rice	187.35	1.10	172	.246***	117.44
Silage, corn	145.14	.79**	125	.061**	46.85
Strawberries	2,910.55	.02*	2,455	8.185***	1,728.04
Sugar beets	228.49	1.72	134	.167*	209.00
Tomatoes, fresh	5,280.24	.11***	2,035	2.441**	1,381.53
Tree and Vine Crops:					
Apricots	1,041.11	.03***	593	.410	643.45
Grapes, raisin	209.01	13.28***	500	.847***	277.23
Grapes, table	1,341.51	.71	980	2.022***	493.85
Grapes, wine	439.67	1.66**	458	.601***	247.95
Lemons	1,507.14	.03	700	.332	717.87
Olives	60.53	.09**	508	.853***	449.57
Oranges	911.39	1.02***	626	−.183	440.92
Peaches	1,680.71	.79*	950	2.024***	469.35
Plums	2,500.21	.67*	1,195	1.828***	688.08

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 here. A * indicates significance at the 90% level, ** indicates significance at the 95% level, and *** indicates significance at the 99% level.

[a] These are the standard errors of the temporal (county-level) regressions used in the cross-sectional analysis.

Third, although diversifiable risk is often assumed to be unimportant in SIM applications, it is found that it does significantly and positively affect the risk premium. Thus, it appears that farmers do require compensation for nonsystematic risk. Fourth, given the results for hypothesis (*c*), it may be the case that a single factor model does not sufficiently reflect agricultural risks. Finally, the results of this study indicate that risk profiles differ by regions,

Table 2. Returns and Risk for Crops Grown Profitably in Imperial County, 1958–86

Crop	Mean Return	Average Mkt. Share	Lease Rate	Beta	SER[a]
	($/acre)	(%)	($/acre)		
Alfalfa hay	88.32	11.47	125	−.111	91.06
Alfalfa seed	91.23	1.03	125	−.135**	78.54
Asparagus	159.53	.20	150	.774*	473.55
Barley	73.01	2.78	100	−.063	48.38
Cantaloupes	718.42	.83**	150	.322	320.96
Carrots	617.92	.40**	150	2.435***	584.13
Cotton	354.88	3.71***	125	−.195	234.17
Onions, dry	469.70	.31	150	1.645***	593.88
Oranges	565.91	.05	150	1.080***	576.84
Sugar beets	818.74	3.69	125	3.141***	1,245.27

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 here. A * indicates significance at the 90% level, ** indicates significance at the 95% level, and *** indicates significance at the 99% level.

[a] These are the standard errors of the temporal (county-level) regressions used in the cross-sectional analysis.

Table 3. Returns and Risk for Crops Grown Profitably in Yolo County, 1958-86

Crop	Mean Return	Average Mkt. Share	Lease Rate	Beta	SER[a]
	($/acre)	(%)	($/acre)		
Alfalfa hay	73.94	2.51	97	.702***	49.22
Beans, dry	49.50	.38*	87	1.031***	81.36
Corn, field	147.25	1.96	105	.636***	56.49
Grain sorghum	39.65	1.88***	62	.559***	42.00
Pears	497.45	.04**	590	6.029***	994.73
Rice	201.34	1.94	176	1.174***	81.46
Safflower	71.61	1.70***	56	.599***	46.42
Sugar beets	234.52	1.71**	130	1.755***	112.51
Tomatoes, process	582.22	3.06	222	2.585***	161.61
Wheat	111.33	3.33	68	.249**	44.96

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 here. A * indicates significance at the 90% level, ** indicates significance at the 95% level, and *** indicates significance at the 99% level.

[a] These are the standard errors of the temporal (county-level) regressions used in the cross-sectional analysis.

hence, beta coefficients should be estimated at the county level, if not the firm level.

As a consequence, it is concluded that an alternate model, such as a MIM, may be needed to deal with the heterogeneous nature of crop markets. Also, defining the market index to include only local crops which are available as choices to decision makers leads to crop betas which are statistically significant more often than those in other studies which use aggregated data. This trait makes disaggregated MIM betas more efficient estimates of relevant risk levels for farm planning.

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