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**THE ECONOMIC EFFICIENCY OF DIVERSIFICATION:
CERTAINTY EQUIVALENCE AND THE
MEAN-VARIANCE MODEL**

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CERTAINTY EQUIVALENCE AND THE MEAN-VARIANCE MODEL

by

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Abstract

THE ECONOMIC EFFICIENCY OF DIVERSIFICATION: CERTAINTY EQUIVALENCE AND THE MEAN-VARIANCE MODEL

The marginal benefit and cost of diversification for Florida orange producers is studied using certainty equivalents. The primary contribution of this study is the application of the mean-variance model to farm management decisions. Results indicate that for moderate and high levels of risk aversion, diversification into strawberry, grapefruit, or additional orange production is not optimal. However, moderately risk-averse Florida orange producers would diversify into grapefruit production, if the annual amortized fixed costs were reduced by as little as 10%.

THE ECONOMIC EFFICIENCY OF DIVERSIFICATION:
CERTAINTY EQUIVALENCE AND THE MEAN-VARIANCE MODEL

Increased variability of farm income and asset values in the 1970s and 1980s has increased the interest in risk management in agriculture. Risk can be managed using several instruments, ranging from forward contracting and other marketing strategies to adaptive control models for irrigation systems. One popular risk management technique is enterprise diversification. At the firm level, a manager tries to control production and price risk by producing a combination or portfolio of enterprises.

A common approach used to evaluate diversification opportunities involves the mean-variance efficiency criterion. The mean-variance efficiency criterion states that an asset is inefficient or dominated if another asset can produce the same or higher rate of return for a lower variance. In diversification, a single activity is constructed by combining two or more individual activities. Several studies have shown diversification to be a useful tool in managing risk.

However, past applications of the mean-variance criterion have often failed to consider the marginal costs and marginal benefits of additional diversification. In the finance literature, it is often assumed that the cost of adjusting a stock portfolio is zero (Markowitz, Ross). The literature has thus constructed the diversification question so that the marginal cost of diversification is zero. Diversification always occurred if the diversified activity dominated the nondiversified asset. Few studies have attempted to identify either the marginal cost or marginal benefit of additional diversification. Recently, increased interest has arisen in the finance

literature concerning the marginal cost and benefit from additional diversification (Statman).

In the agricultural finance literature, the typical crop diversification model emphasizes a set of crops that can be grown from the same initial set of resources. Gross margins are often used to calculate the optimal set of crops (Adams et al., Schurle and Erven). However, this method does not account for the additional costs of diversification, such as investment in specialized equipment, or the extra managerial ability required to operate the diversified enterprise.

This paper suggests a method for deriving the marginal benefit and cost of additional diversification by calculating the certainty equivalent of a risky investment. First, the study examines the marginal benefit and marginal cost of diversification by considering a change in the feasibility region. Next, the study applies the marginal cost and benefit model for a Florida orange producer considering diversifying into either grapefruit, strawberries, or additional orange production.

Certainty Equivalence and the Mean-Variance Criteria

This section examines the theoretical basis of the mean-variance model. Specifically, it shows how the mean-variance criterion is related to the expected utility hypothesis and how this linkage can be exploited to derive the certainty equivalent of an investment opportunity. The discussion here parallels that of Robison and Barry.

At the most basic level, the mean-variance criterion has little theoretical basis. Simply stated, the mean-variance criterion reduces the set of all possible investments to a smaller set of risk-efficient investments. There is little or no guarantee that this efficient set of investments

contains the utility-maximizing choice without additional assumptions. The usual assumption required for equivalence between the mean-variance set of investments and the utility maximizing set of investments is that the returns are distributed normally. Recently, Meyer has shown that equivalence can be guaranteed with a weaker set of assumptions. However, to calculate the certainty equivalents, Freund's more stringent assumptions that returns are distributed multivariate normal and that the agent's utility function is negative exponential are required.

Assuming that preferences are negative exponential, an agent's utility function can be specified as:

$$(1) U(W(X)) = -\exp(-\theta W(X)); \quad X \in I_0$$

where wealth (W) is a function of an investment bundle (X), θ is the Pratt-Arrow absolute risk aversion coefficient, and I_0 is the set of feasible investment bundles. Wealth is generated by investing in the feasible bundle X , such that the returns on X are multivariate normal, $W \sim N(\mu(X), \sigma^2(X))$, where

$$(2) \mu(X) = X'r \text{ and}$$

$$\sigma^2(X) = X'\Sigma X,$$

r is a vector of expected returns, and Σ is the variance-covariance matrix of returns. Bussey has shown that under this specification, the expected utility of investing is

$$(3) E[U(W)] = -\exp(-\theta(\mu(X) - \frac{\theta}{2} \sigma^2(X))).$$

Choosing the vector of activities, X , to maximize expected utility in equation 3 yields the same solution as choosing X to maximize

$$(4) Z = \mu(X) - \theta/2 \sigma^2(X)$$

because equation 3 is a monotonic transformation of equation 4.

In addition to yielding the same maximum, thereby simplifying the process of finding the utility maximizing portfolio, equation 3 also allows calculation of the certainty equivalent for the risky investment. This is simply the certain level of wealth for which the decision maker is indifferent with respect to the risky alternative. To compute the certainty equivalent for a risky opportunity, the expenditure function or inverse utility function is set equal to the expected utility. In this case, we want to find $W^*(X)$ that yields the same utility as $E\{U[W(X)]\}$. The certainty equivalent is

$$(5) \quad W^*(X) = \frac{1}{\theta} \ln(E\{U[W(X)]\})$$

or simply

$$(6) \quad W^*(X) = \mu(X) - \frac{\theta}{2} \sigma^2(X).$$

Thus, the certainty equivalent of the risky investment is equal to the objective function, Z . The above derivation also has a heuristic explanation. By definition, a certainty equivalent has no variance, otherwise it would not be certain. To find the certainty equivalent, the utility function is set equal to the level of expected utility of the risky alternative. By definition, a certain outcome has no variance; therefore, $\mu(X)$ is equal to the expected utility (Z). Thus, the objective of the mean-variance model is equal to the certainty equivalent. Therefore, for any set of assumptions in which expected utility is maximized by maximizing equation (4), Z defines the certainty equivalent.

The Marginal Benefit and Cost of Additional Diversification

The preceding section developed a linkage between the quadratic risk programming model frequently used in studying agricultural diversification and the certainty equivalent of the risky investment. This section extends this linkage by integrating those results with the feasible set of investment alternatives. Specifically, a change in the feasible set will be used to derive the marginal benefit and cost from additional diversification opportunities.

Once the risky investment opportunity has been expressed in terms of a certainty equivalent, standard concepts of deterministic consumer behavior become applicable. For example, since preferences are monotonically increasing in wealth, a consumer will always prefer more wealth. Therefore, the consumer will always prefer the alternative with the higher certainty equivalent. The certainty equivalent already includes an adjustment for risk. Hence, the consumer, in choosing the investment with the greater certainty equivalent, is already taking risk into account.

If a consumer is faced with two risky alternatives, $W(X_0)$ and $W(X_1)$, and the certainty equivalent of $W(X_0)$, $W^*(X_0)$, is greater than the certainty equivalent of $W(X_1)$, $W^*(X_1)$, then the consumer will prefer $W(X_0)$. Further, the maximum price that the consumer is willing to pay for $W(X_0)$, given that he already has $W(X_1)$, is the difference in the certainty equivalents δ , $\delta = W^*(X_0) - W^*(X_1)$. Therefore, given any two investment bundles, X_0 and X_1 , the preferred investment has the higher certainty equivalent, and the most that a consumer is willing to pay for the preferred bundle is the change in certainty equivalents.

Since the marginal benefit can be defined as the most a consumer is willing to pay for an item, the marginal benefit of the additional diversification opportunity is the change in certainty equivalents. Specifically, the marginal benefit (MB) of the incremental diversification opportunity is equal to:

$$(7) \quad MB = W^*(X(I_1)) - W^*(X(I_0)).$$

Mean-variance studies typically have examined diversification based upon gross margins (returns above variable costs). Incremental fixed costs play an important role in determining the desirability of diversification. These incremental fixed costs constitute the marginal costs of diversification, which are often not considered. The marginal costs of diversification can be determined by calculating the net present value of the incremental fixed costs and amortizing those costs over the life of the investment. The amortized fixed costs then can be either subtracted from the mean return (r) in equation 2 or compared directly with the marginal benefit in equation 7. If the marginal incremental fixed costs are subtracted from equation 2, then the investment would be desirable when MB in equation 7 is positive.

Applications

In the late 1980s, orange juice production in Florida appeared quite profitable in comparison with many other agricultural enterprises. However, memories of devastating freezes and increased exports from Brazil indicate that significant risk exists in orange production. Several alternatives are available for Florida orange producers considering expansion. For this study, a Florida orange producer currently has 150 acres of oranges. Three expansion opportunities are considered, including producing 10 acres of strawberries, 50 acres of grapefruit, or another 50 acres of oranges. The expansion

opportunities were chosen such that the managerial ability to operate each of the three alternatives was roughly comparable.

The income data for orange production used in this study were derived from state seasonal yields and cash prices for oranges marketed as frozen concentrated orange juices (FCOJ) for the period 1973-1987. Three orange harvesting periods were chosen: December, February, and April. FCOJ prices were provided by the Florida Department of Citrus in dollars per pound solid. The yield, pound solids per acre, for each marketing period was derived from the state average in boxes of oranges per acre for early and midseason oranges in the December and February marketing periods, and valencia oranges in the April marketing period (Florida Agricultural Statistics, 1988a). The yield variability of FCOJ depends not only on tree yields, such as boxes of oranges per acre, but also on the quality of the oranges.

Average yields for white grapefruit and on-tree prices for Florida white grapefruit between 1973 and 1987 were obtained from Florida Agricultural Statistics (1988a). The variable cost of producing one acre of oranges or one acre of grapefruit was assumed to be \$748.15 (appendix table 1), and all returns were deflated using the personal consumption expenditure component of the implicit GNP deflator (PCE). The marginal cost of diversification, which is the rental rate for another acre of oranges or grapefruit was assumed to be \$630.

The returns to strawberries were computed based on state average prices and yields (Florida Agricultural Statistics 1988b). The variable cost of production for strawberries is \$11,710.54/acre (appendix table 2). The marginal cost of diversification into strawberries includes \$22,000 for additional equipment investment and \$260 dollars per acre for land rental.

The amortized value of the additional equipment for 10 acres, assuming a 10 year equipment life and a 12.5% interest rate, is \$3974. The annual cost of diversification into 10 acres of strawberries is \$6574.

The mean returns and standard deviation of returns for strawberries, grapefruit and each marketing period for oranges are reported in table 1. The returns are gross revenues less variable costs and are expressed in 1987 dollars per acre (appendix table 3). Strawberries had the highest mean return per acre, whereas December-produced oranges had the lowest mean return from 1973-1987. Strawberries also had the highest standard deviation, whereas the April-produced valencia oranges had the lowest standard deviation per acre. The correlation matrix of returns for oranges, strawberries, and grapefruit is reported in table 2. The returns from oranges harvested during different periods are highly correlated. Grapefruit and strawberry returns are less correlated with oranges.

The means, variances, and covariances were used to set up the mean-variance model (see equation 4). Six Pratt-Arrow coefficients of absolute risk aversion were examined, ranging from zero to .0001. The risk-aversion levels were chosen based on Raskin and Cochran and the certainty equivalent. The most risk-averse coefficient examined (.0001) was the only one in which the certainty equivalent was less than the lowest outcome.

The results of the risk programming model for the base scenario are found in the top block of table 3. The base scenario is the optimal plan for the orange producer before expansion. For the risk-aversion coefficients less than or equal to .00001, midseason (February) maturing oranges were raised on 150 acres. Farmers with a risk-aversion coefficient of .00002 raise both

midseason oranges and valencia (April) oranges. Farmers that have a risk-aversion coefficient greater than .00005 grow only valencia oranges.

Oranges and Strawberries

The results for the risk programming model for diversification into strawberries are presented in the second block of table 3. Strawberries offer potential for increasing the expected utility of the farmer, if the farmer's risk-aversion coefficients are 0, .000005, .00001, or .00002. The marginal benefit of diversification difference in certainty equivalents between the base plan and augmented plan into strawberries is \$10,993, \$7,230, \$3,467, and \$1,387, respectively, for the risk-aversion coefficients listed above. The annual amortized fixed cost of diversifying into strawberries is \$6,574. Therefore, only those producers that are risk-neutral or those with a Pratt-Arrow absolute risk-aversion coefficient of .000005 should diversify into strawberries. The marginal costs of diversifying would have to be cut by nearly 50% (less than \$3,467) before the producer with a risk-aversion coefficient of .00001 would be willing to grow strawberries. Those producers who are more risk averse would not want to diversify into strawberries.

The question arises, why not subtract the fixed costs of strawberries from the returns above variable costs? The answer involves the fixity of investment. The solution for a risk programming problem often involves a fraction of an activity (for example, planting 4 acres of strawberries). However, the costs of obtaining fixed facilities are often not proportional. For example, if one is investing in strawberries that require specialized equipment, the costs of obtaining the equipment for the first acre may be much different than the average cost for the greater number of acres. Thus, extrapolating the results may yield incorrect diversification recommendations.

Oranges and Grapefruit

The solution for the risk diversification problem with oranges and grapefruit is given in the third block of table 3. Before considering the marginal costs of diversification, for every level of risk aversion except the highest, grapefruit is raised on all 50 acres. However, the marginal benefit for leasing the grapefruit only exceeds the marginal cost of \$31,500 for Pratt-Arrow risk-aversion coefficients smaller than .000005. The orange producer who has risk-aversion coefficients of .00001, or .00002 would be willing to raise grapefruit, if the annual rent on land reduced by 5% or 8%, respectively. Currently, the more risk-averse managers will not rent the grapefruit grove and more risk-neutral managers will. However, in the current scenario no one will rent the grapefruit grove without planting or maintaining all 50 acres.

Oranges and Oranges

The solution for the risk diversification into production of additional oranges is given in the bottom block of table 3. The marginal benefit for leasing the extra acreage of oranges exceeds the marginal cost for the two smallest risk-aversion coefficients. The producer who has a risk-aversion coefficient of .00001 would rent the 50 acre grove of oranges, if the rent were reduced by 33% (the marginal cost would need to be less than \$21,182).

Summary

The above analysis indicates that only the orange producer with a risk-aversion coefficient of .000005 or less would expand his enterprise after considering the marginal costs of diversification. Although producers who are more risk-averse would want to diversify based on the returns over variable costs, the marginal benefits do not outweigh the marginal costs. However, the

more risk-averse producer might want to consider grapefruit, because the marginal benefit minus the marginal cost of diversification would be positive, if the marginal costs could be reduced by between 5 and 10%. It should be noted that the above analysis is based upon statewide data and that the individual producer will likely face yields that are more variable.

Conclusion

This study uses the certainty equivalent of a risky investment derived from the objective function to evaluate the marginal benefits and costs of diversification opportunities. Specifically, this paper recognizes that the objective value from a popular form of a quadratic risk (mean-variance) programming problem is equal to the certainty equivalent under Freund's assumptions. The change in certainty equivalent between two mean-variance solutions, one without and one with an additional diversification opportunity, is shown to be the marginal benefit of the diversification opportunity. This marginal benefit can be compared with the marginal cost of the opportunity to determine the economic efficiency of additional diversification.

Using this framework, the study evaluates three investment opportunities available to Florida orange producers: strawberry, grapefruit, and additional orange production. The results indicate that the marginal benefit of diversification into any of the enterprises is exceeded by the cost for moderate and high levels of risk aversion. The marginal benefit to additional investment is greater than the marginal cost of diversification for all three enterprises for the profit maximizer and the individual with a Pratt-Arrow risk-aversion coefficient less than .00001. For the moderately risk-averse producer, the marginal benefit of grapefruit production would be greater than the marginal cost, if the costs were reduced by as little as 10%.

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Table 1. Mean and Standard Deviations of the Real Returns for Oranges in Three Harvest Periods, Strawberries, and Grapefruit, 1973 through 1987

Crop	Mean	Standard Deviation
Oranges		
December	\$725.47/ac.	\$494.60/ac.
February	913.57	535.04
April	741.91	388.33
Strawberries	1099.31	1990.17
Grapefruit	727.30	491.01

Table 2. Correlation Coefficients of Returns for Oranges in Three Harvest Periods, Strawberries, and Grapefruit, 1973 through 1987

	Oranges			Strawberries	Grapefruit
	December	February	April		
Oranges					
December	1.000				
February	.903*	1.000			
April	.861*	.902*	1.000		
Strawberries	.356	.347	.299	1.000	
Grapefruit	.093	.180	.029	.464	1.000

* - significant from zero at the 5% level of significance.

Table 3. Optimal Portfolios of Oranges, Grapefruit, and Strawberries for Various Risk-Aversion Levels.

Risk Aversion Coefficient	Certainty Equivalent	Marginal Benefit of Expansion	Marginal Cost of Expansion	Acres of Oranges			Potential Expansion Activity
				Dec	Feb	Apr	
----- Base Plan-----							
0	\$137,036	-	-	-	150	-	-
.000005	120,933	-	-	-	150	-	-
.00001	104,830	-	-	-	150	-	-
.00002	78,007	-	-	-	50	100	-
.00005	26,461	-	-	-	0	150	-
.0001	-58,364	-	-	-	0	150	-
----- Diversification into Strawberries-----							
0	148,029	\$10,993	\$6,574	-	150	-	10
.000005	128,163	7,230	\$6,574	-	150	-	10
.00001	108,297	3,467	\$6,574	-	150	-	10*
.00002	79,394	1,387	\$6,574	-	42	108	4*
.00005	26,461	0	\$6,574	-	-	150	-
.0001	-58,364	0	\$6,574	-	-	150	-
----- Diversification into Grapefruit-----							
0	173,401	36,365	31,500	-	150	-	50
.000005	154,018	33,085	31,500	-	150	-	50
.00001	134,635	29,815	31,500	-	150	-	50*
.00002	107,030	29,023	31,500	-	16	134	50*
.00005	45,685	19,224	31,500	-	-	150	50*
.0001	-49,753	8,011	31,500	-	-	150	27*
----- Diversification into Oranges-----							
0	182,714	45,678	31,500	-	200	-	-
.000005	154,087	33,154	31,500	-	200	-	-
.00001	126,012	21,182	31,500	-	158	42*	-
.00002	88,324	10,317	31,500	-	20	180*	-
.00005	26,461	0	31,500	-	-	150	-
.0001	-58,364	0	31,500	-	-	150	-

*-Expansion would not occur because the marginal cost of expansion exceeds the marginal benefit of expansion.

Appendix Table 1. Budget for Citrus Production 1988.

		\$ Per Acre
PRODUCTION COSTS:		
Discing (2 times)		\$ 17.62
Mowing (2 times)		19.52
General Grove Work (2 labor hours per acre)		15.06
Herbicide (1/2 tree acre treated):		
Application (2 applications)	\$ 19.88	
Material	<u>37.49</u>	
Total Herbicide cost		57.37
Spray 2X:		
Post-Bloom: Application (April)	32.38	
Material	<u>33.66</u>	
Total Post-Bloom Cost		66.04
Summer Oil: Application	32.38	
Material	<u>49.98</u>	
Total Summer Oil Cost		82.36
Dust (Sulphur): Application	7.19	
Material	<u>11.82</u>	
Total Sulphur Cost		19.01
Fertilizer (Bulk): 3 Applications	26.31	
Material (16-0-16, 1,325 lbs)	<u>106.00</u>	
Total Fertilizer Cost		132.31
Topping (Cost/year of topping)		30.83
Hedging (Cost/year of hedging)		22.52
Remove Brush from Trees		5.10
Chop Brush/Mow Brush		9.48
Remove Trees: Pull, Stack & Burn 3 trees with Front-end Loader		14.20
Young Trees--1 thru 4 years of age: (3 trees/acre)		
Water Resets (Avg. 5 times/year)	10.26	
Fertilizer (Appl. & Mat.)	24.16	
Tree Wraps, Sprout, Ridomil/Aliette, etc.	15.43	
Prepare Site & Plant Resets	<u>23.20</u>	
Total Young Trees		<u>73.05</u>
NON-IRRIGATED PROCESSED FRUIT PRODUCTION COSTS		\$564.47
Irrigation (Permanent Overhead System)		
Operating Variable Cost	102.00	
Fixed/Variable Expense	20.91	
Check Irrigation System & Maintenance	<u>2.42</u>	
Total Irrigation Costs		<u>125.33</u>
IRRIGATED PROCESSED FRUIT PRODUCTION COSTS		\$689.80
Supplemental Fall Miticide Spray:		
Application	32.38	
Material	<u>25.97</u>	
Total Fall Miticide Spray		<u>58.35</u>
IRRIGATED FRESH FRUIT PRODUCTION COSTS		<u>\$748.15</u>

Source: Murraro

Appendix Table 2. Strawberries: Estimated Costs of Production in the Plant City, FL Area, 1987-88.

Category	Average per Acre
OPERATING COSTS	----Dollars----
Transplants	1,320.00
Fertilizer and lime	293.00
Fumigant	189.90
Fungicide	492.50
Herbicide	97.38
Insecticide	451.64
Labor	149.88
Machinery	174.90
Interest	279.44
Miscellaneous	
Cover crop seed	35.00
Cut runners	61.00
Dump fee	20.00
Plastic mulch	324.00
Remove plastic	37.00
Transplant labor	165.00
Total operating costs	4,090.54
HARVEST and MARKETING COSTS	
Harvest labor	2,600.00
Packing shed labor	320.00
Haul	300.00
Supervision	200.00
Boxes & cups	1,600.00
Pre-cool & sell	2,600.00
Total harvest and marketing costs	7,620.00
TOTAL COST	11,710.54
Source: Taylor and Smith	

Appendix Table 3. Revenue Less Variable Costs for Oranges in Three Harvest Periods, Strawberries, and Grapefruit, 1973 through 1987.

Year	Oranges			Strawberries	Grapefruit
	December ¹	February	April		
1973	259.90	468.21	387.25	2868.30	1269.54
1974	326.39	512.99	256.82	83.40	780.93
1975	192.46	235.57	250.74	2913.20	627.76
1976	421.77	683.32	619.85	733.40	386.33
1977	-90.58	-149.62	222.32	-615.10	553.33
1978	1198.82	1518.40	1317.43	2809.90	397.25
1979	1282.93	1832.44	1309.49	3107.30	831.65
1980	1354.17	1562.99	1092.69	4457.80	1350.73
1981	756.30	1064.82	819.27	-279.80	1185.12
1982	749.51	754.22	387.40	1149.80	231.03
1983	791.69	814.40	1099.59	-255.60	-155.55
1984	486.82	1022.50	664.39	-3079.70	146.70
1985	1731.98	1417.93	1130.23	971.30	662.12
1986	711.21	841.22	668.53	-815.70	1065.17
1987	708.64	1124.19	902.59	2441.10	1577.37

¹-December of the previous year.

