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PORTFOLIO COMPOSITION AND FINANCIAL PERFORMANCE OF AGRICULTURAL INSURERS

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Abstract:
The paper examines the relevance of portfolio theory in the management of an agricultural insurer. It analyses the financial performance of three agricultural insurers (Israel, USA, and Costa Rica) in relation to the structure of the correlation matrix of each portfolio. It offers a functional relation between an index of portfolio performance and the historical loss ratio; which provides evidence in the fact that portfolio composition is a determinant factor in financial performance.

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1. INTRODUCTION

Agricultural insurance is becoming a widespread way of fostering agricultural development, as it works towards the stabilization of farm incomes. The long time existing program in the United States is being expanded rapidly, and is expected to have a national coverage for all crops by 1990. In Israel, the program created in 1967 now covers most of total crop production [IFNRA,1980]. In Latin America [IICA, 1980] new programs are emerging rapidly besides those established in Mexico in 1960, and in Costa Rica in 1970.

The experience of these agricultural insurers has not been evaluated. Yet, on theoretical grounds, agricultural insurance has been critized by some authors (see Roumasset [1979]) but it has also been favored by others (see Gudger [1980], Koropecky [1980], Ray [1974]). Also emphasis has been given to further investigate how agricultural insurance works [Pomares, 1980]. Research is now in progress but at this stage almost all that can be asserted is that there is a significant variation in the financial performance of agricultural insurers.

Regardless of the degree of government support, the financial performance of these institutions can be, at first glance, appreciated from the historical trend on the overall loss ratio[1/]. Some programs had average historical loss ratio of less than one such as the US (0.98), and Israel (0.85). Others, however, have loss ratios far above one like Costa Rica (3.50) and Mexico(1.83). These later programs have been said to play a major social role, obviously at a very high financial cost.

1/ For simplicity the loss ratio is defined as: $LR = \frac{\text{indeminities paid}}{\text{premiums earned}}$

Agricultural insurance has copied its principles from the other fields of insurance. As such, it has concentrated on acturial procedures based on the assumption that there is independence of events for which insurance is provided. This implies that there is no correlation between the historical performance of losses of the insured items. It can be safely assumed for example, that house fires are independent from car accidents[1/]. Under such conditions actuarial procedures can be a sufficient tool for proper risk management by the insurer: the premium reflects the cost of risk implicit in the variance of returns. These rather strong assumptions, have erroneously been accepted in agricultural insurance. Ray [1974, page 15] recognized the need for selecting crops on the basis of their economic importance, the practicability of insurance operations, and the possibility of insurance operations, and the possibility of balancing the incidence of risks among the selected crops. In his development of actuarial procedures, however, Ray completely ignores this interesting observation.

Following these assumptions, premiums for agricultural insurance are based on the normal curve theory; originated in the earlier work of Botts and Boles 1958 and fully discussed by Ray 1974 . The normal curve method is based on informantion on crop yields for a particular area, but where there is no knowledge about the distribution of farm yields around their average, the county for example. The annual lost cost or pure premium rate per acre is L:

$$L = AC - AR \qquad (1)$$

where:

L = pure premium

A = proportion of total acre with yield $Y_i \leqslant C$

1/ This, however, does not exclude the possibility of two contiguous insured houses may burn or that two insured cars may crash.

C = coverage per acre in yield units

R = mean yield per acre on indemnified acres for particular year

but considering that the mean yield (R) of a truncated normal distribution can be written as:

$$R = U - \frac{d\,\sigma}{A} \qquad (2)$$

where

Y = mean of acre yield Y_i for a particular year

d = height of ordinate of the normal density function at point C

σ = standard deviation of acre yields

then, equation (2) can be rewritten as

$$L - A\,(C - Y) + d\,\sigma \qquad (3)$$

From this formula it is clear that premiums are strictly a function of the standard deviation of yields. In managing the agricultural insurance business, decisions have been based under the assumption that yield covariance effects (positive or negative) do not exist. Hence,there has not been a portfolio management approach to insurance. It is shown in the remaining of this paper that the financial performance of agricultural insurers is determined by the composition of its portfolio and therefore premiums should be based on the variance of yields as well as on the covariance structure among the insured items; particularly if the composition of the portfolio can not be changed considerably by the insurer.

2. THE RELEVANCE OF PORTFOLIO THEORY IN AGRICULTURAL INSURANCE

An agricultural insurer is faced with a different environment than the property -casualty , health, auto or other insurers. In agricultural production , weather is one of the most important hazards and in severe cases it could affect equally all crops. Most of the time, however, given crops species and varieties,

planting dates, regions, etc., it affects crops differently and therefore, there are cases of positive as well as of negative correlations.

The general principles of portfolio theory go back to the origins of decision sciences; but it was only with the pioneering work of Markowitz [1952] that a mathematic formulation was made available[1/]. Even since its appearance, portfolio theory claimed interest among economists and financial analysts. Major theoretical contributions have been made by Tobin [1958], Baumol [1963], and Sharpe [1963, 1967a, 1967b, 1970] among others. The applications have been multiple: In the area of banking are remarkable the works of Chambers and Charnes [1961], Cohen and Associates [1966, 1967a, 1970, 1971], Fama [1980] among others. In the stock market one finds the works of Fama [1965, 1968], Hester [1967, 1968], among others. In the insurance business Borch [1967, 1979], Doherty [1980], Hofflander and Drandell [1969], Kahane and Nye [1975, 1977a, 1977b, 1978], made interesting suggestions, and more recently Cummings and Nye [1981] presented some novel ideas. The number of empirical studies at the firm and market levels in different fields can easily be counted in thousands.

From the principles of portfolio theory, with reference to insurance, there are three determinants of portfolio performance: the disaggregation, i.e. the weight of each insured item (X_i), the variance of returns of the insured items (σ_i^2), and the covariance of returns among the insured items (σ_{ij}).

We can define the portfolio of the agricultural insurer as composed by n items. Its expected return and variance of return can be defined as:

1/ Markowitz's original work was published in 1952 and further extended in 1959. The last edition of his book published in 1976 provides a most complete exposition and very extensive review of literature.

$$E(R) = \sum_{i=1}^{n} X_i R_i \tag{4}$$

$$V(R) = \sum_i \sum_j X_i X_j \sigma_{ij} \tag{5}$$

where:

$E(R)$ = expected return

$V(R)$ = variance of return

X_i = the proportion of the i^{th} insured item, therefore $\Sigma X_i = 1$

R_i = the return of the i^{th} item

σ_{ij} = variance-covariance matrix of returns

A brief additional explanation about the variance of the portfolio would suffice for an understanding of the principles: the variance of return of the portfolio can be written as:

$$V(R) = \sum_i V(R_i) + \sum_{i \neq j} \sum_i \text{cov}(R_i, R_j) \tag{6}$$

In matrix notation the variance of return is:

$$V(R) = [X_1 \quad X_2 \ldots\ldots X_n] \begin{bmatrix} \sigma_{11} & \sigma_{12} \ldots\ldots & \sigma_{1n} \\ \sigma_{21} & \sigma_{22} \ldots\ldots & \sigma_{2n} \\ \cdot & \cdot & \\ \cdot & \cdot & \\ \cdot & \cdot & \\ \sigma_{n1} & \sigma_{n2} \ldots\ldots & \sigma_{nn} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ \cdot \\ \cdot \\ \cdot \\ X_n \end{bmatrix} \tag{7}$$

Thus, the larger the negative correlation of returns among items i.e. the absolute value of a negative covariance, the smaller the variance of return of the portfolio. In addition, as equation (5) shows, the variance of the portfolio is a function of the proportion of each item in the portfolio. Therefore, the larger X_i the more weight that item (with a large or small variance) will have in the portfolio variance.

3. A COMPARATIVE ANALYSIS OF AGRICULTURAL INSURANCE PORTFOLIOS

The purpose of this section is to present evidence that the portfolio of agricultural insurers show varying degrees of correlation among insured items and also to demonstrate that the better the structure of the portfolio, the lower the average loss ratio of the insurer. The analysis is based in three cases studies for which historical information was available.

The Case of the Israel IFNRA

The Israeli program began its operations in 1966/67 insuring five crops with a total coverage of IL.86.5 million. Currently (1978/79) the program includes 21 crops and poultry with a total of IL.10620.2 million. IFNRA operates with premiums paid 50 percent by farmers and 50 percent by the government. When establishing IFNRA, the government granted it a guarantee that any deficits would be coveraged by the government (50 percent as a long term loan). This guarantee has been used only once as a result of a severe frost in the winter of 1972/73, when the overall loss ratio was 3.66[1/].

IFNRA's portfolio is highly concentrated in citrus which on the last three years averaged 31.48 percent of total coverage. Cotton plus citrus, vegetables, grains, apples and poultry, currently account for 89 percent of total coverage. The other 17 crops account for the remaining 11 percent. Given this situation the

1/ The only other time when the overall loss ratio exceeded one was in 1973/74 (=1.05). During the other 11 years it fluctuated between 0.22 and 0.85.

Table 1. Israel, Correlation Matrix of

Loss Ratios of six main crops1/

	Citrus	Cotton	Veget.	Grains	Apples	Poultry
a	31.48	23.06	7.78	3.65	4.71	18.29
Citrus	**1.000**	**- 0.276** (0.4400)	**0.871** (0.0005)	**0.038** (0.9106)	**- 0.190** (0.575)	**0.034** (0.926)
Cotton		**1.000**	**- 0.122** (0.705)	**- 0.130** (0.720)	**0.188** (0.579)	**0.032** (0.933)
Veget.			**1.000**	**- 0.110** (0.747)	**- 0.361** (0.248)	**- 0.013** (0.971)
Grains				**1.000**	**- 0.343** (0.302)	**- 0.078** (0.831)
Apples					**1,000**	**- 0.273** (0.444)
						1,000

1/ These crops account for 89 percent of total coverage. Other 17 crops account for the remaining 11 percent. The analysis uses data for the period 1967/68 to 1979/80.

a Percentage of total coverage. (Average of last years).

portfolio analysis that follows is done only for the six main items.

The correlation matrix of the loss ratios is shown in Table 1. Out of the relevant 15 correlation coefficients, ten are negative while only five are positive. None of the negative coefficients are statiscally different from zero, while only one of the five positive coefficients is statiscally different from zero. In addition, the negative correlation coefficients are on the average larger than the positive ones.

Although no claim can be made for statistical significance of the correlation coefficients, the fact that 10 out of the 15 are negative provides evidence for a well structured portfolio. It should be recognized, however, that although citrus is not highly correlated with other items except poultry; its large weight in the portfolio poses a potential danger. In a closer analysis of performance it was observed that except for 1974/75, loss ratios greater than one were always reported for at least two crops and for as many as ten. It is obvious that without such a well diversified portfolio IFNRA would have not remained financially solvent without recurring to government grants or subsidies.

The Case of the U.S.FCIC

The U.S. crop insurance program began in 1948 with 7 crops in 40 states. The program grew at a conservative rate in terms of coverage until 1975, when due to energy costs it experienced a significant increase. Although the number of states has increased considerably within those states. However, following the path of land ownership concentration in the U.S., the number of policies issued has been in the last 5 years (1974/78) almost 30 percent smaller than 10 years before

In contrast with the Israeli program, the total loss ratio was never very large. The maximum value was 1.57 and the minimum was of 0.26 (in only one year) but in fact most of the time the LR has been between 0.60 and 1.25. The average LR over 30 years is 0.98.

The FCIC program is well diversified over regions. However, nine crops (out of 31) currently account for 92.6 percent of total coverage. Moreover, three crops (corn, tobacco, and wheat) account for 73.6 percent of total coverage. Although these three crops are grown in different regions of the largest agricultural country in the world, they are in most cases positively correlated in their loss ratios. The correlation matrix is shown in Table 2 for the nine main crops in the FCIC portfolio. From the 36 relevant correlations coefficients, 14 are negative while 22 are positive. On the average the positive correlation coefficient are larger than the negative ones, and at least 3 of them are strongly significantly different from zero. The most serious cases are the correlations between soybeans/corn, soybeans/sorghum, wheat/barley, wheat/soybeans, and wheat/tobacco. The case of the U.S. illustrates clearly that crop diversification and geographical dispersion per se are not a sufficient condition for a well diversified portfolio.

The structure of the portfolio--where to some extent, there is a "control mechanism" through negative correlation--has allowed the FCIC to remain financially viable, but with an almost insignificant margin.

The Case of the Costa Rican INS

The Costa Rican crop insurance program began in 1970 with only two crops (rice and corn), and throughout the following years cotton, sorghum, and beans where added. Although, the loss ratio during the pilot year (1970) was very small (0.07), the program began immediately after that year to lose money in incredible amounts. Overall, the program has never had a year without losses,hence requiring increasing government subsidies.

A recent study of the INS agricultural insurance program (Academia de Centroamérica, 1980) pointed out that, in spite of its adequate Law and Rules and Regulations, the program has been a financial disaster because of problem attributed to the premium, determination procedures, the concentration of production, politically motivated decisions, and the lack of an adequate reserve and funds more extensive field supervision.

Leaving aside the political problems and premiums determination practices and other administrative problems, it is clear that the high concentration in rice (74 percent of total coverage) is a good reason for the poor performance of the portfolio; in spite of rice not being the riskiest of all crops and in spite of having negative correlations with the next two most important crops, cotton and sorghum. The high and significant correlation between rice and corn is currently unimportant because the very small proportion of corn in the portfolio.

Table 2. United States, Correlation Matrix of Loss Ratios of nine main crops 1/

	Barley	Citrus	Corn	Cotton	Sorghum	Peanuts	Soybean	Tobbaco	Wheat
a 2/	1.44	1.27	28.23	3.84	1.40	2.47	9.21	26.56	18.84
Barley	1.	- 0.056 (0.779)	0.164 (0.450)	0.204 (0.351)	- 0.152 (0.521)	- 0.271 (0.291)	0.013 (0.951)	0.183 (0.404)	0.294 (0.174)
Citrus		1.	- 0.002 (991)	0.136 (0.490)	- 0.106 (0.655)	- 0.191 (0.460)	0.090 (0.675)	- 0.102 (0.606)	- 0.295 (0.126)
Corn			1.	0.098 (0.600)	0.163 (0.491)	- 0.152 (0.561)	0.339 (0.105)	0.029 (0.876)	0.191 (0.303)
Cotton				1.	0.193 (0.415)	- 0.101 (0.698)	0.467 (0.021)	0.017 (0.926)	0.033 (0.856)
Sorghum					1.	- 0.035 (0.894)	0.339 (0.144)	- 0.269 (0.252)	0.072 (0.762)
Peanuts						1.	0.234 (0.365)	- 0.113 (0.666)	0.189 (0.466)
Soybean							1.	- 0.210 (0.325)	0.336 (0.108)*
Tobbaco								1.	0.418 (0.019)
Wheat									1.

1/ These crops account for 92.26 percent of total coverage. Other 22 crops account 7.74 percent. The analysis uses data for the period 1948 - 1978.

2/ Percentage of total coverage. (Average of four last years).

Table 3. Costa Rica, Correlation Matrix
of Loss Ratios of all crops

	Rice	Corn	Cotton	Sorghum	Beans
a 2/	72,37	1.20	16.26	8.86	1.31
Average Loss Ratio	3.294	3.693	2.565	5.718	5.300
Rice	1.000	0.764 (0.010)	-0.425 (0.294)	-0.431 (0.393)	1/
Corn		1.000	-0.038 (0.928)	-0.069 (0.897)	1/
Cotton			1.000	0.130 (0.805)	1/
Sorghum				1.000	1/
Beans					1.000

1/ Only two years.

2/ Percentage of total coverage. (Coverage of last four years).

It suggests, however, that expanding insurance in corn in the same area would lead to similar, if not greater, problems than the current ones. Clearly, gains could be derived by expanding cotton and sorghum at the expense of rice or else introducing new crops in other regions with negative correlations.

The analysis performed provides clear indication that the financial performance of an agricultural insurer is closely related to the structure of its portfolio. The following section takes the historical data of the Israeli experience to find a functional relation between portfolio performance and financial evolution.

4. A FUNCTIONAL RELATION BETWEEN PORTFOLIO VARIANCE AND FINANCIAL PERFORMANCE

From the comparative analysis of the previous sections it can be inferred that an insurer would have a better financial performance (reflected in the loss ratio) when the variance of its portfolio is smaller[1/]. However, also from portfolio theory, the variance of returns is not considered in isolation but in relation to the expected return. In fact, the loccus of points that are the combination of the maximum return attainable with a given variance, define the set of feasible portfolios. Hence, investors would trade risk for returns as a function of their own preferences along this set.

For the purpose of this analysis, I have defined a Index of Portfolio Performance (IPP) as the inverse of the coefficient of variation.

$$IPP = \frac{E\ (R)}{V\ (R)} \qquad (8)$$

1/ As it was discussed earlier, the size of the aggregate portfolio variance depends on the individual shares and the variance-covariance matrix of returns.

The larger this coefficient, the better the structure of the portfolio; and as a result the smaller will be the loss ratio. The case of Israel was chosen to test this hypothesis.

The variance of the portfolio is calculated for each time period using equation (6). Assuming that the matrix remains invariable, the portfolio variance for each time period was calculated by replacing the corresponding X_i vectors which change from year to year. The return of the portfolio is calculated for each time period using equation (4).

The Israeli experience was used to test the hypothesis presented above. The summary of relevant variables calculated from the Israeli data are given in Table 4.

The relation between the IPP and the loss ratio is shown in Figure 1. To test for the best fit two alternatives models were selected and the results are as follows:

$$IPP = 0.399 - \underset{(-10.91)^*}{0.347}\,LR\ , \quad R^2 = 0.915 \qquad (9)$$

$$\text{Log}\ IPP = 0.537 - \underset{(-19.18)^*}{0.622}\,LR\ , \quad R^2 = 0.971 \qquad (10)$$

* numbers in parenthesis are t values

1/ In the case of the semilog model, the dependent variable was added a + 1.00 to handle the negative logarithms of numbers less than minus 1.00.

Table 4. Israel, Main Parameters of the Insurance Operations, 1967-1979

Year	Premium (PR)	Indemnities (IN)	Return (R)	Variance of return V (R)	Loss Ratio LR	Index of Portfolio Perfomance IPP
1967	2.065	1.275	0.789	5.82	0.62	0.135
1968	3.940	3.304	0.636	4.39	0.84	0.145
1969	8.117	6.315	1.817	107.94	0.78	0.017
1970	13.455	11.781	1.674	70.43	0.88	0.024
1971	18.385	13.982	4.403	44.19	0.76	0.099
1972	20.194	73.968	- 53.774	64.15	3.66	- 0.836
1973	29.452	31.080	- 1.760	93.68	1.05	- 0.027
1974	55.160	12.308	37.988	159.20	0.22	0.238
1975	71.695	19.713	41.396	162.20	0.27	0.255
1976	103.524	58.009	58.411	221.80	0.56	0.263
1977	133.534	48.500	79.061	256.88	0.36	0.308
1978	200.578	48.837	121.035	215.67	0.24	0.561
1979	261.940	224.377	37.563	217.94	0.81	0.172

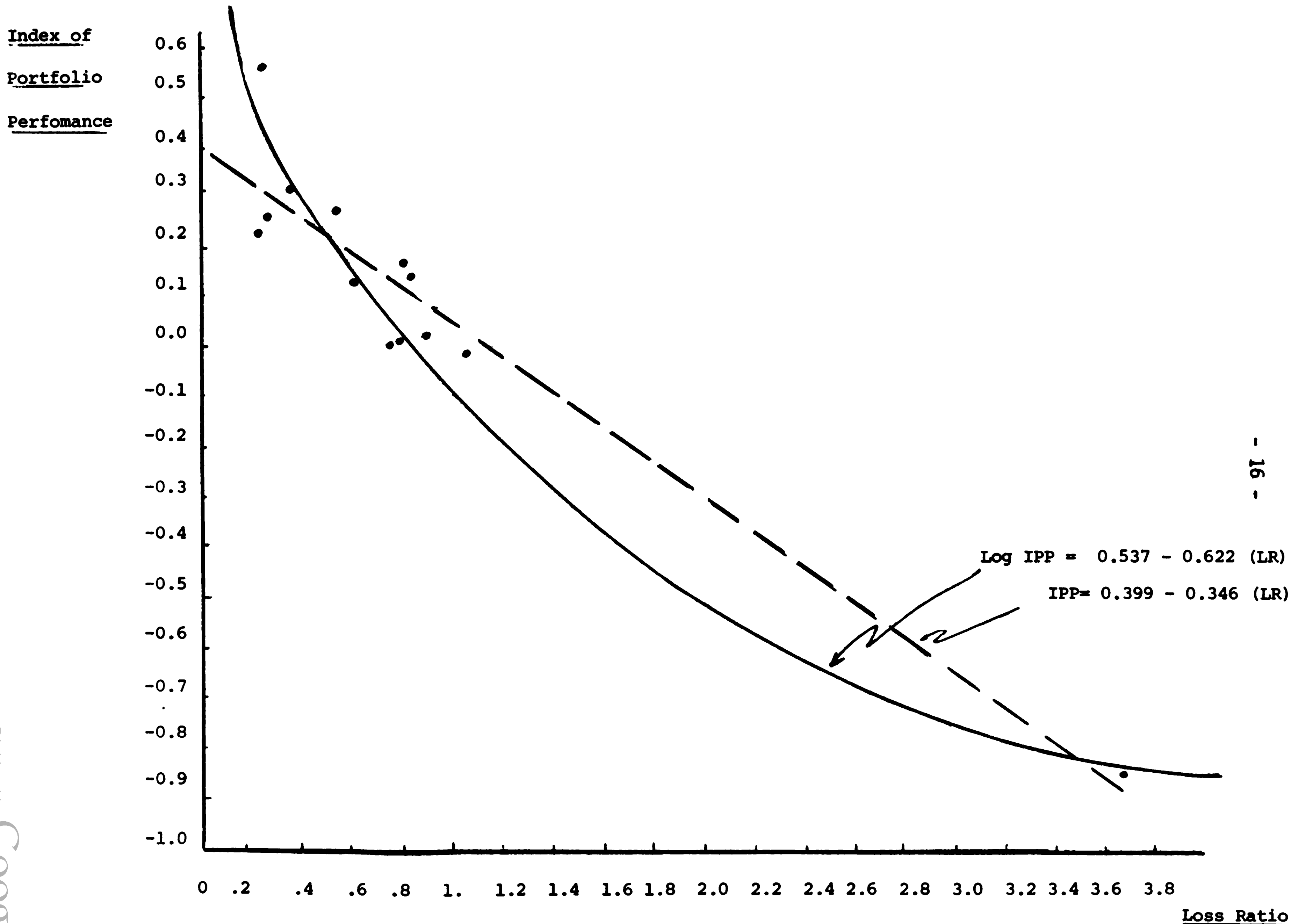

Figure 1. Israel, Relation Between the Index of Portfolio Perfomance and the Loss Ratio

It can be concluded without difficulty that, as hypothesized, there is a negative relation between the IPP and LR. No definite conclusions are offered at this stage as to whether, in general a linear or log-linear function would offer the best fit; however, in this case the log-linear model performed better.

The important implication of this analysis is the following: the minimum loss ratio is attainable with the maximum Index of Portfolio Performance. The later can be improved by raising premiums of by choosing the portfolio with the minimum variance. Playing with both parameters depends on political conditions as much as on analytical skills.

5. CONCLUSIONS

Agricultural Insurance has based management decisions only on actuarial methods, neglecting three elements within an insurance portfolio that must be taken into account to manage and orient the institution's policies: the variance of returns of each individual insured item, the proportion of each item in the portfolio and the covariance of returns among items. Portfolio Theory offers a framework of analysis to account for these three elements seeking the best performance of the portfolio and hence the minimum loss ratio. This in turn implies a reduced premium for the insureds as it is not necessary to create a larger reserve to handle heavy losses. It would likewise have implications for government subsidies and administrative expenses for government subsidies and administrative expenses. Finally, stabilized portfolio performance would affect reinsurance decisions and the rates offered by the reinsurance markets.

A comparative analysis of three agricultural insurers (Israel, the United States, and Costa Rica) offers evidence of the importance of exploting the concepts of portfolio management for a financially successful insurance program. The following conclusions are worth emphasizing.

- The larger the spread of shares of total coverage among the items of the portfolio, the less danger of a significant loss of returns for a particular

item.

- Other things constant, the smaller the variance of return of a particular item, the greater the desirability of including it in the portfolio.

- The larger the number of negative correlations among insured items, and the more (statistically) significant they are, the higher the likelihood of a better distribution of disasters over time.

The analysis made here, although simple has important implications for the management of agricultural insurers.

First, the generation of premium income for the insurer should be based on joint management of the structure of the portfolio and the premium rates. Premiums shouldbe higher not only for the crops with the highest loss ratio but also for those that, through a covariance effect or through a share effect, endanger the financial position of the institution.

Second, premium determination procedures based on normal curve theory, should account for covariance effects among insured items to enhance distributional effects of crop insurance programs.

Third, pilot programs, particularly in developing countries, should not concentrate on one crop, even when the expected variance of returns is not very large. The portfolio should, from the begining, be well diversified. The later implies not just various crops and/or livestock in various regions, but crops, cycles and regions that show historical yields that are negatively correlated.

Clearly the administrative costs play an important role in the degree of disaggregation of the portfolio at initial stages and for the determination of a growth path.

Fourth and not less important, is the implication derived from this analysis that agricultural insurers, which rely heavily in actuaries' advice, may benefit considerably from assistance provided by investment analysis, particularly of those specialized in the issues of risk management through portfolio analysis.

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