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An Application of Game Theoretic Model for the Agricultural Crop Selection in Nepal

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Introduction

It is quite obvious that agriculture plays a vital role in Nepalese economy. Here in our country more than 80 per cent of the total working people depend on agriculture and it is clear that the living standard of the people can only be improved by raising the efficiency of the agricultural production. An agricultural efficiency represents the effectiveness not only of the land and labour but also by the other factors such as managements, capital investment, various inputs, price of the products etc. To be more frank, the efficiency improvement is the technique to optimise the use of the resources available.

The agricultural production can be increased by two ways:one by making more land for cultivation and the other by increasing the productivity. The former one seems to be strictly restricted because of the limited supply of land in nature, but in the latter case agricultural inputs play the important role. Each farm receives inputs of labour and management from the farmer. But for the improvement in productivity other types of inputs are also desirable. They may include different types of chemical fertilizers, high yielding varieties (seeds), pesticides, scientific tools and machineries, power, transportation and irrigation facilities. In order to use such

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inputs a farmer must have good economic condition. We can expect the only source of income for a farmer by selling his own products. Thus, the increase in the production of agricultural commodities helps to increase the income of the farmer who inturn will be able to use more inputs required to raise the productivity. So an agriculture that is progressing, in the sense that individual farms are raising the productivity, has to be one in which many farmers are using desired inputs. Again, we can easily speculate that, without the farmers being given good return for their production they will not be happy and the production will not be what we want to have. The study of price response to production is gaining ascedency in developing as well as developed countries too.

The growth of expenditure in agricultural development in our country emphasizes the urgency that the nation has felt enhance up the agricultural productivity. The urgency can be viewed mainly through two approaches:

Firstly, the demand for food is increasing day by day because of the increasing rate of population. The population of Nepal has increased from 5.53 millions in 1930 to 15.02 millions in 1981. The planners have to say that the population will go on increasing in future too. Thus, if this high demand for food is not fulfilled the consequences will be very serious and can hinder developments in other sectors also.

Secondly, agriculture is the main source of national income and the country's foreign trade is largely based upon agricultural commodities. About 65% of the gross national product and about 80% of the total earnings from the export of the country depends on agricultural commodities. So to promote the foreign trade and to earn more foreign currency it is of utmost importance to accelerate the agricultural development. Besides this, most of the industries in our country are agro-based. For their smooth running and to make more profitable they need a sound agricultural reinforcement.

It is thus observed that the entire economic development of our country seems to be based upon the agricultural development. But the achievement is not an easy task. The agriculture in a country depends fully on thousands and millions of individual farms of different sizes and their types. What is to be produced and how, on each farm is determined by the farmers. The farmer of subsistence farm makes his decisions on the basis of what his farm and his family labour can produce. But to raise the productivity the farmers must be able to fulfil the required inputs. As discussesd above, we can expect a farmer to use the desired inputs only when he receives substantial amount of cash by selling his own product. So one should not take farmer for granted, for they are most important link in the development of agricultural sector.

An individual farmer is annually confronted with the decision of what to plant. This decision is not only a funtion of his estimated yield for various crops, but also by the estimated price of that crop at the harvest time – some months in the future. This price is, in general, dependent upon the total production of that year which in turn is dependent upon the crop decision of all the farmers and their average yields for the same season. In this context a competitive game between the individual farmer and the group exists.

The table no. I shows the production statistics for the four major winter crops; wheat, maize, potato and oilseeds for the year 1968-69 to 1977-78 based upon the agricultural data from His Majesty's Government, Department of Food and Agricultural Marketing Services.

However, yield is an increasing function of time (reflecting the impact of improved technology upon agriculture). In addition, the price variations is rather wide. This indicates the dynamic nature of agriculture. It should be noted that the changes in total crop – land in these four crops is rather small from year to year. The mean total crop-land is 883500 hectares. Expansion and contraction of agriculture as a whole is rather difficult. It is hard to locate new farms with the prospects as good as those already settled. Contraction of agricultural plant (sector) is equally difficult. Farmers who leave the land must have other occupations or places to go, which are hard to find when agriculture is depressed. The best interests of the individual producer are usually served by producing near the capacity of his farm and equipments. The total agricultural land of the country consequenty continues at a nearly constant rate from year to year, except when disturbed by widespread droughts or floods.

The above four crops, mentioned in the table I, are essentially the major winter crops in our country. In winter season, when the farm becomes vacant an individual farmer can make his decision to plant any one of them on his land. With these considerations a gross income criterion can be made to determine the optimal acreage allocation among the four crops for an individual farmer, in the sense that the decision about to plant for the individual farmer is based upon the probability of one crop relative to the other crops alternatives. For

Table I

Crop Statistics

Area in '000 Hectares
Production in '000 M. Tons
Yield in Tons/Hectare.
Price in Rs. /Kg.

Year	Wheat				Maize				Potato				Oilseeds			
	Production	Area	Yeild	Price	Production	Area	Yield	Price	Production	Area	Yield	Price	Production	Area	Yield	Price
1968/69	233	208	1.12	1.56	765	422	1.81	1.11	250	43	5.81	1.00	54	101	0.53	1.79
1969/70	265	226	1.17	1.57	795	433	1.83	1.21	263	46	5.72	1.08	57	103	0.55	1.94
1970/71	293	228	1.29	1.64	833	446	1.86	1.19	273	49	5.57	1.24	55	106	0.52	2.18
1971/72	223	239	0.93	1.86	759	439	1.73	1.32	293	51	5.75	1.17	57	111	0.51	2.29
1972/73	312	259	1.20	2.29	822	446	1.84	1.69	294	51	5.76	1.51	57	112	0.51	2.93
1973/74	308	274	1.12	2.47	814	453	1.80	1.70	306	53	5.77	1.49	62	114	0.54	3.62
1974/75	331	291	1.14	3.11	827	458	1.80	1.95	307	54	5.69	1.76	56	113	0.50	4.63
1975/76	357	328	1.09	2.51	748	453	1.65	2.04	312	53	5.83	1.68	68	113	0.60	3.47
1976/77	382	348	1.10	2.71	797	445	1.79	1.86	269	53	5 08	1.84	61	118	0.52	3.54
1977/78	411	366	1.12	2.28	840	445	1.88	2.19	341	51	6.68	2.48	78	133	0.58	4.45

such situation an individiual farmer would attempt to maximize his gross income against the forces of nature. But since nature cannot be conceived as possessing a direct antagonism to the farmer and rationally trying to outwit him, this can be considered a pure maximization problem in the classical sense.

2 OBJECTIVES OF THE STUDY

In general the objective of this study is to develop a game theoretic model for an agricultural crop selection problem in Nepal with a view to maximize the gross income of an individual farmer. More specifically, the objectives of this study include:

1. Among the four agricultural crops: wheat, maize, potato and oilseeds, to make an attempt to suggest an individual farmer to make the best decision for the optimal allocation of that crop from which he can get the maximum profit.

2. Reducing the problem to a two-person zero-sum game between an individual farmer and a hypothetical combination of all the forces that determine market prices and the importance of the individual withholding crop intentions information from the group as part of his optimal strategy to be indicated.

3. To determine the optimal allocation of the total crop-land for these four crops from the game theoretic view points and to compare the optimal allocation for the period 1968/69 to 1977/78.

4. Correlations will be shown between the actual allocations and the game theoretic optimal allocation. Meanwhile price elasticities and demand constants for these four crops will be computed by two-stage least square (2-SLS) regression method.

3 METHODOLOGY

Selection of Crops:

The crops selected for the present study are:

a) Wheat

b) Maize

c) Potato and,

d) Oilseeds (especially mustard seeds)

We all know that paddy is the most important summer cereal crop in our country and it occupies more than 60% of the lotal cultivable land during summer season. So that, in summer season, if there is a land suitable to plant paddy then there is no any profitable alternative cereal crop to plant for an individual farmer.

But in winter when the farm becomes vacant an individual farmer can plant any one of the above four cereal crops. They are essentially the four major winter cereal crops of our country and can be planted on almost every cultivable land. All of these four crops can be sown in the same season in Terai, river–valleys and on the lower Mahabharat range upto 10,000 ft. and above this altitude. These crops can be sown in spring season. The winter sowing period ranges from mid-November to mid-January and the spring period may differ in different areas.

An Agricultural Game

It is discussed earlier that the individual farmer is annually confronted with the decision of what to plant in his farm in order to get a maximum gross income. The traditional game theory approach in determining acereage allocation for an individual farmer is to develop a one–person zero–sum game model. But here in this problem the farmer would attempt to maximize his income not only against the very worst that the nature can do to him but also by the crop decisions of all the other farmers, the policies of the buyers of grains and the regulations of the government. It can be assumed that, unlike the nature, all the other farmers and the buyers of the grains are also actively pursuing opposing objectives of that individual farmer, which in turn reduces the significance of the one-person game approach.

A more sophisticated view of the crop selection problem can be obtained from a simple two person zero–sum game model ; by considering the individual farmer in competition with a hypothetical combination of all the forces that determine market prices for agricultural products. This model can provide sufficiently good output results as to supply insight into the criteria utilized by government's agricultural programmes in making crop selection decisions.

The hypothetical combination of forces would contain all the other farmers and the buyers of grains as well as the nature too. Inclusion of the buyers of the grains in the group is necessary to make an order in zero-sum game; i.e. the two players have opposing objectives. By restricting the policy of the buyers of the grains to paying a price determined by demand activities, however, the freedom to choose strategies for the group will only be influenced by the crop allocation decisions of the combination of farmers. Although the forces of nature to determine the values of the crop yield, this item will be employed in the model as a parameter. The value of yield (tons/hectare) will be used to determine the optimal strategies.

The effects of government's legislations are only indirectly in the model Their past influence is reflected in the price and production statistics used to derive the demand elasticity curves for the four crops.

The basic premise of the model is that the individual wants to make the best decision for crop selection against anythi ıg that may happen to him. This is precisely the minimax criterion of the game theory. Although it is difficult to justify on practical grounds the rationale for a large group caring particularly what one individual does, nontheless an outlook for the individual would assume that the group could do its worst to him. Using that as a basic assumption in the present study; let the individual farmer, who desires to allocate optimally his farm among the four crops (wheat, maize, potato, oilseeds) be the BLUE player. His opponent, the RED player, will be the hypothetical combination described above.

In effect in this model, Blue desires to allocate his acreage to the four crops in such a manner that he can assure himself a maximum pay-off even when Red may do his worst against Blue. Further, Red has a rationale for doing his worst against Blue simply because he wants to maximize his own income by minimizing the pay-off to Blue. Thus the value of the game to Blue will be his gross income from the four crops based upon the minimax principle of the theory of games.[1]

Sources of Data

The findings of this study are totally based on the secondary data, primarily collected by some government agencies. The sources are as follows:

Prices and production of crops: HMG, Department of Food and Agricultural Marketing Services.

General Price Index: Nepal Rastra Bank.

Population: International Financial Statistics.

1. Sidney Moglewer : *A Game Theory Model for Agricultural Crop Selection.* Econometrica, Vol. 30, No. 2, (April 1962); pp. 257.

Current and Constant GDP_c : Central Bureau of Statistics.

Price of Fertilizers: Agricultural Inputs Corporation.

Statistical Tools Used

The following are the major statistical tools applied in the present study:

(a) **Two-stage least squares (2-SLS):** While 2-SLS is the tidious and difficult method it is also statistically sound and most likely to yield coefficients that are unbiased and consistent. Thus, when we are interested in the coefficients and want to draw information from them, 2-SLS ought to be used.[1] While OLS method will yield spurious results.

In this method, first we take the least squares regression of the dependent variable (Y) on the only exogeneous variables to find the estimates for Y and in the second stage we take these estimated values as one of the exogeneous variables and again apply the OLS method to get the required estimates of the coefficients.

(b) **Multivariate log linear Model:** Multivariate log linear model of the type log (production) $= \alpha + \beta_1 \log \text{Pest} + \beta_2 \log GDP_c + \beta_3 \log \text{Popl}^n$ is used to estimate the price elasticity for all the four crops.

(c) **F-test:** This test is applied to observe whether a relationship between the independent variables and the dependent variable exists or not in the multivariate log linear model; that is to say whether the model used is significant or not.

Analysis of Price Elasticities and Demand Constants

Price Elasticities

For the first stage, the model is:

Price of the i^{th} crop = f (Price of fertilizers, GDP_c , Population)

i. e. $Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$

1. Neal P. Cohen, Estimating Demand Curves–the Case of Maize in Nepal, The Economic Journal of Nepal, Vol. 1, No. 4, Oct. 1978, EIC – T.U., p. 66.

Where, Y_i = Price of the i^{th} crop indexed.

X_1 = Average price of A/sulphate, complex, urea and potash indexed.

X_2 = Index of current GDP deflated by GPI = Real income.

X_3 = Population in millions of people.

Table II

Price Index for Cereal Crops in Nepal

Year	Price of Wheat indexed (Y_1)	Price of Maize indexed (Y_2)	Price of Potato indexed (Y_3)	Price of Oilseed indexed (Y_4)	Price of fertilizers indexed (X_1)	GDP_c Indexed (X_2)	Population in Million (X_3)
1968-69	100.00	100.00	100.00	100.00	100.00	100.0000	10.98
1969-70	100.64	108.60	108.00	108.38	100.00	99.3009	11.25
1970-71	105.13	107.50	124.00	121.79	100.73	104.8996	11.56
1971-72	119.23	119.40	117.00	127.93	124.98	109.9135	11.81
1972-73	146.79	152.70	151.00	163.68	124.98	98.3431	12.06
1973-74	158.33	152.70	149.00	202.23	190.91	120.5961	12.32
1974-75	199.35	175.30	176.00	258.65	190.91	113.9340	12.57
1975-76	160.89	183.90	168.00	193.85	204.60	118.1073	12.86
1976-77	173.71	167.70	184.00	197.77	209.10	130.9438*	13.14*
1977-78	179.48	197.40	248.00	248.61	209.10	121.4694*	13.42*

*Denotes estimated figures.

The estimated prices of the four crops are as follows:

Estimated price for wheat is, $\hat{Y}_1 = 41.6675 + 0.8038\,X_1 - 1.7430\,X_2 + 14.1343\,X_3$

Estimated price for Maize is, $\hat{Y}_2 = 98.5638 + 0.6084\,X_1 - 2.1800\,X_2 + 32.306\,X_3$

Estimated price for potato is, $\hat{Y}_3 = -578.6930 - 0.1440\,X_1 - 1.051\,X_2 + 71.422\,X_3$

and Estimated price for oilseeds is,

$$\hat{Y}_4 = -2.1178 + 1.239X_1 - 2.7800X_2 + 23.9642X_3$$

Using the value of price of fertilizers indexed X_1, the real income indexed X_2 and the population X_3, the estimated prices for the above four crops can be derived for the period 1968–69 to 1977–78 as follows:

Table III

Estimated Prices for Cereal Crops in Nepal

Year	Estimated Indexed Price for Wheat	Estimated Indexed Price for Maize	Estimated Indexed Price for Potato	Estimated Indexed Price for Oilseed
1968–69	102.94	98.99	86.02	106.91
1969–70	101.95	101.41	104.61	114.84
1970–71	109.34	115.41	122.19	108.09
1971–72	126.95	131.20	121.28	130.19
1972–73	131.49	140.60	161.30	168.35
1973–74	160.27	154.26	164.99	184.40
1974–75	173.56	174.48	171.85	218.91
1975–76	181.89	183.73	186.20	231.22
1976–77	184.01	188.68	192.06	207.82
1977–78	182.37	190.73	222.02	240.87

For the Second Stage the regression model is: $Q_I = f$ (Pest, GDPc, Population)

Where, Q_i = Quantity of production of the i^{th} crop (Quantity demanded)

Pest = Estimated price of the i^{th} corp

So that, $Q_i = A\ \text{Pest.}^{\beta_1}\ \text{GDP}_c^{\beta_2}\ \text{Pop.}_n^{\beta_3}$

We know that the coefficients or elasticities remain unchanged taking lograrithm too.

Therefore $\log Q_i = \log A + \beta_1 \log Pest + \beta_2 \log GDP_c + \beta_3 \log Pop^n$.

$$\text{or, } Y_i = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$$

Thus the required price elasticity is β_1 .

Table IV

For Wheat

Year	$\log Q_i = Y$	$\log Pest = X_1$	$\log GDP_c = X_2$	$\log Population = X_3$
1968–69	5.3674	2.0124	2.0000	1.0406
1969–70	5.4232	2.0086	1.9969	1.0504
1970–71	5.4669	2.0386	2.0208	1.0630
1971–72	5.3483	2.1035	2.0410	1.0722
1972–73	5.4942	2.1189	1.9928	1.0813
1973–74	5.4886	2.2049	2.0813	1.0906
1974–75	5.5198	2.2395	2.0564	1.0993
1975–76	5.5529	2.2598	2.0723	1.1092
1976–77	5.5821	2.2648	2.1168	1.1186
1977–78	5.6138	2.2610	2.0846	1.1278

Now, we can summarize the results by the following table:

Results of the Regression Analysis

Crop	Variables	Coefficients	R^2	Adj.R^2	F–cal.	$F_{3,9}$ at 5%
	$\log pest = X_1$	$\beta_1 = -0.334$				
WHEAT	$\log GDPc = X_2$	$\beta_2 = -0.379$	0.7959	0.7704	7.913*	4.76
	$\log Pop^n = X_3$	$\beta_3 = 4.3424$				
		Constant $\alpha = 2.2669$				

i.e. $\log QW = 2.2669 - 0.334 \log pest - 0.379 \log GDP_c + 4.3424 \log Pop^n$.

Therefore, the required price elasticity β_1 for wheat= -0.334. Which shows that doubling of price (i.e. cent percent increase in price) of wheat causes a reduction in the demand by 33.4 per cent.

Now, to calculate the demand constant with respect to price and production, the relation yields:

the demand constant $c = \text{Anti} \log(\bar{Y} - \hat{\beta}_1 \bar{X}_1)$

$= 1.601 \times 10^6$

For Maize, the data as follows:

TABLE V

For Maize

Year	$\log Q_i = Y$	$\log Pest = X_1$	$\log GDPc = X_2$	$\log Pop = X_3$
1968-69	5.8837	1.9956	2.0000	1.0406
1969-70	5.9004	2.0060	1.9969	1.0504
1970-71	5.9206	2.0622	2.0208	1.0630
1971-72	5.8802	2.1180	2.0410	1.0722
1972-73	5.9149	2.1480	1.9928	1.0813
1973-74	5.9106	2.1883	2.0813	1.0906
1974-75	5.9175	2.2418	2.0564	1.0993
1975-76	5.8739	2.2642	2.0723	1.1092
1976-77	5.9015	2.2759	2.1168	1.1186
1977-78	5.9243	2.2804	2.0846	1.1278

The calculations yield the following table of regression analysis:

Crop	Variables	Coefficients	R^2	Adj.R^2	F–cal	$F_{3,9}$ at 5%
	log Pest $= X_1$	Constant $\alpha = 5.3381$				
MAIZE	log GDPc $= X_2$	$\beta_1 = -0.2895$	0.7931	0.7672	6.8376	4.76
	log Pop $= X_3$	$\beta_2 = -0.2212$				
		$\beta_3 = 1.513$				

i.e. $\log Q_M$ — $5.3381 - 0.1895 \log \text{Pest} - 0.2212 \log \text{GDPc} + 2.5130 \log \text{Pop}^n$

Therefore, the required price elasticity β_1 for Maize $= -0.2895$

It shows that a 100 percent increase in price of maize causes a reduction of its demand by 28.95 percent only.

Now to calculate the demand constant for maize, the relation gives:

The demand constant c $= \text{Anti log } (Y — \beta_1 \overline{X_1})$

$= 3.369 \times 10^6$

TABLE VI

For Potato

Year	$\log Q_i = Y$	log Pest $= X_1$	log GDPc $= X_2$	log Pop$^n = X_3$
1968–69	5.3979	1.9346	2.0000	1.0406
1969–70	5.4200	2.0194	1.9969	1.0504
1970–71	5.4362	2.0868	2.0208	1.0630
1971–72	5.4669	2.0835	2.0410	1.0722
1972–73	5.4683	2.2076	1.9928	1.0813
1973–74	5.4857	2.1673	2.0813	1.0906
1974–75	5.4871	2.2352	2.0564	1.0993
1975–76	5.4942	2.2700	2.0723	1.1092
1976–77	5.4298	2.2846	2.1168	1.1186
1977–78	5.5398	2.3464	2.0846	1.1278

Now, the summary of the results is as follows:

Crop	Variables	Coefficients	R^2	Adj.R^2	F. cal	$F_{3,9}$ at 5%
		Constant $\alpha = 4.1872$				
	log Pest $= X_1$	$\beta_1 = -0.2653$	0.9799	0.9774	980000	4.76
POTATO	log GDPc $= X_2$	$\beta_2 = -0.8046$				
	log $Pop^n = X_3$	$\beta_3 = 3.2205$				

i.e. $\log Q_P = 4.1872 - 0.2753 \log Pest - 0.8046 \log GDPc + 3.2205 \log pop.$

Therefore, the required price elasticity for Potato $\hat{\beta}_1 = -0.2653$. That is to say, a 100 per cent increase in price of potato causes a reduction in the amount purchased by 26.53 per cent.

Now, to have the demand constant the relation gives

$$\text{Demand constant } c = \text{Anti log } (\overline{Y} - \hat{\beta}_1 \overline{X_1})$$

$$= 1.086 \times 10^6$$

Lastly for Oilseeds the data are as follows:

TABLE VII

For Oilseeds

Year	log $Q_i = Y$	log pest $= X_1$	log GDPc$=X_2$	log Pop$=X_3$
1968-69	4.7324	2.0291	2.0000	1.0406
1969-70	4.7559	2.0600	1.9969	1.0504
1970-71	4.7404	2.0338	2.0208	1.0630
1971-72	4.7559	2.1145	2.0410	1.0722
1972-73	4 7559	2.2263	1.9928	1.0813
1973-74	4.7924	2.2658	2.0813	1.0906
1974-75	4.7482	2.3403	2.0564	1.0993
1975-76	4.8325	2.3638	2.0723	1.1092
1976-77	4.8513	2.3176	2.1168	1.1168
1977-78	4.8921	2.3818	2.0846	1.1278

and the calculations yield the following table of resressions analysis:

Crop	Variables	Coefficients	R^2	Adj. R^2	F–Cal	$F_{3,9}$ at 5%
		Constant $\alpha = 2.3668$				
	log Pest $= X_1$	$\beta_1 = -0.2065$				
OIL SEEDS	log GDPc $= X_2$	$\beta_2 = 0.1334$	0.7993	0.7742	7.9733	4.76
	log Pop $= X_3$	$\beta_3 = 2.3984$				

That is, $\log Q_0 = 2.3668 - 0.2065 \log \text{Pest} + 0.1334 \log \text{GDPc} + 2.3984 \log \text{Pop}.$

Therefore, the required price elasticity for Oilseeds $\hat{\beta}_1 = -0.2065$ i.e., to say a doubling of price of oilseeds causes a reduction in the amount purchases by 20.65 per cent

Now the demand constant can be calculated by the relation which yield:

The required demand constant for Oilseeds

$$c = \text{Anti log } (\bar{Y} - \hat{\beta}_1 \bar{X}_1)$$
$$= 0.1749 \times 10^6$$

Determination of Value of the Game

Since we obtained the least squares price elasticities and the demand constants for the four crops as follows:

Period 1968/69—1977/78

Crop	Elasticities E_i	Demand constants C_i	$1/E_i$
Wheat	– 0.3340	1.601×10^6	– 2.9940
Maize	– 0.2895	3.369×10^6	– 3.4542
Potato	– 0.2653	1.086×10^6	– 3.7693
Oilseeds	– 0.2065	0.1749×10^6	– 4.8426

Now, to determine the average value of the Game for the period under consideration we utilize the following values also:

Average yield on wheat $Y_1 = \bar{Y}_1 = 1.1258$ M. ton/Hectare

Average yield on maize $Y_2 = \bar{Y}_2 = 1.8018$ M. ton/Hectare

Average yield on potato $Y_3 = \bar{Y}_3 = 5.7698$ M. ton/Hectare

Average yield on Oilseeds $Y_4 = \bar{Y}_4 = 0.5382$ M. ton/Hectare

and the total average crop land for these four crops = L = 883500 Ha.

Thus, the total payoff to Blue is given by,

$$M = \sum_{i=1}^{4} Y_i \, L \, x_i \left(\frac{y_i}{k_i}\right)^{1/\alpha_i} \quad \text{where, } K_i = c_i / \bar{Y}_i \bar{L}$$

and $\sum_{i=1}^{4} x_i = 1$; $\sum_{i=1}^{4} y_i = 1$; $x_i \geq 0$; $y_i \geq 0$ $\forall i = 1, 2, 3, 4$.

so that, $K_1 = c_1 / \bar{y}_1 \bar{L} = 1.601 \times 10^6 / 1.1258 \times 883500 = 1.6096$

similarly, $K_2 = c_2 / \bar{y}_2 \bar{L} = 2.1164$; $K_3 = c_3 / \bar{y}_3 \bar{L} = 0.2130$ and

$$K_4 = C_4 / \bar{Y}_4 \bar{L} = 0.3678 \quad \therefore \left(\frac{1}{K_1}\right)^{1/\alpha_1} = (1/1.6096)^{\frac{1}{0.3340}} = 4.1583$$

Therefore, $\left(\frac{1}{K_2}\right)^{1/\alpha_2} = 13.3254$; $\left(\frac{1}{K_3}\right)^{1/\alpha_3} = 0.00294$

and $(1/K_4)^{1/\alpha_4} = 0.0079$

Thus, the total pay off the Blue is,

$$M = 1.1256 \, L \, x_1 \, y_1^{-2.994} \, .4.1583 + 1.8018 \, L \, x_2 \, y_2^{-3.4542} \, 13.3254$$

$$+ 5.7698L \, x_3 \, y_3^{-3.7693} \times 0.00294 + 0.3383L \, x_4 \, y_4^{-4.8426} \, 0.0079$$

$$= 4.6814L \, x_1 \, y_1^{-2.994} + 24.0097L \, x_2 \, y_2^{-3.4542}$$

$$+ 0.0170L \, x_3 \, y_3^{-3.7694} + 0.0043L \, x_4 \, y_4^{-4.8426}$$

So that the required value of the game is,

$$V = \min_{y} \max_{x} (4.6814L\, x_1\, y_1^{-2.994} + 24.0097L\, x_2\, y_2^{-3.4542}$$

$$+0.0170L\, x_3\, y_3^{-3.7694} + 0.0043L\, x_4\, y_4^{-4.8426}$$

To have the maximum x, we can take xi = 1 since xi=1 since xi=0 or 1 randomized for any i.

$$\therefore V = \min \max (4.6814L y_1^{-2.994} \text{ or } 24.0097L\, y_2^{-3.4542}$$

$$\text{or } 0.0170L\, y_3^{-3.7694} \text{ or } 0.0043L\, y_4^{-4.8426})$$

which occurs when,

$$V = 4.6814\, y_1^{-2.994} = 24.0097\, y_2^{-3.4542} = 0.0170\, y_3^{-3.4692}$$

$$= 0.0043\, y_4^{-4.8426}$$

Now, the problem is how to get the values for y_1, y_2, y_3 and y_4 for which the solution is as follows:

Since we have, $y_1 + y_2 + y_3 + y_4 = 1$ .... (a) and each $y_i \geq 0$ and we obtained

$$V = 4.6814 y_1^{-2994} = 24.0097\, y_2^{-3.4542}$$

$$= 0.0170\, y_3^{-3.7694} = 0.0043\, y_4^{-4.8426} \quad \text{......... (b)}$$

Since the first equation is in linear form and second is nonlinear one these two equations cannot be solved directly. For the solution, we can take any arbitrary value for v and then find the values for y_1, y_2, y_3 and y_4 then test whether these values satisfy the condition (a) i. e. $\sum_{i=1}^{4} y_i = 1$ or not.

Now, at first let us suppose that V = 100 then

$$4.6841\, y_1^{-2.994} = 24.0097\, y_2^{-34542} = 0.017\, y_3^{-3.7694} = 0.0043\, y_4^{-4.8426} = 100$$

So that,

$$y_1 = (100/4.6814)^{-1/2.994} = 0.3597;$$

$$y_2 = (100/24.0097)^{1.3.4542} = 0.6616;$$

$$y_3 = (100/0.017)^{-1/3.7694} = 0.1000 \text{ and}$$

$$y_4 = (100/0.0043)^{-1/4.8426} = 0.1254$$

Thus $\sum_{i=1}^{4} yi = 1.2467$ which is not possible because $\sum_{i=1}^{4}$ yi cannot exceed 1. So our assumption that V=100 is not possible. Since there is an inverse relation between V and if so to reduce the values of yi's V must be greater 100.

So that let V=200

$$\therefore y_i = (200/4.6814)^{-1/2.994} = 0.2853$$

Similarly, $y_2 = 0.5413$, $y_3 = 0.0832$ and $y_4 = 0.1087$

$$\therefore \sum_{i=1}^{4} y_i = 1.0185 \text{ which is still greater than } 1.$$

so that V also must be greater than 200.

Now, let V = 225 then, $y_1 = 0.2743$; $y_2 = 0.5232$; $y_3 = 0.0807$ and $y_4 = 0.1061$

$$\therefore \sum_{i=1}^{4} y_i = 0.9842 \text{ which shows that V must be between 200 to 225}$$

i. e. 200 < V < 225.

Now, let us assume V = 210 then, $y_1 = 0.2807$; $y_2 = 0.5337$; $y_3 = 0.0821$ and $y_4 = 0.1076$.

$$\text{Thus } \sum_{i=1}^{4} y_i = 1.0041$$

It shows that V lies between 210 to 225. So that let us suppose the value for V=215, then $y_1 = 0.2785$; $y_2 = 0.5301$; $y_3 = 0.0816$ and $y_4 = 0.1071$.

$$\text{so that, } \sum_{i=1}^{4} y_i = 0.9973$$

Which gives the idea that V must lie between 210 to 115. Now, let us take the value for V as 213:

Then $y_1 = 0.2794$; $y_2 = 0.5316$; $y_3 = 0.0818$ and $y_4 = 0.1073$

$$\therefore \sum_{i=1}^{4} y_i = 1.0001 \text{ which is nearly acceptable.}$$

Then $y_1 = 0.2794$; $y_2 = 0.5316$; $y_3 = 0.0818$ and $y_4 = 0.1073$

$\therefore \sum_{i=1}^{4} yi = 1.0001$ which is nearly acceptable.

Again if we take $V = 213.1$

Then, $y_1 = 0.2794$, $y_2 = 0.5315$, $y_3 = 0.0818$ and $y_4 = 0.1073$

so that $\sum_{i=1}^{4} yi = 1.0000$

The average value of the game $V = 213.1$ is fully acceptable.

Hence, the solution of the game is as follows:

The value of the game $V = 113.1$ Rs. per Hectare

$y_1{}^* = 0.2704$; $y_2{}^* = 0.5315$; $y_3{}^* = 0.0818$ and $y_4{}^* = 0.1073$

$xi - 0$ or 1 randomized for any in i

But we know that the total pay off to blue is,

$$M = 5.6814L\, x_1\, y_1^{-2.994} + 24.0097L\, x_2\, y_2^{-3.4542}$$

$$= 0.017L\, x_3\, y_3^{-3.7694} + 0.0043L\, x_4\, y_4^{-4.8426}$$

So that at the value where $y - y^*$ (Red's optimal strategy) the probabilities for paying any one of the four possible strategies for Blue when $x_i - 1$ are designed by α's and can be found by solving the following set of equations

$$-\alpha_1 \frac{\partial M}{\partial y_1}\bigg|\, x_1 = 1 + \alpha_2 \frac{\partial M}{\partial y_2}\bigg|\, x_2 = 1 = 0$$

$$-\alpha_1 \frac{\partial M}{\partial y_I}\bigg|\, x_I = 1 + \alpha_3 \frac{\partial M}{\partial y_3}\bigg|\, x_3 = 1 = 0$$

$$-\alpha_1 \frac{\partial M}{\partial y_I}\bigg|\, x_I = 1 + \alpha_4 \frac{\partial M}{\partial y_4}\bigg|\, x_4 = 1 = 0$$

and, $\alpha_I + \alpha_2 + \alpha_3 + \alpha_4 = 1$ where $\alpha i \geq 0$

Thus,

$$-\alpha_I\, (4.6814L\, x - 2.994\, y_I^{-3.994}) + \alpha_2\, (24.0097L - 3.4542\, y_2^{-4.4542}) = 0,$$

or, $2282.4389\, \alpha_1 - 1384.8333\, \alpha_2 = 0$ ... ... (i)

Similarly, $2282.4389\, \alpha_1 - 9822.7917\, \alpha_3 = 0$ ...... (ii)

$2282.4389 \alpha_1 - 9602.0638 \alpha_4 = 0$ .... (iii)

and $\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 = 1$ .... (iv)

The solution yields the following results:

$\alpha^*_1 = 0.3207$

$\alpha^*_2 = 0.5286$

$\alpha^*_3 = 0.0745$

$\alpha^*_4 = 0.0762$

Therefore, Blue should select with the probability distribution given by the set of α 's of the four crops and plant all his crop land by that crop.

Crop Allocation Analysis

Since, $y^*_1 = 0.2694$, $y^*_2 = 0.5315$, $y^*_3 = 0.0818$ and $y^*_4 = 0.1073$ so that the only optimal strategy (crop allocation) for Red is to plant maize.

But, Blue should randomly select one of the four crops with the probability distribution given by the set of y's and plant all his acreage by that crop. But we obtained $\alpha^*_1 = 0.3207$, $\alpha^*_2 = 0.5286$, $\alpha^*_3 = 0.0745$ and $\alpha^*_4 = 9.0762$. So that Blue Should also give first priority to plant all his crop land.

Now, if Red knew before hand what crop allocation Blue planned to employ, he could adjust his own crop allocation to reduce the pay-off to Blue, though the mangitude of the pay-off to Blue is extremely small. On the other hand, if Blue knew that Red were not employing an optimal allocation, he could adjust his strategy to account for this fact. For instance, if maize were going to be overplanted, Blue should plan on wheat. The basic aspect of this model is the emphasis on the direct competition between the individual farmer and the group.

Comparison between Game Theoretic Optimal Allocations and Actual Crop Allocations for the Period 1968/69 - 1977/78

In the context of this game, Red contains essentilly allt he Nepalese farmers. Thus the actual strategy of Red is equivalent to the actual division of crop-land for the four crops. The following table shows a tabular comparison of the value of y for each of the four crops derived from actual crop-land statistics from (Table 1) and from the solution described above.

Table VIII

Comparison of Game Theoretic optimal allocations and Actual Crop Allocations

Year	Wheat		Maize		Potato		Oilseeds	
	y^*	y_a	y^*	y_a	y^*	y_a	y^*	y_a
1968—69	0.2751	0.2687	0.5304	0.5452	0.0822	0.0556	0.1123	0.1305
1969—70	0.2732	0.2797	0.5335	0.5359	0.0843	0.0569	0.1090	0.1274
1970—71	0.2621	0.2750	0.5363	0.5380	0.0871	0.0591	0.1145	0.2279
1971—72	0.2211	0.2845	0.5752	0.5226	0.0862	0.0607	0.1175	0.1321
1972—73	0.2717	0.2984	0.5315	0.5318	0.0833	0.0588	0.1135	0.1290
1973—74	0.2805	0.3065	0.5314	0.5067	0.0816	0.0593	0.1065	0.1275
74—75	0.2771	0.3177	0.5292	0.5000	0.0820	0.0590	0.1117	0.1234
1975—76	0.2787	0.3464	0.5491	0.4784	0.0780	0.0942	0.0942	0.1193
1976—77	0.2817	0.3610	0.5245	0.4616	0.0877	0.0550	0.1060	0.1224
1977—78	0.2951	0.3678	0.5307	0.4472	0.0746	0.0513	0.0996	0.1337

N.B. : y^* represents minimax criterion optimal allocation and
y_a represents actual allocation.

The correlation coefficients between the game theoretic allocations and the actual allocations for the four crops are as follows :

for wheat, $\rho=0.5625$

for maize, $\delta=0.2250$

for potato, $\rho=0.6856$*

for oilseeds, $\rho=0.4306$.

Conolusion

The aporoach of using a gross income pay-off and analyzing agricultural crop selection as a crop-land allocation problem has been presented in privious pages. But the model ignores many factors that do influence the crop land allocation. Some of these factors are government crop control, crop rotation programmes, allocation with other crops not included in the model (i.e. pea, gram, barley, etc.). But these crops (Wheat, Maize, Potato and Oilseeds) are largely marketed under competitive conditions through commercial channels and the validity of the minimax criterion for a free market is indicated. This is the basic justification for the model.

The difference in value between the set of α's and the set of y^*'s should be noted. At first glance it may appear that since Blue represents any individual farmer, it should be possible to apply central limit theorem for the values of the α's for every individual farmer contained in Red and prove the approach to y^* in the limit, thus yielding another set of predictions for crop allocation to Red. This view is not possible for this model since independence does not exist between the individuals comprising Red and thus the central limit theorem does not apply. In fact, once α's are established for Blue, these would influence the values of α's for Green, a second individual farmer in a three-person game and so on. Thus it is not surprising to have the values of α^* different than the values of y^* in the simple two-person game model of this type.

Further insight into the conservative protection of a minimax criterion can also be noted by considering the quantitative values of the set y^*'s. On the average, Blue has the same optimal strategy of planting maize followed by wheat, oilseeds, and potato as has the Red. The major hazard for Blue in this model is that he **may** select a crop that would be over-produced and thus receive a very low price for it. The rate of change of price with respect to production can be derived from the equation :

$$\frac{\delta p_i}{\delta q_i} = \frac{1}{\alpha_i} \frac{p}{q_i}$$

It is readily seen that, other things being the same, decline in the price is lowered for an elastic commodity than for an inelastic one as production increases. In the present study it is obtained that wheat is the only elastic crop (E= – 0.3340). Thus, there is a great deal of protection for Blue in having the greatear probability for planting wheat, since there will be least adverse effects if Red did overplant wheat. On the other, oilseeds are the most inelastic crop (E= – 0.2065) and it is the third alternative crop to Blue. So that, Blue should properly have the lesser chance to commit to oilseeds. In effect, the values of α^* are highly sensitive to be values of E, thus the model protects Blue against non-optimal Red strategies.

Lastly, it should be pointed out that minimax is not the sole criterion to use in the selection of crops; but however, it protects against undue losses which in turn will be helpful in maximizing the gross income of an individual farmer.

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Book Review

George Gilder, **Wealth and Poverty,** *Kalyani Publishers, New Delhi, 1982, Pages 306, Price I.C. Rs. 30, Index and References.*

This book is an essay on the limitation of contemporary economics in analysing the sources of creativity and progress in all economies. This book highlights on the most critical problems of contemporary society. For example, it discusses about how to increase wealth and curtail poverty. While talking about the nonmaterial forces like creativity, technological adventure, motivation, etc., he analyses how misguided policies undermine these true sources of wealth.

The central theme of *Wealth and Poverty,* is the need to extend to the poor the freedoms and opportunities, the values of family and faith, that are indispensable to all wealth and progress which is also a central theme of American liberalism.

The book is divided into three parts. The first is denoted as the mandate for capitalism and the second and third parts, like the crisis of policy and the economy of faith respectively, have altogether twenty one essays.

Gilder, in his essay, "The Supply Side", acknowledges classicist Theory of Perfect Competition as extremly useful in depicting the behaviour of particular markets for existing goods. But, he argues, it has little to do with the central activity of capitalism. For example, perfect competition actually comes to mean no competition at all in a situation of equilibrium where all participants have perfect information and in which companies can change neither prices nor products and can essentially affect neither supply nor demand. Thus perfect competition excludes most supply-side behaviour.

Gilder documents the evidences of how incentive system has crippled and affected the productivity. He confidently states that the so-called "Just" redistribution of wealth has not brought any benefits to the poor. He is shocked to note that over the last fifty years there has been no shift in the disttribution of wealth and income in the United States (P. 11)

This is a fascinating and useful book which encompasses tremendous wealth of insights.

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