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DIVERSIFICATION OF PUNJAB AGRICULTURE:
AN ECONOMETRIC ANALYSIS

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The introduction of high-yielding varieties (HYVs) of cereal crops, particularly wheat and rice, have brought about what has been termed as the green revolution. Punjab State has been on the forefront in the adoption of these HYVs due to the strong surface irrigation base supplemented by the spurt in minor irrigation. The production of foodgrains has risen from 33.89 lakh tonnes in 1965-66 to 147.78 lakh tonnes in 1983-84 in the State. Wheat production increased from 19.16 lakh tonnes in 1965-66 to 94.16 lakh tonnes in 1983-84 and paddy production increased from 2.92 lakh tonnes in 1965-66 to 45.39 lakh tonnes in 1983-84.[1] Punjab's share in foodgrains to the central pool increased phenomenally from ten per cent in 1967-68 to 45 per cent in 1983-84.[2] In view of the fact that other States are catching up fast with the Punjab State in the production of foodgrains and against the perspective of a fairly easy food situation as reflected in the sizable quantum of stocks (more than 26 million tonnes), it seems quite useful to study the prospects for diversification of agriculture. In some earlier studies, we have shown that there is a vast scope for enterprise diversification through adding of dairy, poultry, etc., in the enterprise mix of the farmers.[3] Although some studies have been conducted abroad on the determinants of diversification,[4] there is a conspicuous lack of such studies in India. The present study is intended to examine the factors affecting diversification at the *(a)* macro and *(b)* micro levels. The information thus generated, it is hoped, would help in the formulation of policies towards diversification to inject greater strength through reduced instability as well as opening up greater opportunities for growth.

METHODOLOGY

The present study is based on both primary and secondary data. The primary data were collected under a major Punjab Government project entitled, "Cost of Production of Principal Crops" for the year 1983-84 operated by the Department of Economics and Sociology, Punjab Agricultural University, Ludhiana. Secondary data for the analysis were collected from the Statistical Abstracts of Punjab. The whole study was divided into three parts. In first part, diversification trend of Punjab economy was studied. For this purpose, secondary data on domestic product at constant prices (1970-71 prices) for different sectors of the economy were taken from the Statistical Abstract, Punjab, 1984. To measure the diversification trend of the economy amongst its different sectors, two measures, *viz.,* the Herfindahl and Entropy Indexes were used :

1. Government of Punjab : Statistical Abstracts, Issued by the Economic Advisor to Government, Punjab, Chandigarh.

2. Government of India : Bulletin on Food Statistics, Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi, Various Issues.

3. D. S. Sidhu and A. J. Singh, "Diversification Possibilities of Punjab Agriculture", in Papers and Proceedings, National Symposium on Land and Water Management, Indian Ecological Society, November 9-11, 1978; A. J. Singh and K. K. Jain. "Prospects for Diversification of Agriculture in Ludhiana District", *Agricultural Situation in India,* Vol. XXXIV, No. 6, September 1979; and A.J. Singh and K.K. Jain, "Farm Planning under Risk and Uncertainty : An Application of Parametric Linear Programming", *Indian Journal of Agricultural Economics,* Vol. XXXVIII, No. 2, April-June 1983.

4. Rulon D. Pope and Richard Prescott, "Diversification in Relation to Farm Size and Other Socio-Economic Characteristics", *American Journal of Agricultural Economics,* Vol. 62, No.3, August 1980.

Herfindahl Index = H = $\sum_{i=1}^{n} p_i^2$ where p_i is the proportion of income from the ith sector of the economy, n is the total number of sectors.

Entropy Index = E = $\sum_{i=1}^{n} p_i \text{Log}(1/p_i)$,

E was calculated for two groups of sectors of the economy. Firstly, it was calculated by taking agriculture, livestock, forestry + fishery + mining and quarrying and secondary and tertiary sectors as the five groups in the economy. Secondly, it was calculated by taking primary, secondary and tertiary sectors as three groups.

The value of Herfindahl Index (H) varies from zero to one. It takes the value one when there is complete specialisation and value zero when there is 'perfect' diversification, *i.e.,* it has inverse relationship with diversification. E is the Entropy measure popularised in economics by Theil. Its value varies from zero to 'Log n' (maximum possible) when there is 'perfect' diversification and zero in the case of complete specialisation, *i.e.,* E has direct relationship with diversification. This index is decomposable and has all the desiderata of a good measure.[5] This property can help in assessing the grouping error.[6]

In the second part, crop diversification measures, namely, Herfindahl and Entropy were calculated using proportionate area under different crops for different years to study the trend of crop diversification in Punjab agriculture.[7] Herfindahl Index was calculated for crops which are currently being grown in the State. Entropy was also calculated for these crops, then these crops were pooled to form five groups, namely, paddy+wheat, other foodgrains, oilseeds, cash crops and fodders. Then these groups were further amalgamated to form four main groups, namely, foodgrains, oilseeds, cash crops and fodders. The difference of first two Entropies reflects change due to grouping while the difference of second and third Entropies reflects change due to grouping of paddy and wheat with other foodgrains.

In the third part, regression analysis was done with secondary data of different districts as cross-sections for the years 1971-72 and 1981-82. Herfindahl and Entropy indices of crop diversification were calculated and these were regressed on different explanatory variables as indicated below :

The regression model used was :

$$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 X_6 + u$$

where dependent variable $Y = 1-H$ or E

X_1 = fertilizer consumption in terms of nutrients per thousand hectares of net sown area,
X_2 = number of regulated markets per thousand sq. km.,
X_3 = inequality in the distribution of holdings as measured by Entropy index,
X_4 = standard deviation of value productivity of competing crops, *i.e.,* σ_1^2 and σ_2^2 are the variances of per hectare value productivity for competing crops in *kharif* and *rabi* seasons. Then the $\sigma = \dfrac{\sigma_1^2 + \sigma_2^2}{2}$ was taken as a measure of standard deviation.

X_5 = number of tractors per thousand hectares of net sown area,
X_6 = percentage of gross irrigated area to gross cropped area,
u = error term assumed to follow normal distribution with zero mean and constant variance.

5. F. Bourguignon, "Decomposable Income Inequality Measures", *Econometrica*, Vol. 47, No. 4, July 1979.

6. A. B. Atkinson : Economics of Inequality, Clarendon Press, London, 1975.

7. H. Theil : Economics and Information Theory, North-Holland Publishing Co., Amsterdam, 1967.

For pooled analysis, pooling both the years, other variables included were average rainfall, cropped area per agricultural worker and percentage area irrigated by tubewells as proxy for assured irrigation.

Further, linear regression analysis approach was used at the micro level data for the year 1981-82. In all, 168 farmers' data spread over the whole of Punjab were used in this approach with the following model specification :

$$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_3 + b_4 X_4 + b_5 X_5 + b_6 D + U$$

Y=E or 1–H

X_1 = operational area of the farm,
X_2 = number of family members on the farm,
X_3 = income from dairying,
X_4 = distance of the farm from the nearest regulated market,
X_5 = per hectare capital investment on the farm,
D = dummy for land, owned=0 and mixed (owned+leased in)=1
U=error term.

$U \sim N (0, \sigma^2)$ and $E (U_i, U_j) = 0$ $i \neq j$.

Here during all this analysis, we have used two measures of diversification in order to ascertain whether the response of different variable used is robust to the diversification measures used.

I

TRENDS IN INTER-SECTORAL DIVERSIFICATION OF PUNJAB ECONOMY

Table I depicts the inter-temporal trends in inter-sectoral diversification of the Punjab economy over the period 1970-71 to 1983-84. It would be seen that the Herfindahl index

TABLE I. INDICES OF DIVERSIFICATION IN PUNJAB ECONOMY
FOR DIFFERENT YEARS 1970-71 THROUGH 1983-84

Index	Year			
	1970-71	1975-76	1980-81	1983-84
(1)	(2)	(3)	(4)	(5)
Herfindahl (based on 5 groups)	0.3019	0.2903	0.2833	0.2800
Herfindahl (based on 3 groups)	0.4334	0.4105	0.3831	0.3804
Entropy I (based on 5 groups)	0.9528	0.9841	1.0210	1.0251
Entropy II (based on 3 groups)	1.3003	1.3171	1.3302	1.3369
Difference (II–I)	0.3475	0.3330	0.3092	0.3118

Entropy I calculated on the basis of three sectors (primary, secondary and tertiary sectors).

Entropy II calculated on the basis of five sectors (agriculture, livestock, forestry+fishery+mining, secondary and tertiary sectors).

for the three sectors decreased from 0.4334 in 1970-71 to 0.3804 in 1983-84 and for the five sectors decreased from 0.3019 to 0.2800. So inter-sectoral diversification has been continuously on the increase over this period. Similarly, Entropy index increased from 0.9528 in 1970-71 to 1.0251 in 1983-84 based on the three sectors' analysis and from 1.3003 to 1.3369 over the same period for the five sectors' analysis of the State economy. Again, this reflected an increase in the diversification of the State economy. The declining trend in the difference of Entropy indices based on the three and the five sectors' classification of the economy reflected increasing diversification within the primary sector.

II

INTER-TEMPORAL TRENDS IN CROP DIVERSIFICATION

Table II reflects the inter-temporal trend in crop diversification in Punjab. Increase in Herfindahl Index showed continuous decrease in diversification over the years. The crop

TABLE II. TREND OF INDICES FOR CROP DIVERSIFICATION IN PUNJAB

Index	Year					
	1965-66	1970-71	1975-76	1980-81	1983-84	Percentage change in (6) over (2)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
Herfindahl I (20)	0.1729	0.2157	0.2034	0.2364	0.2724	+57.55
Herfindahl II (5)	0.2625	0.3090	0.3105	0.3970	0.4707	+79.31
Herfindahl III (4)	0.4561	0.5144	0.5265	0.5449	0.5773	+26.57
Entropy I (20)	2.0678	1.9738	2.0169	1.8481	1.6871	−18.41
Entropy II (5)	1.4426	1.3596	1.3379	1.2052	1.0675	−26.01
Entropy III (4)	1.0147	0.9300	0.9070	0.8719	0.8123	−19.95
Entropy (I–III)	1.0531	1.0438	1.1099	0.9762	0.8748	−16.93
Entropy (II–III)	0.4279	0.4296	0.4309	0.3333	0.2552	−40.36

economy of Punjab has been getting oriented towards paddy-wheat rotation. Entropy I was calculated for all possible crops (20), Entropy II and III were calculated for five and four crop groups respectively. A gradual decline in Entropy I, II and III over the years also confirms the steady decrease in diversification. The Entropy index of diversification based on 20 crops declined by 18.41 per cent over the period 1965-66 to 1983-84, while the Entropy III index based on four commodity groups declined by 19.95 per cent over the same period. However, the Entropy II index based on five commodity groups declined the sharpest, i.e., by 26.01 per cent. This clearly indicated that the treatment of paddy-wheat as a separate commodity group pushed up the decline in the index of diversification. In other words, paddy-wheat rotation has been of critical importance in declining diversification or increasing specialisation in crop farming. This is supported by the trends in differences of Entropy indices. Differences in Entropies I and III reflect the diversification within the four commodity groups, while differences in Entropies II and III are indicative of diversification due to treatment of paddy plus wheat as a separate commodity group. It would be seen that the difference of Entropies I and III declined by 16.93 per cent only as compared to a much steeper decline in the difference of Entropies II and III which works out to 40.36 per cent. This highlights that the major decline in diversification has been induced by the paddy-wheat rotation.

III

FACTORS AFFECTING CROP DIVERSIFICATION

In order to examine the determinants of diversification, it was found useful to conduct the analysis at both macro and micro levels as under.

Macro Perspective

Table III depicts the results of the regression analysis conducted to study the factors affecting diversification defined as 1–Herfindahl index and Entropy E. It would be seen that diver-

TABLE III. REGRESSION COEFFICIENTS FOR LINEAR FUNCTION IN 1971-72 AND 1981-82
WITH HERFINDAHL AND ENTROPY AS DEPENDENT VARIABLES

Sr. No.	Variable details	With Herfindahl			With Entropy		
		1971-72	1981-82	Pooled	1971-72	1981-82	Pooled
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Constant	1.0342 *** (13.56)	0.5037 ** (3.80)	0.7405*** (7.41)	3.1475*** (16.56)	0.2577 (0.34)	1.6100** (2.75)
1.	Fertilizer consumption (per thousand crop hectares)	0.4715 (0.66)	−1.2607** (3.32)	−0.7493 *** (3.08)	1.1227 (0.63)	−5.5104* (2.52)	−3.5943** (2.53)
2.	Number of regulated markets (per thousand sq. km.)	−0.0261 (1.39)	0.0123 (0.96)	0.0266* (1.84)	−0.1284 (1.80)	0.1266 (1.73)	0.0961 (1.13)
3.	Inequality in distribution of holdings	−0.1568 (2.04)	0.4489 (1.99)	+0.0437 (0.56)	−0.9700*** (5.06)	2.1515 (1.66)	−0.1434 (0.32)
4.	Standard deviation of per hectare productivity value	−0.0002 * (2.21)	0.0001* (1.82)	0.00002 (0.77)	−0.0010** (4.32)	0.0004 (1.94)	0.0001 (0.70)
5.	Number of tractors per thousand hectares of net sown area	−0.0060 * (2.34)	0.0012 (1.22)	0.0007 (0.76)	−0.0092 (1.44)	0.0043 (0.76)	0.0025 (0.49)
6.	Percentage of irrigated cropped area	0.0001 (0.19)	0.0006 (1.00)	−0.0008** (2.24)	−0.0002 (0.12)	0.0031 (0.85)	−0.0022 (0.98)
7.	Assured irrigation (per cent area irrigated with tubewells)			−0.0008*** (3.30)			−0.0018 (1.32)
8.	Cropped area per agricultural worker			0.0263 (1.14)			0.1354 (1.00)
9.	Rainfall			0.0002 (0.82)			0:0017 (1.21)
	Coefficients of determination R^2	0.8599	0.8333	0.7861	0.9455	0.7714	0.6398

Figures in brackets indicate t-ratios.
*** Significant at 1 per cent level.
** Significant at 5 per cent level.
* Significant at 10 per cent level.

sification based on Herfindahl index was affected negatively and significantly by standard deviation of per hectare value productivity and tractor density per thousand hectares of net sown area in the year 1971-72. The former implied that the greater the gap in per hectare value productivity between competing crops, the lesser the diversification. In other words, the greater the variability in value productivity of different competing crops, the greater the degree of specialisation towards more remunerative crops. Further, the greater the tractor density in an area, the lower the degree of diversification. The analysis with Entropy as the dependent variable for the year 1971-72 indicated that diversification was affected negatively and significantly by standard deviation of per hectare value productivity and skewness

in the distribution of holdings. Thus, the higher the inter-crop productivity variability and inequality in the distribution of holdings, the lower the diversification.

The results of the analysis for 1981-82 with Herfindahl index of diversification indicated that fertilizer consumption per cropped hectare was the most important significant factor impinging on diversification. The analysis with Entropy as the dependent variable also brought out fetilizer consumption as a significant variable having a dampening effect on diversification.

The pooled analysis of the two years 1971-72 and 1981-82 indicated that diversification with Herfindahl index was affected positively and significantly by market density and negatively and significantly by fertilizer consumption, per cent area irrigated by tubewells and percentage of irrigated cropped area respectively. Thus, the higher the fertilizer consumption and assured irrigation, the lower the diversification, whereas the higher the market density, the higher the diversification. Similarly, the pooled analysis with Entropy index as dependent variable showed that fertilizer consumption was the crucial variable adversely affecting diversification.

Micro Perspective

The results of the factors affecting diversification at the micro level are depicted in Table IV. It would be seen that diversification defined as (1–H) where H is the Herfindahl index

TABLE IV. RESULTS OF REGRESSION ANALYSIS BASED ON MICRO LEVEL DATA IN PUNJAB, 1981-82

Dependent variable	Intercept	Farm size	Family size	Dairy income	Dummy for leasing in land	Distance from market	Assets per hectare	R^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Y_1 (Herfindahl Index)	0.6575*** (18.08)	–0.0009 (0.27)	+0.0100*** (3.46)	+0.000002 (0.89)	–0.0149 (0.78)	–0.0094*** (4.27)	–0.000003*** (2.88)	0.2376
Y_2 (Entropy Index)	0.7203*** (31.14)	–0.0027 (1.29)	–0.0053*** (2.87)	+0.000002 (1.23)	–0.0179 (1.47)	–0.0045*** (3.22)	–0.000002*** (2.85)	0.1708

Figures in brackets indicate t-ratios.
*** indicate significant at 1 per cent level.

depended positively and significantly on the number of family members and negatively and significantly on the distance from the market and the assets per hectare. The results of the regression analysis based on Entropy as the index of diversification indicated that the same variables with the same signs affected diversification significantly which reflected the robustness of the indices used to measure the extent of diversification.

CONCLUSION

From the foregoing analysis it can be inferred that *(i)* the Punjab economy is undergoing gradual diversification in favour of secondary and tertiary sectors, while the cropping pattern is getting gradually oriented towards foodgrains particularly wheat and rice as measured by both Herfindahl and Entropy indices. *(ii)(a)* At the macro level diversification is significantly and adversely affected by fertilizer consumption, inter-crop value productivity variability, tractor density, skewness in the distribution of holdings and per cent cropped area irrigated. It is positively affected by market density. And *(b)* at the micro level, diversification is inversely related to size of farm, distance from the market and assets per hectare and directly related to family size and dairy income.