An Analysis of Economies of Scope in Irrigated Agriculture in the Punjab (Pakistan)

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Abstract

In this paper scope economies for a sample of 387 farms in the Punjab province of Pakistan were estimated using nonparametric techniques and sources of economies of scope were determined by using econometric techniques. The result indicated that diversified farming in crop, livestock and custom hiring enterprises results in cost savings of 17.81% for all enterprises, 17.36% in the crop sector, 15.84% in the livestock sector and 1.90% for custom hiring. Econometric results indicate that overall economies of scope are inversely related to farm size, positively to location of farms nearer to the head reaches of canals and positively to the amount of capital used on a farm. The existence of Scope economies in Pakistan agriculture implies that production functions in agriculture are interdependent and the effects of Government policy of setting support prices of individual crops may affect resource allocation with respect to other crops on the same farms.

Introduction

Analysis of economies of scope is used to determine the cost savings associated from producing multiple products rather than specialising in a single product by a firm. Baumol, Panzar and Willig (1981) state that economics of scope are necessary for the existence for multi-product firms. They state that if joint production is not cheaper than production in a specialised way, the specialised firms will drive the diversified firms out of business. Widespread existence of multi-product farms, particularly the small ones, in developing countries may be explained through the benefits of economies of scope. From a technical point of view, the existence of economies of scope in the long run reflects technological interdependence among production functions. From a policy point of view, existence of economics of scope implies that the effects of

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a policy affecting the technology, output, or price of one of the products will be transmitted to other products.

In Pakistan, the government sets the support price of a crop on the basis of the cost of production of that crop[1]. Ali (1990) studied the supply response of five major crops to the government procurement prices[2]. Using a multi-output model for the period 1957-1986, he found that "a price policy based on the single crop cost of production is faulty because it does not take into account the cross effects on the production of other crops" (op. cit, p.323).

Variables related to managerial characteristics of farmers, methods of irrigation, interaction with financial institutes and farm size might all affect scope economies. Current research on the crop or livestock sector in Pakistan usually assumes that enterprises are technologically independent. Custom hiring of capital equipment is also common on irrigated farms in the Punjab because farms may be too small to utilise that equipment fully. The effect of custom hiring as a sub sector of mixed crop farming on other sub sectors has not yet been determined in Pakistan agriculture. In this analysis of scope economies custom hiring has been included as a sub sector in mixed farming.

The Concept and Measurement of Scope Economies

Economies of scope refer to the cost savings attributable to joint production. Economies of scope exist if the sum of costs of producing the optimal levels of individual outputs in specialised firms is greater than the cost of producing the same optimal output levels in a multi-product firm. Assume $C(Y_1)$ is the cost of producing output 1 in a specialised firm while $C(Y_2)$ is the cost of producing output 2 in a specialised firm and $C(Y)$ is the cost of producing the same amounts of both products in a joint firm, then, if:

$$C(Y_1) + C(Y_2) > C(Y), \tag{1}$$

economies of scope exist. For two outputs, economies of scope, SC (Y) is defined as:

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[1] Support prices for different crops are recommended to the Government of Pakistan by a semi-autonomous body called the Agriculture Prices Commission (APCOM). The policy of APCOM is that the recommended price should be such that it covers at least the expenses involved in raising the crops.

[2] Wizarat (1981), Pinkney (1989), and Ali (1990) found that Pakistani farmers are responsive to price incentives.

$$\mathbf{SC}\ (Y) = \frac{C(\mathbf{Y}_1) + C(\mathbf{Y}_2) - C(Y)}{C(Y)} \qquad (2)$$

If SC(Y) is greater than zero, economies of scope exist. Economies of scope can be estimated by using parametric or non-parametric methods. Chavas and Aliber (1993) introduced a non-parametric approach for estimating economies of scope. They found that the crop and livestock sectors enjoyed fairly large economies of scope. They also found that economies of scope were inversely related to farm size. Following Chavas and Aliber (1993), the following model is specified for this data:

$$Minimize\ C_p(Y) = \sum_{N=1}^{N} P_{pn}X_{pn}$$

Subject to

$$\text{(i)} \quad \sum_{K=1}^{K} Z_k X_{km} \leq X_{pn}, \qquad n = 1,\ldots\ldots,N$$

$$\text{(ii)} \quad \sum_{K=1}^{K} Z_k Y_{K1} \geq Y_{pi}, \qquad i = 1,\ldots\ldots,M$$

$$\text{(iii)} \quad \sum_{K=1}^{K} Z_k = 1 \qquad k = 1,\ldots\ldots,K$$

$$\text{(iv)} \quad Z_k \geq 0, \qquad \text{For all k,} \qquad (3)$$

In this model $C_p(Y)$ is the minimum cost to produce the ith output of farm p, (i=1,2,.....,M), P_{pn} is the price of farm p's input n, and x is the optimum use of input n for farm p to produce its bundle of outputs. The variable Z_k is the intensity of the use of farm k's technology where k ranges from 1 to K. The intensity variables are used to construct the frontier technology set and are constrained to sum 1. The constraint allows the cost function to exhibit variable returns to scale. This linear programming model is solved for each farm in the sample and measures the minimum cost of producing the current bundle of outputs. To calculate the cost of producing only one output or a subset of that output, the constraint set (ii) in equation (3) is adjusted. For example, to calculate the cost of producing only output 1, the constraint set (ii) in equation (3) would be indexed for i=1. To calculate the cost of producing output 2 through M, the constraint set (ii) in equation (3) would be indexed for i=1,..., M. The minimum cost of producing any combination of output bundles in subsets or individually can be calculated by resolving this linear programming problem after adjusting the output constraint (ii).

Economies of scope are measured at the optimal level of output, which is obtained when a firm is producing on the frontier and no slack inputs and outputs exist. If slacks exist, they have to be adjusted before the nonparametric economies of scope models are solved. Testing for slacks can be thought of as testing for the sufficient conditions. Banker, Charnes and Cooper (1984) suggest a two-step procedure for testing if slacks in outputs and inputs exist. For this purpose, first the following linear programming model is solved:

$$\textit{Maximize } h_p = \sum_{m=1}^{M} \alpha_m y_{pm}$$

Subject to

(1) $$\sum_{n=1}^{N} \beta_n X_{pn} = 1,$$

(2) $$\sum_{m=1}^{M} \alpha_m y_{km} - \sum_{n=1}^{N} \beta_n X_{pn} \leq 0 \qquad k = 1,\ldots\ldots,K,$$

(3) $$\alpha_m \geq \delta,\ \beta n \geq \delta \qquad \forall\, m, n,$$

(4) $$\delta \geq 0. \tag{4}$$

In this model, X_{kn} is the nth input used by the k_{th} production unit, y_{km} is the mth output produced by the kth production unit, α_m and β_n are constants, the subscript p represents the production unit whose efficiency is being measured relative to the whole sample and δ is a small "non-Archimedean" quantity. Next solve the following model:

$$\text{Minw}_p = (\omega_p - \delta\ [\ \sum_{n=1}^{N} S_n + \sum_{m=1}^{M} S_m^{+}])$$

Subject to

(i) $$O = \omega_p X_{pn} - \sum_{k=1}^{K} Z_k X_{pk} - S_n^{-} \qquad n = 1,\ldots.N,$$

(ii) $y_{pm} = \sum_{k=1}^{K} y_{pm} Z_k - S^{+}_{m},$ m = 1,....M,

(iii) $Z_k, S^{-}_{n}, S^{+}_{m} \geq 0$ $\forall$ n,m,k.

(iv) $\delta > 0.$ (5)

Comparing the optimal solutions from equations (4) and (5), if $h_p \neq \omega_p$, then the slack in inputs and/or outputs exist. To determine these slacks, a final model, which was used by Charnse, Cooper and Rhodes (1978), is estimated:

Max Θp

subject to

(1) $\sum_{k=1}^{K} Z_k y_k - \mathbf{\Theta}_p\, y_1 > 0,$

(2) $\sum_{k=1}^{K} Z_k X_k \leq X_p$,

(3) $zk \geq 0,$ k=1,2,....K (6)

where Y_K is the sub-vector of outputs with y_{KM} as its components and X_K is the sub vector of inputs with X_{kn} as its components. This model is solved for each of the k farms where slacks exist. The optimal solution for this consists of the values ($\mathbf{\Theta}^{*}_{0}, s^{+*}, s^{-*}$ and Z_k) where s^{+*} represents slacks in outputs and s^{-*} represents slacks in inputs. If s^{+*} or s^{-*} has any positive components, then the farm's input and output vectors are redefined as $X^{\wedge}_{p} = X_p - s^{-*}$ and $Y^{\wedge}_{p} = Y_p\, \mathbf{\Theta}^{*}_{p} + s^{+*}$, respectively. After the required adjustments are made, the scope model (3) is estimated.

Description of Data, Sample and Variables

The data used in this analysis were obtained from Punjab Economic Research Institute (PERI)[3] which collected it in the crop year May 1990 to

[3] PERI had already published a report on this data before this data set was obtained from them. See S.A. Shahid, M. Ul-Haq, and M.J. Khan (1992) *Benchmark Survey of Irrigation Systems Management and Rehabilitation Project Phase II In Punjab (Pakistan),* Lahore, Punjab Economic Research Institute.

April 1991 from five districts (Vehari, Khanewal, Multan, Faisalabad and Gujrat) located in the central part of the Punjab for a benchmark survey for an irrigation project. In this study data of only 387 farms is included which produced the following crops: cotton, wheat, rice, sugarcane and corn. These crops covered 90 percent of cropped area of sample farms. They are also the major crops of irrigated agriculture in the Punjab. Appendix Tables 1 and 2 provide a summary of the socio-economic characteristics of farms and their operators. 200 sample farmrs were not literate. The family size averaged 8.79 members resulting in availability of substantial family labour. On average, 129 man-days of total labour per acre were used, with 111 man-days contributed by family labour. The average cropping intensity on sample farms was 156% of cultivated area. The average farm size was 8.70 acres. Only 3.88% of farms exceeded 25 acres. Most of the irrigated area is either canal irrigated only, or tube-well irrigated only.

Appendix Table 3 gives a general categorisation of inputs used in this study. Following Grabowski and Pasurka (1988) the capital stock was measured as the total value of livestock, machinery, implements and buildings, capital input was measured as a flow variable by adding the return to farm capital to the average depreciation cost of farm assets. Buildings were assumed to depreciate at 2% per year, machines and their implements at 10% and hand tools at 20%. The return to farm capital was calculated at 10.59% that was the weighted average rate of interest on all scheduled bank advances in 1991 [GOP (1994), Table 7.7, Statistical Appendix]. Hired labour was measured in man-days hired, family labour in adult male units of full time farmers in the family working for the whole year. Family labour was valued at the wage rate of hired labour. Inputs for livestock consisted of only purchased inputs. It was assumed that all fodder crops produced by sample farms were fed to animals and included as an input.

Outputs used in the study were classified into three categories: (a) crops, (b) livestock, and (c) custom hiring services. The latter represent the family's non-labour resources (land, tractors, and tube-wells). Livestock production consisted of milk and non-milk outputs. The third output consisted of custom hiring of land and farm machinery services that is quite common in the sample area. The number of sample farmers producing different outputs is given in Table 2. In this sample, crops contributed 71%, livestock products 25%, and custom hiring 4% of the total farm revenue. Similarly, the inputs were aggregated in the categories as shown in Table 3. For the purpose of aggregation, each input and output prices were normalised on their mean price. Solution of the linear programming model showed that slacks in inputs or outputs existed for 11 farms. The input and output quantities for these farms were adjusted before the economies of scope measures were calculated.

Measures of Scope Economies for the Sample Farms

The means for estimated scope economics are presented in Table 1 below.

Table 1: Estimates of Scope Economies on Sample Farms

Measure of Scope Economy	Mean	Standard Deviation	Minimum	Maximum
Overall	0.1781	0.1166	-0.5259	0.5663
Animal Products	0.1584	0.1142	-0.5259	0.4756
Crops	0.1736	0.1140	-0.5259	0.5613
Custom Hiring	0.0190	0.0600	-0.5970	0.2886

For the sample as a whole, the average economies of scope (i.e., average reduction in cost due to diversification) equals 17.81% for diversified farming, 1.90% for custom hiring, 17.36% for the crop sector and 15.84% for the livestock sector. Thus, on average, diversification results in a 17.81% reduction in costs when compared to specialised farming operation. In this sample, 17 farmers produced only crop outputs, so they were specialised and had, by definition, a scope measure of zero. Out of the 370 farmers who had mixed farming, one farmer obtained diseconomies of scope, whereas all others had economies of scope. These results show that in Punjab agriculture, there are substantial economies of scope, particularly from the crop and livestock enterprises. Economies of scope due to the livestock sector are much larger compared to the relative contribution of livestock products to total farm output.

The average economies of scope from custom hiring for the whole sample are low because 83% of farmers had zero custom hiring output. For the sample of farmers who custom hired, overall economies of scope were 21.6% and custom hiring scope economies were 12.2%. Although crops and livestock diversification has higher cost savings, custom operations in Punjab agriculture brings about a cost reduction of 12.2% by increasing the utilisation of the (fixed) capacity of assets.

This study finds that combining custom hiring of non-labour resources with crop and livestock enterprises results in further cost savings. The popularity of mixed farming in the Punjab reflects the existence of cost savings from joint production. Research on crop sector production which excludes the livestock sector, or visa versa, in the Punjab is not likely to be appropriate. Finally, changes in pricing policy related to the crop sector will have substantial effects on the livestock sector.

Sources of Scope Economies

After determining that substantial economies of scope existed in Punjab agriculture, it was important to identify the factors that were associated with greater cost savings from diversification. A Tobit model (Greene 1990) was used to determine the factors associated with overall scope economies for various enterprise combinations and custom hiring. Only one farmer had a negative economies of scope measure. This observation was deleted from the analysis. Economies of scope were hypothesised to be a function of the age of the head of household, the level of education, the irrigation method used, the district in which the farm was located, farm size in cultivated acres, whether or not the farmer obtained loans from an institutional source. A value of 1 was assigned if the farm was situated along the first half of the canal and zero to others. Results are presented in Table 2 below.

Table 2: Tobit Estimates of Overall Scope Economies on Sample Farms

Parameter	Estimate	t-value
Constant	0.13522	2.55*
Age	0.00405	2.13*
Age Squared	-0.00004	-2.03*
Education	-0.00052	-0.41
Canal Irrigation	0.02112	1.21
District 1	-0.02752	-1.07
District 2	-0.03740	-1.44
District 3	-0.09736	-3.42*
District 4	-0.07042	-2.27*
Farm Size (acres)	-0.00402	-4.70*
Loan (binary variable)	-0.02205	-1.91
Capital (Rs)	0.0000	3.31*
Situation towards head of the Canal (Binary variable)	0.03042	2.26*
Loglikelihood	296.345	-
Number of Observations	386	-
Positive observations	370	-
Chi-square	83.05*	-

* implies significant at 5 % level.

Factors significant at the 5% level of significance in explaining scope economies include age, age-squared, acres, capital, the district in which the farm is located, and the location along the canal. Economies of scope increase as the value of capital owned by a farmer increases. Overall economies of scope are negatively related to farm size. Smaller farms have larger cost savings from diversification than larger farms.

The variables for District 3 and District 4 are negative and significant implying that the average economies of scope are lower for these districts than that of the excluded district Gujarat. The average scope economies of District 1 and District 2 are not significantly different from that of Gujarat[4]. Gujarat is more diversified compared to other districts that are predominantly cotton-wheat growing districts. So Gujarat enjoys the largest amount of economies of scope of all districts in this sample. On specialised farms fixed facilities are unutilised or underutilised when the crop has been sown, whereas on a multi-product farm, facilities are jointly used. This economises cost of production. The variable "situation towards head of the canal" is positive and significant at 5% implying that farms located towards the head of the canal achieve more economies of scope. Both the age and the age-squared variables are significantly different from zero. The second derivative is negative indicating that economies of scope increase at a decreasing rate with age. May be older farmers are traditional while the younger ones have diversified their products.

Table 3 below gives estimates of the Tobit regression for custom hiring enterprises.

Table 3: Tobit Estimates of Scope Economies for Custom Hiring on Sample Farms

Parameter	Estimate	t-value
Constant	-0.17129	-1.25
Age	0.00249	0.5
Age Squared	-0.00002	-0.38
Education	-0.00232	0.70
Canal Irrigation	-0.07142	-1.76
District 1	-0.04361	-0.74
District 2	-0.12565	-1.94
District 3	-0.10018	-1.44
District 4	-0.13783	-1.50
Farm Size (cultivated acres)	-0.00043	-0.22
Loan (binary Variable)	-0.00135	-0.05
Capital Owned (Rs)	0.000002	5.24*

[4] The included districts are as follows: District 1 - Faisalabad, District 2 - Khanewal, District 3 - Vehari, and District 4 - Multan. The excluded district is Gujarat.

Situation towards head of the Canal (Binary variable)	0.05646	1.65
Logliklihood	-65.4626	-
Number of Observations	386	-
Positive observations	63	-
Chi-square	64.96*	-

* Implies significant at 5% level.

The table shows that scope economies from custom hiring are positively and significantly related to amount of capital. Thus farms with more capital have a higher ability to achieve cost savings from custom work than those without. Farm size and age are not related to the ability to achieve cost savings from custom hiring activities. Regional differences appear to be less important in custom hiring than they were for the overall economies of scope measures.

Summary and Conclusions

This study used non-parametric techniques to measure scope economies for a sample of 387 irrigated Punjab farms in Pakistan. Outputs included all livestock products, five major crops of Pakistan (i.e., wheat, cotton, sugar cane, rice and maize) and custom hiring services produced by sample farmers in the survey year 1990-1991. Large economies of scope exist in Punjab agriculture, especially from crop and livestock enterprises. Combining custom hiring of non-labour resources with crop and livestock enterprises results in scope economies of 12.2% for those farmers which custom hire. The popularity of mixed farming in the Punjab reflects the existence of cost savings from joint production. Research on the crop sector production which excludes the livestock sector, or vice versa, in the Punjab is not likely to be appropriate. Changes in pricing policy related to the crop sector will have substantial effects on the livestock sector.

Overall economies of scope measures differ depending on farm size, the amount of capital invested, and the location of the farm in the Punjab. Larger farms have less incentive to diversify than smaller farms. Farms located in the Vehari and Multan districts have less cost savings from diversification than from the Faisalabad, Khanewal, or the Gujarat districts. Farms with more capital have more opportunities which in all likelihood arise in custom hiring. Farms located towards the canal head derive more overall scope economies than those situated towards the tail end of canals because the former have a more abundant and reliable supply of canal irrigation water than the latter. Age is also statistically significant in explaining differences in economies of scope measures. Custom hiring economies of scope are higher for those farmers with more capital.

Finally, smaller farms choose to practice mixed farming in order to decrease the cost of production. Larger scope economies on smaller farms may provide an explanation of why smaller farms have survived despite the erosion of their efficiency relative to larger crop farms as a result of the availability of mechanical technologies to large farmers in the post-green revolution period. On the whole, this study has produced new insights in the farming system in Pakistan.

Appendix Table 1: Farmers Major Socio-Economic Characteristics of the Sample

Attribute	Mean	Standard Deviation	Minimum	Maximum
Farm Manure (Loads)[a]	6.67	7.92	0	75.89
Fertiliser (Nut. Kgs)[a]	91.22	46.97	0	336.55
Total Labour (Man days)[a]	128.78	106	10.44	627.89
Family Labour (Man days)[a]	111.46	108.48	3.20	627.89
Area Sown/Cultivated Acre	1.56	0.38	0.36	2.77
Irrigation Water (Acre feet)	2.55	0.72	0.23	6.75
Canal Irrigation-Acres	46.79	47.34	0	275.68
Tube-well Irrigation-Acres	42.74	63.73	0	481.00
Mixed Irrigation-Acres	7.80	27.14	0	207.75
Cultivated area (Acres)	8.70	8.19	1	62
Institutional Loans (Rs)	9354	34415	0	487200
Bullock Operations (Acres)	4.51	6.38	0	26.89
Tractor Operations (Acres)	3.65	2.94	0	18.49
Age of Operator (years)	46.27	15.49	12	90
Years of Schooling	3.93	4.59	0	16
Family Size (numbers)	8.79	4.23	2	29
Farms with debt (%)	37.7	48.5	0	100
Farms at head of canal (%)	31.0	46.3	0	100
Capital Stock (Rs)	16,924	44,464	0	24,700

[a] denotes "per cultivated acre". **Source:** compiled from sample data.

Appendix Table 2: Number of Sample Farmers Producing Different Farm Products

Outputs	Number Producing
Crops	386
Wheat	382
Kharif Fodder	351
Rabi Fodder	344
Indigenous Cotton	42
American Cotton	293
Sugarcane	161
Grain Maize	75
Fine Rice	30
Livestock Products	370
Custom Hiring Services Output	63
Total Sample Size	387

Source: compiled from sample data

Appendix Table 3: Inputs Categories used in Analysis

Major Category	Minor Category (if any)
1. Land	
2. Labour (Three Types)	• Family Labour • Annually Hired Labour • Casually Hired Labour
3. Irrigation Water (Two Types)	• Canal Water • Tube-well Water
4. Cultural Operations (Four Types)	• Plowing (by bullocks, tractors) • Leveling (by bullocks, tractors) • Hoeing (by bullocks, tractors, manually) • Planking (by bullocks, tractors)
5. Capital Inputs (Five Types)	• Buildings • Machines (tube-wells, tractors, combines) • Mechanical implements • Hand tools • Livestock
6. Fertilizers	• Chemical fertiliser • Animal manure
7. Seeds (All crops)	
8. Threshing and Picking	
9. Fodders and Feeds	
10. Miscellaneous Costs	• Weedicides • Insecticides • Fuel, Electricity • Repair and Maintenance

Source: compiled from sample data.

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