3. Production Environment and Yield Risk

3

Production Environment and Yield Risk

In this chapter, farming activities of sample households are characterized with estimation results of the extent of yield variability facing each household. As shown in Chapter 2, farming activities, comprising crops and livestock, accounted for the major share of household income. As a necessary background to investigate how the two sectors are interrelated with household consumption characteristics, this chapter first gives relevant information on agricultural production from both technological and economic aspects. Topics include cropping pattern, livestock activities, and irrigation technology and water transactions. Then in the second section, the extent of yield variability at the individual household level is estimated econometrically. An important aspect of the estimated model is that common and idiosyncratic shocks are distinguished. Since very few studies have investigated the idiosyncratic yield shocks in Pakistan's agriculture, the estimation is expected to give an important insight into their magnitude.

I. Farming Systems

1. Cropping Patterns

The rice-wheat zone is characterized by two dominant crops: rice in *kharif* and wheat in *rabi* (Table 3-1). Basmati paddy is the most important crop in *kharif* and also the most important cash crop for farmers in the study area. Area devoted to basmati was around 6 acres on average. The imputed con-

TABLE 3-1

CROPPING PATTERNS OF SAMPLE HOUSEHOLDS

(Acres)

	1988/89		1989/90		1990/91	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Continuously surveyed households only (NOB=59)						
Acreage under basmati	5.676	5.724	5.731	5.076	5.741	5.444
Acreage under wheat	6.022	5.719	5.896	4.971	6.339	5.634
Acreage under *kharif* fodder	2.860	1.847	1.847	1.254	1.845	1.239
Acreage under *rabi* fodder	1.618	1.098	1.545	1.012	1.691	1.263
All households (NOB=97)						
Acreage under basmati	6.226	5.952	6.514	6.158	6.595	6.375
Acreage under wheat	6.856	6.071	6.455	5.368	6.888	5.830
Acreage under *kharif* fodder	2.899	1.819	1.955	1.229	1.916	1.188
Acreage under *rabi* fodder	1.644	1.110	1.659	1.082	1.825	1.285
Absolute value of *t*-statistics[a]						
Acreage under basmati	1.127		1.553		1.635	
Acreage under wheat	1.678*		1.271		1.149	
Acreage under *kharif* fodder	0.264		1.067		0.728	
Acreage under *rabi* fodder	0.284		1.286		1.274	

Source: The author's calculation. The original information was collected by the Punjab Economic Research Institute. See the text in Chapter 2 for more details.
Note: NOB stands for the number of observations.
[a] "Absolute value of *t*-statistics" shows *t*-statistics for the null hypothesis that the means of continuously and noncontinuously surveyed samples are identical.
* The null is rejected at 10%.

sumption expenditure for rice accounted for less than 4 per cent in the family budget on average, indicating that rice is mostly cultivated as a cash crop. All sample households had market surplus of basmati. Other *kharif* crops, such as the IRRI variety of paddy, sugarcane, cotton, and maize for grain, accounted for only minor shares.

Wheat occupied approximately 6 to 7 acres in *rabi* on average. Wheat is the largest source of calorie intake and the imputed consumption expenditure on wheat accounted for 13 to 14 per cent in the family budget.

Next to rice and wheat, fodder crops for livestock animals accounted for a large proportion of cropped land both in *kharif* and *rabi*. *Kharif* fodder crops occupied about 2 acres and *rabi* fodder crops occupied about 1.5 to 2 acres on average (Table 3-1). Most farmers in the area kept livestock animals and allocated a significant proportion of the cultivated land to fodder crops. The dominant fodder crop in *kharif* was jowar (sorghum), and that in *rabi* was berseem, the Pakistani name for Egyptian clover. The sum of areas devoted to fodder

TABLE 3-2

PER-ACRE YIELD OF CEREALS

(*Maunds*/acre)

	1988/89		1989/90		1990/91	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Continuously surveyed households only (NOB=59)						
Basmati paddy	27.70	5.95	29.41	6.08	23.53	5.47
Wheat	27.59	4.60	20.81	5.33	20.10	5.00
All households (NOB=97)						
Basmati paddy	28.46	6.22	29.80	5.93	23.40	4.86
Wheat	27.79	4.91	20.54	5.02	20.25	4.99
Absolute value of *t*-statistics[a]						
Basmati paddy	1.484		0.791		0.323	
Wheat	0.504		0.651		0.354	

Source: See Table 3-1.
Notes: One *maund* is equivalent to approximately 40 kg.
[a] See Table 3-1.

crops and the dominant cereal crops (rice in *kharif*; wheat in *rabi*) exceeded 90 per cent of the cultivated area in each season. According to the Agricultural Census 1990, aggregate figures for these numbers are 80 per cent in the rice-wheat zone and around 90 per cent in the Sheikhupura district (GOP, Agricultural Census Organization 1994).

Since basmati paddy occupies the land for a longer period than other *kharif* crops, crop rotation from basmati to wheat was once a difficult task for farmers. However, the introduction of a new variety called Basmati-385 almost resolved this problem since it is an early maturing variety. In the mid-1980s, Basmati-385 replaced old varieties very quickly in the rice-wheat zone (Sharif et al. 1989; Amir and Aslam 1992). Only this variety was cultivated by sample households during the survey period.

Table 3-2 gives the average land productivity of cereal crops. Twenty *maund*s[1] per acre are equivalent to about two tons per hectare and thirty *maund*s per acre to about three tons per hectare. Therefore, per-acre yields of wheat and basmati are low, compared with neighboring countries and with achievements in research stations in Pakistan (GOP, Ministry of Food and Agriculture 1988). In the study area, mean yields of these two crops stagnated during the 1980s. Not only the food-grain yields were low, but also they fluctuated significantly. Basmati and wheat experienced good harvests in 1988/89. Basmati suffered a bad harvest in 1990/91 and wheat did in 1989/90 and 1990/91. On average, the worst basmati harvest occurred in 1990/91 which was 18 per cent less and the worst wheat harvest occurred in 1990/91 which was 27 per cent less than those in 1988/89. Furthermore, these aggregated numbers conceal substantial yield fluctuations at the individual farm level. This issue will be discussed further in the second section of this chapter.

2. Cost of Production of Basmati Paddy and Wheat

The data set includes ample information on the use of production inputs for basmati paddy and wheat for each household. Data on the quantities of inputs used and output produced on each farm are available, separately for the two crops. Using this information, the technology for, and profitability of, producing these two crops were assessed.

Table 3-3 summarizes factor inputs and output of basmati production in 1990/91. Numbers express per-acre quantities. The table shows unweighted means and standard deviations among households. The mean of paddy output per acre from all observations in 1990/91 was 23.40 *maund*s. To produce this output, labor input of 201 hours per acre, of which 69 were derived from hired labor, bullock labor of 10.5 hours per acre, and tractor use of 3.6 hours per acre were applied. Standard deviations are relatively large and the ranges of variation are wide.

The table also shows these figures by farmland size: marginal (up to 6.25 acres), small (6.25 to 12.5 acres) and medium and large (above 12.5 acres). Output per acre was similar across sizes, implying the absence of positive or negative size-yield correlations. Total labor input was higher in marginal- and small-size farms. Medium- and large-size farms substituted labor by using machinery, such as tractors, reapers, and combine harvesters. The share of hired labor was not low, however, even in marginal farms. It was common even for marginal farmers to hire non–family labor in operations such as transplanting and harvesting. Bullock-labor inputs were the highest in the small-size farms. For marginal farms, since keeping a pair of bullocks is not economical, the farmers relied more on hired tractor service. Larger farms also relied more on tractor services, whether owned or rented.

Table 3-4 shows similar information for wheat. The average output per-acre from all observations was 20.25 *maund*s. Output per acre was higher for farms with larger sizes, but the difference was negligible compared with the standard deviations. To produce this output, labor input of 66.2 hours per acre, of which 19.9 were derived from hired labor, bullock labor of 3.6 hours per acre, and tractor use of 2.4 hours per acre were applied. Total labor input was much lower than that for basmati production because transplantation operation is not required for wheat and harvesting mechanization is more advanced in wheat production in the study area.[2] As in the case of basmati, all

TABLE 3-3

FACTOR INPUTS AND OUTPUT OF BASMATI PER ACRE, 1990/91

	Mean	Standard Deviation	Minimum	Maximum
All size (NOB=97)				
Basmati paddy output (*maund*)	23.40	4.86	15.00	38.00
Total labor (hours)	200.75	34.90	95.46	322.50
Hired labor (hours)	68.93	31.92	1.78	108.00
Bullock labor (hours)	10.51	14.71	0.00	49.12
Tractor use (hours)	3.58	2.01	0.00	8.92
Marginal size (NOB=37)				
Basmati paddy output (*maund*)	22.95	5.23	15.00	38.00
Total labor (hours)	207.68	31.24	160.20	322.50
Hired labor (hours)	52.30	39.86	1.78	108.00
Bullock labor (hours)	7.78	15.53	0.00	49.12
Tractor use (hours)	3.48	1.70	0.00	8.28
Small size (NOB=36)				
Basmati paddy output (*maund*)	23.91	5.05	15.00	38.00
Total labor (hours)	208.48	32.88	155.23	320.11
Hired labor (hours)	82.10	14.86	32.86	102.00
Bullock labor (hours)	14.69	15.10	0.00	43.56
Tractor use (hours)	2.85	1.73	0.00	6.70
Medium and large size (NOB=24)				
Basmati paddy output (*maund*)	23.33	4.05	18.00	33.00
Total labor (hours)	178.45	34.96	95.46	215.44
Hired labor (hours)	74.81	26.05	33.44	99.43
Bullock labor (hours)	8.43	11.64	0.00	31.44
Tractor use (hours)	4.81	2.32	1.00	8.92

Source: See Table 3-1.
Notes: Unweighted mean and standard errors among households are indicated in this table.

sample households hired non–family labor. This applied to marginal farmers also, though they depended relatively less on hired labor. Similarly, bullock labor input was the highest in the small-size farms and tractor use was the highest in the medium- and large-size farms.

Net surplus accrued to farmers from this production process is estimated in Tables 3-5 and 3-6. The value of output from cereal crop production was evaluated at farm-gate prices actually observed. The value of the total output is expressed by the sum of grain value and the value of byproduct (straw) imputed at market prices in villages. For the costs of pesticides, chemical fertilizers, and tubewell water application, the amount actually paid by households was recorded. The costs of factor inputs of human labor, bullock labor, and tractor use were imputed at a single opportunity wage. Considering the varia-

TABLE 3-4

FACTOR INPUTS AND OUTPUT OF WHEAT PER ACRE, 1990/91

	Mean	Standard Deviation	Minimum	Maximum
All size (NOB=97)				
Wheat output (*maund*)	20.25	5.00	6.86	30.00
Total labor (hours)	66.15	13.51	32.08	109.17
Hired labor (hours)	19.92	16.82	0.89	50.57
Bullock labor (hours)	3.57	6.85	0.00	40.50
Tractor use (hours)	2.39	1.17	0.00	5.88
Marginal size (NOB=37)				
Wheat output (*maund*)	19.60	4.84	6.86	30.00
Total labor (hours)	68.68	13.95	42.93	109.17
Hired labor (hours)	12.73	16.33	0.89	50.57
Bullock labor (hours)	2.87	8.15	0.00	40.50
Tractor use (hours)	2.11	0.77	0.00	3.00
Small size (NOB=36)				
Wheat output (*maund*)	20.07	5.40	10.00	30.00
Total labor (hours)	65.18	10.66	40.61	85.50
Hired labor (hours)	19.90	15.86	1.50	48.67
Bullock labor (hours)	4.54	5.64	0.00	14.25
Tractor use (hours)	2.11	0.96	1.00	4.76
Medium and large size (NOB=24)				
Wheat output (*maund*)	21.51	4.57	15.00	30.00
Total labor (hours)	63.68	16.32	32.08	95.75
Hired labor (hours)	31.01	12.97	6.57	48.67
Bullock labor (hours)	3.20	6.39	0.00	25.00
Tractor use (hours)	3.25	1.54	0.75	5.88

Source: See Table 3-1.
Notes: Unweighted mean and standard errors among households are indicated in this table.

tion in the rates and the modes of payment of wages in sample villages,[3] this imputation should be interpreted as a very crude proxy. Using information from the Punjab Economic Research Institute (e.g., Saleem and Cheema 1993), the opportunity wages were estimated at Rs. 40 / man-day (= 7 hours) for human labor, Rs. 15.08 / hour for bullock labor, and Rs. 100 / hour for tractor services.

For basmati paddy (Table 3-5), the value of total output ranged from Rs. 2,090 to Rs. 5,306 per acre. Its unweighted mean among households was Rs. 3,287, whereas its acreage-weighted mean was Rs. 3,246. Because the difference in paddy yields between smaller and larger farm households was not significant, the two means were close. Among the input costs, labor cost was the largest, accounting for about one-third of the value of output. The costs of

TABLE 3-5

OUTPUT VALUE AND INPUT COSTS OF PRODUCTION OF BASMATI PER ACRE, 1990/91

(Nominal Rs.)

	(1)		(2)		Minimum	Maximum
	Mean	Standard Deviation	Mean	Standard Deviation		
Value of basmati paddy	3,188.3	668.6	3,147.2	555.3	2,025.0	5,206.0
Value of paddy and by-products	3,287.3	670.4	3,246.4	556.9	2,090.0	5,306.0
Total labor cost	1,147.1	199.4	1,056.5	222.7	545.5	1,842.9
Hired labor cost	393.9	182.4	428.4	146.0	10.2	617.1
Bullock cost	158.4	221.9	146.6	197.3	0.0	740.7
Tractor cost	357.6	201.1	408.7	219.5	0.0	892.3
Seed cost	20.2	6.9	19.9	5.7	8.9	53.3
Farmyard manure and fertilizer cost	321.7	146.7	348.0	113.4	40.5	996.0
Plant protection cost	57.3	78.7	66.3	83.0	0.0	338.0
Tubewell irrigation cost	451.4	295.2	460.7	191.9	0.0	1,440.0
Combine and reaper costs	10.3	44.5	29.1	70.9	0.0	200.0
Net surplus	763.3	735.2	710.8	629.9	–610.1	2,426.0
Net surplus + family labor wage	1,516.6	761.4	1,338.9	638.6	8.9	3,326.2

Source: See Table 3-1.
Notes: (1): Unweighted mean and standard errors among households are indicated.
(2): Mean and standard errors are weighted by the size of area under basmati paddy.

tractor use, fertilizer, and tubewell water were similar in magnitude, accounting for about one-tenth of the output value, respectively. Net surplus after subtracting all labor and other costs in the table was estimated at a little more than Rs. 700 per acre. Considering the opportunity land rent at about Rs. 750, and other charges of land revenue and canal water charges (Rs. 64), and interests on investment (Rs. 127) (Saleem and Cheema 1993), the operator's return should be negative. With family labor wages added, household income from basmati production became positive for most sample observations, however. These results show that the cultivation of basmati under the ongoing price structure was at a level that leaves no operator's profit. Returns were just sufficient for the farmers to keep farming.

For wheat (Table 3-6), the value of the total output ranged from Rs. 857 to Rs. 3,750 per acre. Its unweighted mean of Rs. 2,473 was smaller than its acreage-weighted mean of Rs. 2,566 because larger farms' per-acre yields were higher. Compared with basmati production, the share of labor cost and tubewell water cost to the value of output was smaller, reflecting the nature of

TABLE 3-6

OUTPUT VALUE AND INPUT COSTS OF PRODUCTION OF WHEAT PER ACRE, 1990/91

(Nominal Rs.)

	(1)		(2)			
	Mean	Standard Deviation	Mean	Standard Deviation	Minimum	Maximum
Value of wheat grain	2,191.7	555.8	2,273.0	527.6	754.3	3,300.0
Value of wheat and by-products	2,473.4	642.7	2,566.1	611.2	857.1	3,750.0
Total labor cost	378.0	77.2	357.5	83.3	183.3	623.8
Hired labor cost	113.8	96.1	134.6	87.7	5.1	289.0
Bullock cost	53.8	103.2	51.5	99.4	0.0	610.7
Tractor cost	239.3	117.0	287.0	151.5	0.0	588.3
Chemical fertilizer cost	362.6	133.6	401.8	129.1	175.0	640.0
Plant protection cost	10.6	37.0	25.4	54.2	0.0	250.0
Tubewell irrigation cost	81.7	62.3	93.5	50.4	0.0	272.8
Combine and reaper cost	28.4	95.4	69.9	145.4	0.0	550.0
Net surplus	1,319.0	628.8	1,279.7	624.1	–233.5	2,871.9
Net surplus + family labor wage	1,583.1	647.5	1,502.5	640.9	173.6	3,174.8

Source: See Table 3-1.

Notes: (1): Unweighted mean and standard errors among households are indicated.
(2): Mean and standard errors are weighted by the size of area under basmati paddy.

wheat production. Fertilizer cost and labor cost were the most important inputs in terms of expenditure. Interestingly, when unweighted average among households was used, the mean labor cost was larger than the mean fertilizer cost. When means were calculated with a weight of wheat acreage, the mean fertilizer cost was larger than the mean labor cost. This implies that larger farms used more fertilizer and smaller farms used more labor, which may be explained by the difference in the opportunity costs of these factors among farmers due to the existence of transaction costs (Sadoulet and de Janvry 1995, ch. 9).

Net surplus from wheat production after subtracting all labor and other costs was estimated at about Rs. 1,300 per acre. Due to lower input expenditure, net surplus for wheat became much larger than that for basmati paddy, which is associated with higher output value and higher expenditure. After subtracting the implicit land rent of Rs. 800, land revenue (Rs. 4.6), canal water charges (Rs. 21.6), and interests on investment (Rs. 78.1) (Saleem and Cheema 1993), the mean of operator's return still remained positive, although low. With family-labor wages added, household income from wheat production became more positive. These results show that wheat cultivation was more profitable than that of basmati but the difference was not appreciable. Many sample households cultivate wheat mainly as their staple food, though.

3. Livestock Activities and Mixed Farming

The role of livestock in the study area is closely related to crop production and family consumption (Kurosaki 1995a). First, bullocks provide draft power in crop cultivation, although this role has declined due to the increased use of tractors. Second, she-buffaloes and cows produce milk. Milk is consumed directly and in processed forms such as ghee (butter oil), *lassi* (yoghurt drink), *paneer* (cheese), etc., as well as sold to markets for a daily flow of additional income. Third, livestock provide valuable by-products used as fuel and farm-yard manure. Fourth, crop by-products such as rice straw and *bhusa* (wheat straw) can be utilized effectively as dry fodder. Fifth, crop rotations, including leguminous fodder crops, can improve the soil fertility. Sixth, family labor, especially female or child labor with low and uncertain opportunities for outside employment, can find a stable employment throughout the year in livestock breeding. Seventh, livestock are a liquid form of assets that can be depleted in a bad year and therefore act as an insurance. For these reasons, the social status of a farm household in the study area is a function not only of its landholding size but also of its livestock herd size (Hirashima 1978).

From the viewpoint of risk diversification, keeping livestock is associated with both positive and negative aspects. Yields of fodder crops and milk are not as erratic as those of food grains. On the other hand, keeping livestock implies another source of risk such as disease, death, or theft of the animals. However, the probability that these losses occur simultaneously with crop damages is not likely to be high except for disasters such as a severe flood.

Table 3-7 shows the size of livestock holding. The number of bullocks for cultivation has declined over the three-year survey period, partly due to the development of a tractor service market and partly to the substitution by milch animals. No bullock rental was observed.

Milch animals, especially she-buffaloes, had replaced draft animals in the study area. On average, sample households had two adult she-buffaloes in the first two years and the number rose to about three in the last year. Due to this increase, the overall size of a milch livestock herd as well as of total livestock herd in adult-animal equivalent units (AU)[4] increased in the last year.

Milk yields from cows and she-buffaloes are reported in Table 3-8. On average, an adult she-buffalo (1.28 AU) produces about 1,500 liters of milk a year, a quantity sufficient for household consumption of an average family size. The consumption expenditure on milk and milk products was imputed to

TABLE 3-7

SIZE OF LIVESTOCK HOLDING

	1988/89		1989/90		1990/91	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Continuously surveyed households only (NOB=59)						
Number of adult she-buffaloes	1.932	0.998	1.915	1.055	2.797	0.971
Number of adult bullocks	1.068	1.065	1.203	1.047	0.763	1.147
AU of total milch animals	4.309	2.324	4.357	2.166	5.558	1.989
AU of total draft animals	1.616	1.155	1.751	1.185	1.282	3.361
AU of total livestock animals	5.925	2.909	6.108	2.924	6.840	4.022
All households (NOB=97)						
Number of adult she-buffaloes	1.959	1.029	1.928	1.166	2.979	1.014
Number of adult bullocks	1.031	1.074	1.206	1.050	0.856	1.173
AU of total milch animals	4.297	2.636	4.385	2.540	5.693	2.109
AU of total draft animals	1.586	1.227	1.732	1.186	1.389	3.506
AU of total livestock animals	5.883	3.110	6.116	3.150	7.082	4.150
Absolute value of *t*-statistics[a]						
Number of adult she-buffaloes	0.315		0.132		1.058	
Number of adult bullocks	0.419		0.033		1.119	
AU of total milch animals	0.056		0.134		0.473	
AU of total draft animals	0.295		0.201		1.113	
AU of total livestock animals	0.164		0.033		0.714	

Source: See Table 3-1.
Note: AU stands for adult-animal equivalent unit.
[a] See Table 3-1.

be around 27 per cent of the family budget, a value about twice as large as that of wheat, reflecting the importance of milk as a source of animal protein for sample households. Two to three adult she-buffaloes in milk are more than household consumption needs so that the surplus can be sold to the market. The average milk yield recorded a decrease in the last year because of the herd size expansion.

Table 3-8 gives information on livestock feed in terms of monetary values (nominal) evaluated at village prices. Green fodder from specialized fodder crops such as jowar and berseem accounted for the largest share of feed expenditure, and for about 80 per cent of the total expenditure. These fodder crops are cut into pieces, mixed with dry fodder, and fed to animals without further treatment. Common sources of dry fodder are *bhusa* and rice straw produced from the farm. Green and dry fodder are complements rather than substitutes in milk production. Concentrate feeds are essential for milk production. In the study area, cottonseed cake is used for this purpose. Since the cake is not produced in the villages, it is purchased from markets.

TABLE 3-8

MILK YIELDS AND FODDER FEEDING

	1988/89		1989/90		1990/91	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Continuously surveyed and milk-producing households only (NOB = 58, 59, 58)[a]						
Milk yields (*maund*/AU)	30.91	9.84	29.39	10.37	26.94	9.53
Green fodder expenditure (Rs.)	1,547.0	699.0	1,551.7	731.8	1,622.0	191.7
Dry fodder expenditure (Rs.)	457.9	344.2	481.5	316.9	395.6	253.2
Concentrate expenditure (Rs.)	192.6	91.7	138.3	112.2	134.9	780.3
All milk-producing households (NOB = 96, 97, 96)[a]						
Milk yields (*maund*/AU)	31.85	10.32	30.43	10.26	27.18	9.28
Green fodder expenditure (Rs.)	1,589.5	685.6	1,676.5	799.0	1,653.9	221.8
Dry fodder expenditure (Rs.)	507.7	343.0	558.8	410.5	420.4	246.2
Concentrate expenditure (Rs.)	202.1	104.1	137.7	103.4	153.6	797.1
Absolute value of *t*-statistics[b]						
Milk yields (*maund*/AU)	1.108		1.243		0.312	
Green fodder expenditure (Rs.)	0.746		1.908*		0.483	
Dry fodder expenditure (Rs.)	1.751		2.298**		1.211	
Concentrate expenditure (Rs.)	1.103		0.067		1.013	

Source: See Table 3-1.

[a] One household in year 1988/89 and another in year 1990/91 did not produce any milk.

[b] See note a to Table 3-1.

* The null is rejected at 10%.

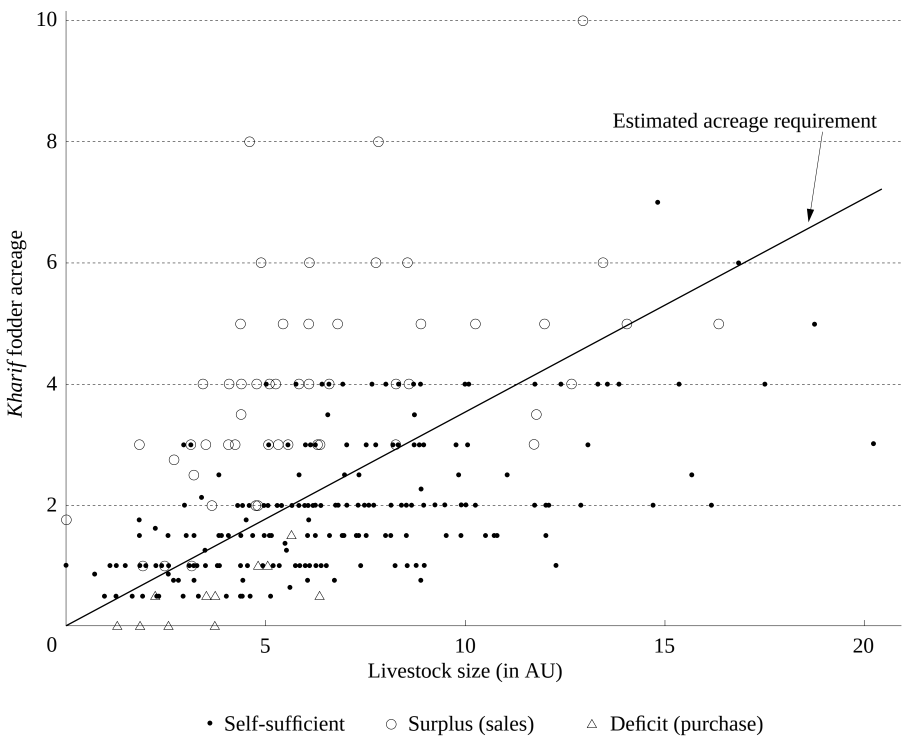
** The null is rejected at 5%.

4. Land Allocation and Production Assets

Two types of crops, cereals and fodder, compete for land in the study area. How did sample households determine the land allocation between the two crops? Two hypotheses for crop choices are examined graphically below.

The first hypothesis is the fodder-sufficiency-first model, which is based on the assumption that farmers first put aside their land for their fodder requirement and never depend on outside markets to compensate for the deficit as long as land was available to produce it. The mathematical programming literature often employs this assumption (Gotsch et al. 1975; Perry 1982). If farmers produce surplus fodder, they can sell it but cannot purchase deficit fodder. The assumption might have been valid for earlier days in the Pakistan Punjab when markets for fodder were relatively less developed. However, it does not seem to be appropriate presently considering that a number of sample

Fig. 3-1. Fodder Acreage and Livestock Herd Sizes in *Kharif*



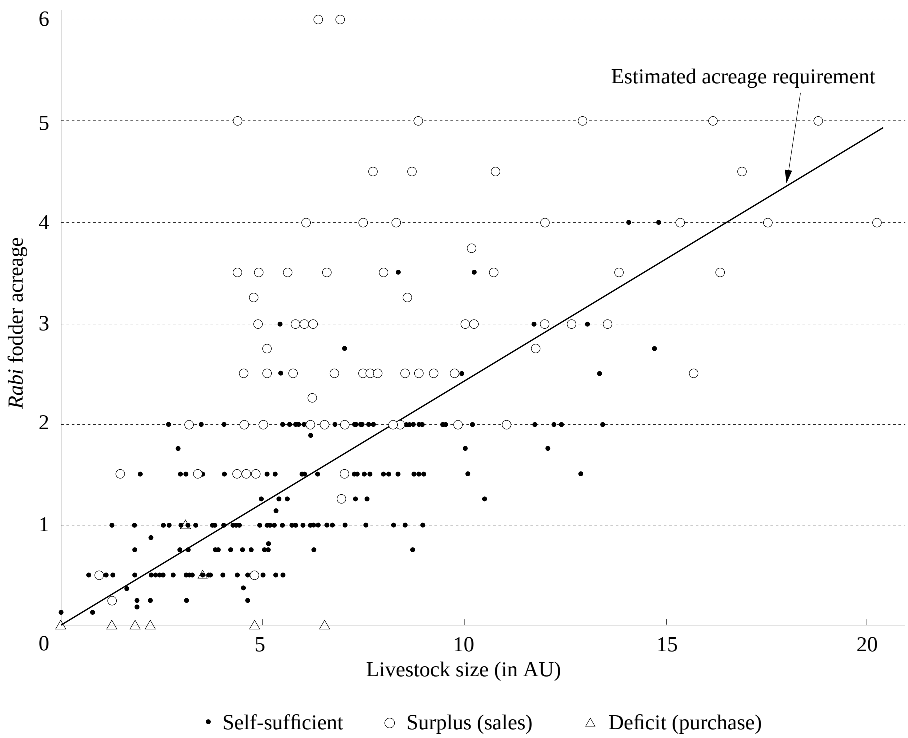
Source: Drawn by the author. See Table 3-1.

households purchased fodder even though land was available to grow fodder crops.

Figures 3-1 and 3-2 plot fodder acreage against the size of livestock herd to examine whether this hypothesis is valid. Sample households were classified by their marketing status into three categories: those who were self-sufficient (no sale and no purchase), those who sold to the market, and those who purchased from the market. The straight line shows the required fodder acreage based on the mean value of fodder inputs to livestock animals.[5]

As a crude approximation, the fodder-sufficiency-first model explains the observations partially in a sense that all the deficit households lay below the line of estimated acreage requirement and most of the surplus households above the line. In this sense, household crop choices were close to the behavior under missing fodder markets, despite observed participation in fodder markets. However, under the fodder-sufficiency-first hypothesis, deficit house-

Fig. 3-2. Fodder Acreage and Livestock Herd Sizes in *Rabi*

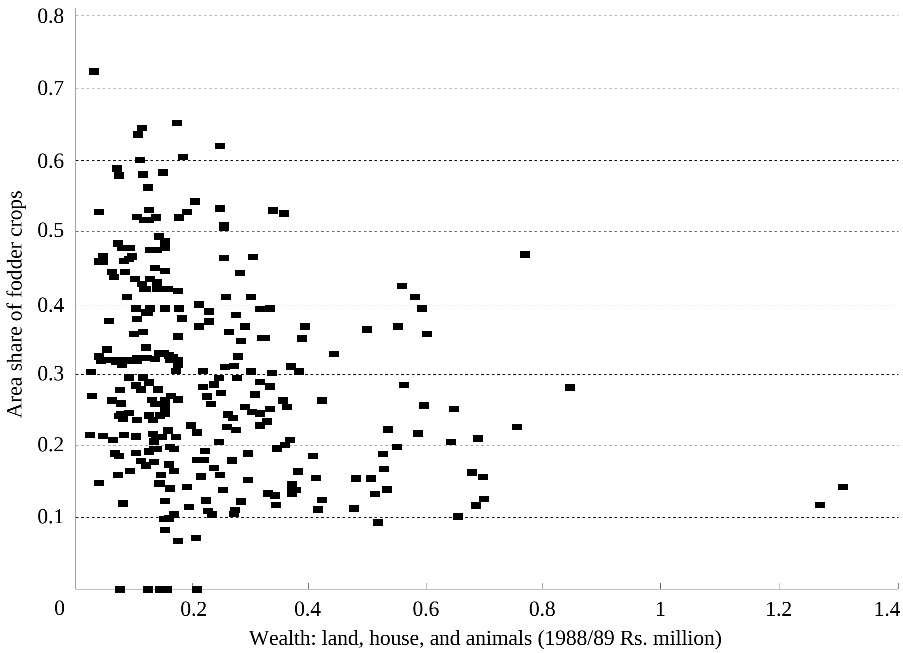


Source: Drawn by the author. See Table 3-1.

holds should have allocated all available land to fodder. This is not supported by the data since all deficit households in the sample allocated a substantial proportion of their land to non-fodder crops. Therefore, the data do not support strictly the simple hypothesis of a fodder-sufficiency-first model. The conclusion is the same when the acreage share of fodder is plotted against the livestock herd size per farmland.

Another hypothesis is a portfolio model that characterizes households' land allocation decisions as a portfolio choice between two risky activities: a food-grain crop and a fodder crop. If three conditions hold, the portfolio theory predicts that the shares of the two crops should be a monotonic function of the agent's wealth (Arrow 1971; Feder 1980; Just and Zilberman 1983). The three conditions are: the household is maximizing expected utility from the net revenue from two activities; the distribution of per-unit profits from the activities is independent of the household's production choice;[6] and, the risk preference

Fig. 3-3. Share of Fodder Acreage and Household Wealth in *Kharif*

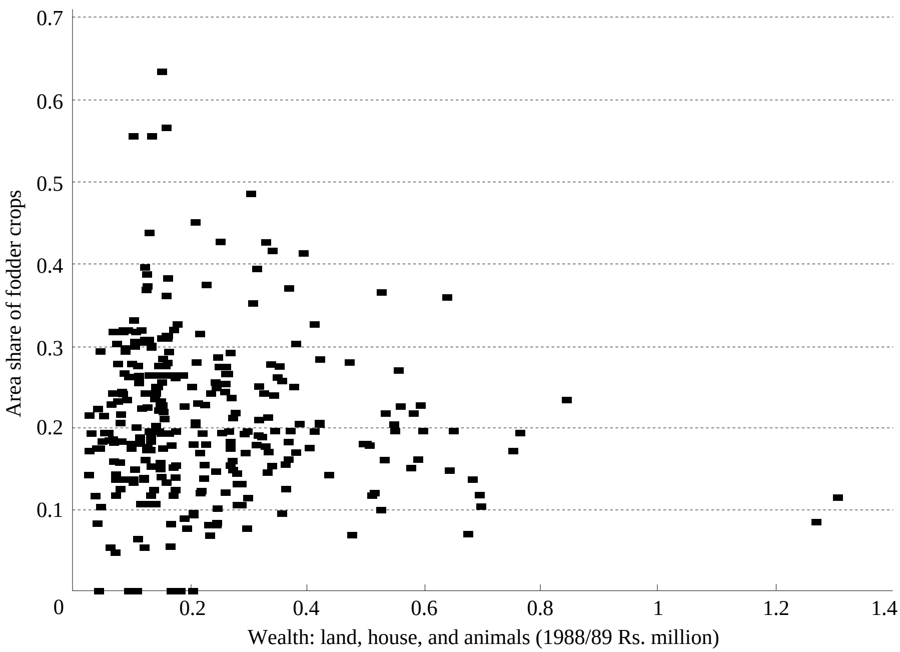


Source: Drawn by the author. See Table 3-1.

structure is homogeneous among households and the Arrow-Pratt coefficient of relative risk aversion is a monotonically increasing or decreasing function of the agent's wealth. Under this set of assumptions, the share of each activity is invariant when the coefficient of relative risk aversion is constant with respect to wealth (Arrow 1971, pp. 119–20). When it is not, the share either increases or decreases with wealth monotonically depending upon the sign and the magnitude of the covariance of the net revenues from the two risky activities (Just and Zilberman 1983).

Figures 3-3 and 3-4 plot the share of fodder crops to available land against the household wealth. Available land defined as the sum of the land cultivated with fodder crops, wheat or basmati, and the current fallow.[7] Household wealth is defined here as the sum of the land value, livestock value, and house value, evaluated at 1988/89 prices.[8] The two figures show neither a monotonically increasing nor a monotonically decreasing relationship between the share and the wealth level, which is suggested by a simple portfolio hypothesis. At lower levels of wealth, shares vary significantly among households; as wealth increases, there seems to be a convergence to a certain level. These results may

Fig. 3-4. Share of Fodder Acreage and Household Wealth in *Rabi*



Source: Drawn by the author. See Table 3-1.

be due to the heterogeneity in risk preferences among households or to the possibility that households consider other aspects than net revenue from crops when they maximize expected utility (Chapter 6).

5. Farm Mechanization, Tubewell Irrigation, and Water Transactions

The number of bullocks for cultivation has declined (Table 3-7), because tractor power is now widely available. Although only 14 per cent of sample households owned tractors, almost every household had access to tractor services (Table 3-9). Cultivation using tractors is a rule rather than an exception in the study area, implying that the level of technology applied is more advanced than the national average, which is consistent in taking account of the context of agriculture in the Punjab (GOP, Agricultural Census Organization 1987). Tractor cultivation services are available in the villages on a fixed wage basis.

Another important characteristic of the Punjab agriculture is the use of tubewells with diesel or electric pump sets. Although the study area is 100 per cent irrigated by perennial canals, water supply is uncertain and cannot meet farmers' need in time and in quantity. Tubewell technology fills this gap in water requirement. In the Punjab province as a whole in 1990, the cultivated area irrigated by canals and tubewells accounted for 53 per cent of the total irrigated area, whereas the area irrigated by canals alone accounted for 25 per cent and the area irrigated by tubewells alone accounted for 20 per cent (GOP, Agricultural Census Organization 1994).

The number of sample households who owned tubewells increased in the second year and they accounted for about three-fourths in the last two years (Table 3-9). Therefore, the majority of households owned tubewells. Even if a household did not own a tubewell, it had access to tubewell water by purchasing.

Water transactions observed in the study area consisted of water sales on an hourly cash basis. In various areas in South Asia, land tenancy contracts linked with water transactions have been observed since the tubewell technology became popular (Fujita and Hossain 1995; Shah 1993). Such arrangements were not observed among the sample households, although a three-party-sharecropping arrangement among landlords, tenants, and tubewell owners prevails in the more water-scarce area of the rice-wheat zone in the Punjab (Ali 1995). In Pakistan in general, fixed cash payments are becoming popular, although sharecropping arrangements are also prevalent (Chaudhry 1990).

In Tables 3-10 to 3-12, information on tubewell irrigation and water transactions is summarized for the continuously surveyed households. Sample households with tubewells used both canal and tubewell water for cultivating basmati and wheat, except for some cases where only canal water was applied to wheat (Table 3-10). Some of the households without tubewells relied only on canal water and others purchased tubewell water to supplement canal water. Water purchase was more common in the cultivation of basmati than wheat. This is understandable since water control is more critical in cultivation of paddy than wheat. The number of households who purchased water declined in the last two years when some of the households became tubewell owners.

Table 3-11 lists water rates paid by sample households who purchased tubewell water. The rates ranged from Rs. 12 to Rs. 30 per hour. The range of variation was small except for basmati in 1988/89. Comparison of Tables 3-10 and 3-11 shows that the nominal water rates remained unchanged and displayed a smaller intra-year variation in later years as the number of tubewell owners increased. One interpretation of this finding is that households who purchased more expensive water in the first year were the ones who became tubewell owners in later years. Another interpretation could be the effect of increased competition among potential water sellers in later years because the number of tubewell owners increased. These data suggest that discriminatory

TABLE 3-9

NUMBER OF HOUSEHOLDS WHO OWNED AND USED MACHINERY

	1988/89		1989/90		1990/91	
	No.	%	No.	%	No.	%
Continuously surveyed households only (NOB=59)						
Households who owned a tractor	6	10.2	6	10.2	7	11.9
Households who used tractor cultivation	56	94.9	59	100.0	58	98.3
Households who owned a tubewell	34	57.6	45	76.3	44	74.6
Households who used tubewell water	55	93.2	54	91.5	48	81.4
All households (NOB=97)						
Households who owned a tractor	14	14.4	13	13.4	13	13.4
Households who used tractor cultivation	93	95.9	97	100.0	95	97.9
Households who owned a tubewell	59	60.8	73	75.3	70	72.2
Households who used tubewell water	91	93.8	88	90.7	81	83.5

Source: See Table 3-1.

TABLE 3-10

IRRIGATION METHODS ADOPTED BY SAMPLE HOUSEHOLDS

	Only Canal Water		Canal & Tubewell Water		Total
	Nonowner	Owner	Nonowner	Owner	
1988/89					
Basmati	6	0	19	34	59
	(10.2)	(0.0)	(32.2)	(57.6)	(100.0)
Wheat	19	0	6	34	59
	(32.2)	(0.0)	(10.2)	(57.6)	(100.0)
1989/90					
Basmati	6	0	8	45	59
	(10.2)	(0.0)	(13.6)	(76.3)	(100.0)
Wheat	10	1	4	44	59
	(16.9)	(1.7)	(6.8)	(74.6)	(100.0)
1990/91					
Basmati	12	0	3	44	59
	(20.3)	(0.0)	(5.1)	(74.6)	(100.0)
Wheat	14	2	1	42	59
	(23.7)	(3.4)	(1.7)	(71.2)	(100.0)

Source: See Table 3-1.

Notes: 1. Continuously surveyed households only.
2. "Owner" and "Nonowner" correspond to the ownership of a tubewell.
3. Figures in parentheses are percentages.

TABLE 3-11

PRICES ACTUALLY PAID BY BUYERS OF TUBEWELL WATER

(Rs./hour)

	Mean	Standard Deviation	Minimum	Maximum	NOB
1988/89					
Basmati	18.89	4.95	12	30	19
Wheat	22.50	2.74	20	25	6
1989/90					
Basmati	15.13	1.36	12	16	8
Wheat	13.50	1.73	12	15	4
1990/91					
Basmati	16.67	2.89	15	20	3
Wheat	20.00	0.00	20	20	1

Source: See Table 3-1.
Note: Continuously surveyed households only.

TABLE 3-12

TUBEWELL WATER COSTS BORNE BY TUBEWELL OWNERS

(Rs./hour)

	Mean	Standard Deviation	Minimum	Maximum	No. of Tube-well Owners	Ratio of Price/Cost[a]
1988/89	13.14	3.75	4.99	22.26	34	1.504
1989/90	12.42	1.99	9.17	16.59	45	1.174
1990/91	13.67	2.05	8.73	17.79	44	1.281

Source: See Table 3-1.
Note: Continuously surveyed households only.
[a] The mean of water prices obtained from Table 3-11 divided by the mean of water costs shown in this table.

pricing, as in the monopoly model, does not operate in the study area.

To further investigate the nature of water transactions, hourly average costs of tubewell water application by tubewell owners are indicated in Table 3-12. To derive the average costs, the sum of depreciation of tubewells, interest payments, operators' wages, imputed family wages, operation and maintenance costs, and fuel and electricity costs was divided by the total number of hours of operation. Theoretically, marginal costs should be estimated. However, because of data availability, average costs were used as their proxies. If per-hour costs are well below the water rates, a high bargaining power of water sellers is suggested. The average water cost was estimated at around Rs. 13 per hour (the first column of Table 3-12). The ratio of the average water rates calculated from Table 3-11 to the average water costs was estimated at around 1.5 in the first year, followed by 1.2 to 1.3 in the subsequent years (the last column of Table 3-12). These figures are more or less smaller than those estimated for Bangladesh and India (Fujita and Hossain 1995; Shah 1993). This finding is consistent with the larger number of potential tubewell water sellers in the study area. Competition among water sellers, whether explicit or potential, might result in water rates which are not exploitatively high.

These investigations strongly suggest that private transactions of groundwater pumped up by tubewells contribute to efficiency gains by giving non-tubewell-owners access to additional water. To what extent this efficiency gain is instrumental in equalizing production efficiency between owners and nonowners will be investigated further below.

II. Estimation of Yield Variability

One of the unexplored issues in the empirical risk literature in Pakistan is the extent of yield variability at the individual farm level (Chapter 2). This section estimates parameters characterizing yield variability of four major crops (basmati, *kharif* fodder, wheat, and *rabi* fodder) at the farm level.[9] An empirical model is proposed in which crop yields vary according to household characteristics and are subject to idiosyncratic risks. The yield risk perceived by farmers is the variability of per-acre yield after differences due to these characteristics are controlled.

1. The Empirical Model

Variability in the regional average of per-unit yield is assumed to be common among sample households. However, an individual household encounters a production risk that differs from the risk in the average yield for two reasons. First, output yields at the individual farm level are affected by idiosyncratic risks such as field-specific production problems. By definition, idiosyncratic risks are statistically independent of common risks that affect sample households equally. Due to the existence of the idiosyncratic yield risk, the coefficient of variation (*CV*) of individual yield is larger than that of average yield. Second, technology is not identical among households in farm production activities. Expected yield and yield variance may differ from farmer to farmer due to differences in, for example, land quality, ownership of machinery, and the educational level of the household head.

Incorporating these two aspects, a simple model of yield multiplier in the following form is adopted:

$$\begin{aligned} y_{hit} &= y_{it}\left\{u_i\left(Z_{ht}\right)+\eta_{hit}\right\}, \\ u_i\left(Z_{ht}\right) &= \sum_k \beta_{ki} Z_{hkt}, \end{aligned} \tag{3.1}$$

where y_{hit} is the per-unit yield of farm activity i for household h in year t, assumed to be a product of y_{it} and a household yield multiplier $u_i(Z_{ht})+\eta_{hit}$; y_{it} is the average yield in year t that is also stochastic due to the common shock; $u_i(Z_{ht})$ represents a deterministic portion of the household yield multiplier, where Z_{ht} is a vector of household characteristics that affect yield distribution; and η_{hit} is an additive idiosyncratic error with mean zero.

The function $u_i(Z_{ht})$ could be interpreted as a reduced-form equation of household production decisions. If the theory of duality holds, the function becomes a supply function of per-acre yields with the vector Z_{ht} consisting of market prices and household characteristics of fixed production assets; and if the duality theory breaks down, the function should also include household consumption characteristics in the vector Z_{ht} (Pope 1982; Pope and Just 1991). Because the data cover a three-year period with price variations that are almost collinear with yearly dummies, price variables are not included.

A convenient aspect of model (3.1) is that a square root of the estimated variance of η_{hit} has an intuitive meaning of the coefficient of variation of yields due to idiosyncratic shocks. If this number is high, it implies that individual yields vary significantly around the average yield in the year. To define y_{it} in a consistent manner, the model was estimated for the subset of sample households that were surveyed continuously.

As shown in (3.1), the function $u_i(Z_{ht})$ is approximated linearly with the household characteristic variables represented by a dummy variable for tractor ownership (*TRDUMMY*), a dummy variable for tubewell ownership (*TWDUMMY*), the number of family members per acre (*FAMA*), and the years of completed education of the household head (*EDU*). Since these variables are predetermined when households decide on land allocation, they are treated as exogenous variables in the estimation. The variables are constructed based on the household data described in Chapter 2. To extract full information on the panel data, another model with household dummies was estimated also. This model is expected to correct the bias from unobserved household characteristics by what is known in the panel data analysis as “fixed effects” (Judge et al. 1985, ch. 13). One disadvantage of the model with fixed effects is that coefficients on agricultural machinery dummies become unstable due to their high collinearity with household dummies. Therefore, the discussion below on estimation results is mostly based on the specification without household fixed effects.

2. Estimation Results

Estimation results for a model without household dummies are given in Table 3-13 together with statistics of the exogenous variables. Estimation results with household fixed effects are reported in Table 3-14. The education level of the household head *EDU* raises the yield significantly for basmati, wheat, and *rabi* fodder. Therefore, education improves management efficiency in the farm, as emphasized in the literature on human capital (Schultz 1961; Lockheed, Jamison, and Lau 1980; Jamison and Lau 1982).

If the coefficient on *TWDUMMY* is significantly different from zero, it implies that water markets are not functioning well because factor marginal productivities are not equalized between owners and nonowners. If the coefficient is positive, it implies that households with tubewells enjoyed higher productivity. This is consistent with the hypothesis of the owner's superiority in water input use over water buyers. On the other hand, an orthodox theory of waterseller's monopoly implies that marginal productivity of water should be higher for water buyers' land because of price discrimination. A negative coefficient on *TWDUMMY* is consistent with this hypothesis.

As Table 3-13 shows, the tubewell ownership dummy has a positive effect on basmati and *kharif* fodder yields, although it is not statistically significant. The sign is negative for wheat and *rabi* fodder crops, but again the coefficients are not statistically significant. Results reported in Table 3-14 are also mixed. These findings are consistent with the existence of an active water market. Once the cropping choice is made, whether the supplementary water comes from households' own tubewells or from water markets does not affect crop yields significantly.

The above statement does not mean that water markets are perfect. It merely suggests that factor marginal productivities are likely to be equalized among sample households. Another, stronger version of the hypothesis of efficient water markets should require that households' production decisions be separable from their status in tubewell ownership. Chapter 6 will show that the effect of tubewell ownership is more evident in land allocation decisions. In this sense, water transactions among sample households failed to achieve full gains from trade.

The coefficients on the tractor ownership dummy are not significant, either. The existence of an active tractor-service market explains this lack of significance.

3. Importance of Idiosyncratic Risks

Overall fit of the regression results in Table 3-13 is not good, suggesting

TABLE 3-13

REGRESSION RESULTS OF YIELD MULTIPLIER MODEL

	Basmati	*Kharif* Fodder	Wheat	*Rabi* Fodder	Statistics of Independent Variables[a]
Constant	0.944	0.924	0.996	1.008	
	(19.9)	(26.0)	(19.9)	(28.4)	
TRDUMMY	–0.072	0.054	0.045	–0.056	0.107
	(1.38)	(1.39)	(0.81)	(1.46)	[0.310]
TWDUMMY	0.042	0.040	–0.056	–0.006	0.695
	(1.09)	(1.38)	(1.39)	(0.22)	[0.462]
FAMA	–0.007	0.032	–0.001	–0.014	1.202
	(0.33)	(2.15)	(0.07)	(0.95)	[0.900]
EDU	0.019	0.001	0.017	0.008	2.288
	(4.26)	(0.44)	(3.78)	(2.60)	[3.576]
Mean of dependent variable	1.000	1.000	1.000	1.000	
Standard deviation of dependent variable	0.217	0.151	0.226	0.154	
Number of observations	177	171	177	176	
R^2	0.111	0.036	0.089	0.049	
Square root of the estimated variance	0.207	0.150	0.218	0.152	

Source: See Table 3-1.

Notes : 1. Dependent variables = multiplier over average yield in each year.
2. Continuously surveyed households only.
3. The absolute values of *t*-statistics are indicated in the parenthesis.
4. Estimated by ordinary least squares.

[a] Means are given first, followed by the standard deviations in brackets.

that idiosyncratic risk is important in determining yields. The square roots of the estimated variance of η_{hit} range from 0.15 to 0.22. The results are similar when household fixed effects are corrected—the square roots are in the range of 0.11 to 0.18, only slightly smaller than indicated by Table 3-13.[10] These findings are supported further by examining the household data from a different angle. Table 3-2 showed that the sample average of annual basmati yield was the highest in the second year, followed closely by that in the first year. The third year suffered a bad harvest. Nevertheless, yield pattern at the individual household level is different from the average pattern. The households that experienced a worse yield in the first or second year than in the last year numbered twenty-two out of fifty-nine, implying that more than one-third of the sample households experienced an adverse idiosyncratic shock in the years of good harvests on average.

TABLE 3-14

REGRESSION RESULTS OF YIELD MULTIPLIER MODEL WITH HOUSEHOLD FIXED EFFECTS

	Basmati	*Kharif* Fodder	Wheat	*Rabi* Fodder
TRDUMMY	–0.118 (1.37)	0.202 (2.34)	0.155 (1.59)	–0.021 (0.34)
TWDUMMY	0.118 (2.59)	0.043 (0.95)	–0.098 (1.90)	–0.005 (0.14)
FAMA	–0.037 (0.73)	0.025 (0.49)	–0.085 (1.47)	–0.037 (1.00)
EDU	0.194 (9.20)	0.188 (9.07)	0.217 (9.12)	0.190 (12.5)
Household dummies[a]	(omitted to save space)			
R^2	0.660	0.352	0.600	0.656
Square root of the estimated variance	0.157	0.152	0.177	0.112

Source : See Table 3-1.

Notes :
1. Dependent variables = multiplier over average yield in each year.
2. Continuously surveyed households only.
3. The absolute values of *t*-statistics are indicated in the parenthesis.
4. Estimated by ordinary least squares.
5. See Table 3-13 for the statistics of variables and the number of observations.

[a] Only those household dummies that are not completely collinear with *TRDUMMY* and *TWDUMMY* are included. The number of those independent dummies is 58.

Similarly, the average wheat yield in the region was very high in the first year, followed by two bad years. The sample households that experienced the highest yield in the second or third year numbered ten out of fifty-nine. These households experienced a favorable idiosyncratic shock in the years of bad harvests on average.

Therefore, idiosyncratic disturbances were found to be important in determining crop yields at the individual farm level in the region. In the ICRISAT villages in semiarid India with mostly rain-fed agriculture, the *CV*s of crop yields at individual farms were estimated to range from 31 per cent to 69 per cent (Walker and Ryan 1995, Table 8.5). Since Walker and Ryan's numbers reflect a mixture of common and idiosyncratic risks, they are not strictly comparable to the estimates here. But it might be safe to conclude that irrigated agriculture in the Pakistan Punjab is subject to idiosyncratic yield shocks that may be smaller than in the ICRISAT area but larger than we expect from 100 per cent irrigated agriculture.

III. Summary and Conclusions

In the first section of this chapter, farming activities of sample households have been described. Sample households' cropping pattern is dominated by a major cash crop (basmati), a staple food crop (wheat), and green fodder crops for livestock. Every household in the region combines crop activities and livestock activities in one farm. Milk production is the most important livestock activity, for which, green fodder is the major input. Milk is not only an important consumption item but also an important source of income.

Households in the region face several types of production risks. Variability in crop yields has been estimated in the second section using a model that distinguishes common and idiosyncratic risks. It has been found that idiosyncratic yield risk is important to the extent that the coefficient of variation of yields at the farm level ranges from around 11 per cent to 22 per cent.

In the study area, tubewell irrigation in addition to canal irrigation has become popular with active groundwater transactions. Because of the active water transactions, crop yields at farms without tubewells are not significantly lower than those at farms owning tubewells. Nevertheless, the production risk of irrigation water is significant. It is conjectured that households' cropping decisions are affected more by control of the irrigation risk, which is possible with tubewell ownership, than crop yields are. This conjecture will be verified in Chapter 6.

Chapters 2 and 3 have now provided sufficient information on production characteristics of sample households. This information will be used in the following chapters in which theoretical models of household behaviors are applied to the study region. Before this application, another dimension of background information should be investigated: market institutions and price risk. This is the topic of the next chapter.

Notes

1 One *maund* is equivalent to approximately 40 kg.
2 See Smale (1987) for the adoption of harvesting mechanization in the rice-wheat zone.
3 For instance, the tractor charge per acre for basmati preparatory ploughing was Rs. 50/run (one run takes about 0.5 hour), that for basmati preparatory planking was Rs. 20/run (one run takes about 0.25 hour), that for basmati seedbed ploughing was Rs. 60/run (one run takes about 0.75 hour), and that for basmati seedbed

planking was Rs. 30/run (one run takes about 0.25 hour). Hired workers for paddy transplanting were paid around Rs. 40/day, those hired for basmati harvesting and threshing were paid 1/10 to 1/8 of basmati output, those hired for wheat harvesting were paid 1.5 to 3.5 *maund*s of wheat per acre, and workers hired for wheat threshing were usually paid around 20 kg of wheat per day.

4 The adult-animal equivalent units (AU) used in this study are obtained from the Punjab Economic Research Institute and as follows. Draft animals: 1.0 for adult bullocks / he-buffaloes, 0.57 for young bullocks / he-buffaloes, 0.57 for adult donkeys, 0.28 for young donkeys, and 1.0 for adult horses. Milch animals: 1.28 for adult she-buffaloes, 0.96 for young she-buffaloes, 0.72 for adult cows, 0.54 for young cows, and 0.20 for adult goats. Equivalent units slightly different from the above are also used in Pakistan. Qualitative results in this study were unchanged if different units were used.

5 The required fodder acreage for self-sufficiency was estimated at 0.35 (0.19) acres/AU in *kharif* and 0.24 (0.12) acres/AU in *rabi*. Standard deviations are indicated in the parenthesis and the number of observations is 170 in *kharif* and 174 in *rabi*.

6 This condition is not necessary for a certain class of production technology. For example, the constant-returns-to-scale specification in Feder (1980) results in the independence of input choice from land allocation decisions.

7 This definition is also used in the structural household model in Chapters 6 and 8. Results in the text were unchanged if the current fallow was excluded.

8 Land and livestock were major sources of wealth for sample households. Results were unchanged if house value was excluded.

9 The section is based on Kurosaki (1997).

10 “Only slightly smaller” in a sense that net-profit variability at the farm level estimated from Table 3-13 is very close to that estimated from Table 3-14 (see Tables 5-3 and 5-4 in Chapter 5).