5

Variability in Net Profits at the Individual Farm Level

What matters to risk-averse households when they decide on crop production is the variability of net profit, rather than that of yields or prices per se. In this chapter,[1] therefore, profit variability at the individual farm level was estimated using information supplied in previous chapters. Price variability has been estimated already in Chapter 4. Yield variability due to shocks idiosyncratic to individual farms has been estimated in Chapter 3. Variability in net profits at the individual farm level is obtained by adding adjustments for idiosyncratic yield risk and input costs to a model for the regional average of per-unit revenues.

Estimating profit variability at the farm level is important because profit variability is the major factor that determines income risk for farmers. Increased income risk is itself a loss of welfare to risk-averse households. It might make modern crop technology less attractive to farmers and delay agricultural development in developing countries. For these reasons, there is a large literature on price and yield variability (Kuchiki 1990; Anderson and Hazell 1989; Newbery and Stiglitz 1981; Johnson 1975). Nevertheless, only a few studies have investigated the variability of net profits at the individual farm level, mainly due to the difficulty in obtaining data.[2] Experimental yield data have been also accumulated from agricultural research stations (Anderson and Hazell 1989, Part II). On the other hand, reliable data on yield and input at the farm level are not often available as panel data with a time-series dimension.

The scarcity also applies to South Asian agriculture. Some authors have estimated crop income variability from the ICRISAT data from India (Walker and Ryan 1990; Walker 1989). For Pakistan, however, to the author's knowledge, only a few studies are available either on price variability (Mohammad 1983, 1985; Byerlee and Iqbal 1987), or on aggregate crop yield variability (Ahmed and Mahmood 1992). Therefore, an attempt was made in this chapter to fill this gap by estimating net profit variability at the individual farm level in the rice-wheat zone in Pakistan's Punjab. Results will be compared to those from the ICRISAT data. The covariances of prices of major consumption commodities and crop profits were also estimated since they are an important determinant of crop choices for households who face uncertain food prices and therefore want to avoid consumption price risk by growing the food crop on their farms (Kurosaki 1995b, chap. 3; Fafchamps 1992a).

I. A Model of Profit Variability

By definition, per-acre profit of a crop is the product of its price and yield, minus total production costs per acre. In this study, it is assumed that market price disturbances are commonly shared by sample households in a village, an assumption verified in Chapter 4. Regarding the sources of yield variability, it is assumed that yields at the individual farm level are subject to both common and idiosyncratic disturbances.

Therefore, a general model for the per-acre profit of crop i on farm h in year t can be expressed as

$$\pi_{hit} = p_{it}(\varepsilon_t) y_{hit}(Z_{ht}, \varepsilon_t, \eta_{hit}) - w_t(\varepsilon_t) \cdot x_{hit}(Z_{ht}), \tag{5.1}$$

where ε is a vector of common disturbances that affect output price p_i, input price vector w, and per-acre crop yield y_{hi}; η is a vector of idiosyncratic disturbances that affect y_{hi}; and x is an input vector for crop production. The per-acre crop yield y_{hi} is a realized level, which might be different from the desired or planned level of yield that should be a solution to household's optimization problem. The vector Z_h denotes household characteristics. A model for per-animal milk profit is defined similarly.

Since in this chapter emphasis is placed on profit variability perceived at the beginning of an agricultural year when households decide on crop production plans, it is assumed that the input price vector (w) for crop production is non-stochastic because the prices of important inputs in crop production such as fertilizer and seeds are known at that time. On the other hand, w for milk production remains stochastic because the price of the most important input in milk production, green fodder, is unknown at the time of crop planting.

For the estimation, yield at the individual farm level is specified as a multiple of the regional average yield and a household specific multiplier, which is subject to idiosyncratic shocks. Algebraically, it is expressed as

$$y_{hit} = y_{it}(\varepsilon_t)\{u_i(Z_{ht}) + \eta_{hit}\}. \tag{5.2}$$

Inserting (5.2), equation (5.1) becomes

$$\pi_{hit} = Rev_{it}(\varepsilon_t)\{u_i(Z_{ht}) + \eta_{hit}\} - w_t(\varepsilon_t) \cdot x_{hit}(Z_{ht}), \tag{5.3}$$

which shows that the part of gross revenues affected by common shocks can be expressed in one term: “per-unit gross revenue in the region” (*Rev*). The yield multiplier model of $u(Z) + \eta$ has been already estimated in Chapter 3. Therefore, what is needed is to estimate the variability of *Rev* for each farm activity.

II. Estimating the Variability of the Regional Average of Gross Revenues

A time-series model similar to that used for price variability in the second section of Chapter 4 was applied to the regional average of gross revenues from major crop activities. The revised model for the average revenue is

$$\begin{aligned} \ln Rev_{it} &= a_i + b_i t + u_{it}, \\ u_{it} &= \mu_{R_i} u_{i,t-1} + \varepsilon_{R_i t}, \end{aligned} \tag{5.4}$$

where t is a time variable measured in years associated with an annual trend rate of b, and μ is an auto-regression coefficient for an AR(1) error term. Fitted values are defined similarly as in equation (4.2) and the *CV* and the correlation coefficients of revenues are approximated similarly as in equation (4.3) in Chapter 4. Basmati support prices are also included for the basmati revenue equation, as in Chapter 4.

The average gross revenues in the region were calculated as the product of annual prices and per-acre yields in the region each year. See Chapter 4 for the price data. Data on crop yields were obtained from a computerized database (GOP, Ministry of Food, Agriculture and Co-operatives, Economic and Policy Analysis Project 1992a, 1992b). For basmati and wheat yields, data for the Sheikhupura district were used. For fodder yields, since data for the Sheikhupura district were not available, data for the Punjab province were used. The yield of *kharif* fodder crops was represented by that of jowar, and that of *rabi* fodder by that of berseem.[3]

Data on per-unit yield of milk are not available as a time series. The existing data are simple interpolations of survey results in the livestock census conducted every ten years (GOP, Agricultural Census Organization 1989; GOP, Ministry of Food, Agriculture and Livestock 1994). Therefore, the estimation of milk revenue equations was not attempted and it is assumed that the variability of average milk revenue was due only to price variability.

Table 5-1 gives the regression results for the period from 1971/72 through 1990/91. Coefficient estimates for the time trends were mostly positive and significant. Revenues from green fodder increased with the annual growth rate of 13 to 15 per cent. These growth rates surpass corresponding figures for basmati (6.5 per cent) and for wheat (9 per cent). These trend coefficients indicate a pattern similar to that of the coefficients for prices. The similarity suggests that the revenue and the price of a crop tended to move together in the study area. The growth rate of the wheat revenue was higher than that of basmati revenue because wheat yield per acre improved during the study period. Basmati yield per acre stagnated during the same period, resulting in the lowest growth rate of its revenue.

Table 5-2 shows the estimates of *CV* and ρ constructed from the regression results for average revenues in Table 5-1 and those for price series reported in Table 4-2. The *CV*s of revenues from cereal crops (wheat and basmati) were more stable than those of green fodder revenues. As expected, the price and the regional average revenue of a commodity are highly correlated—ρ is estimated in the range of 0.68 (wheat) to 0.99 (*kharif* fodder). Also, fodder revenues and milk revenues are positively correlated with ρ values of 0.44 in *kharif* and 0.33 in *rabi*. This is expected since the milk price tends to be higher when the price of green fodder, its most important input, is higher.

III. Converting Gross Revenue Variability into Net Profit Variability

Assuming a simple model of input costs, in which the costs are proportional to expected revenues, the model in (5.3) becomes

$$\pi_{hi} = Rev_i\left\{u_i\left(Z_h\right)+\eta_{hi}\right\}-w\cdot x_{hi}\left(Z_h\right), \tag{5.5}$$

where

$$E\left[w\cdot x_{hi}\left(Z_h\right)\right]=c_i E\left[p_i\cdot y_{hi}\right]=c_i\cdot u_i\left(Z_h\right)E\left[Rev_i\right]$$

and c_i is the mean ratio of input costs to revenue.

Other specifications were also examined, but the estimated values of *CV* and ρ did not change appreciably. The model in (5.5) was adopted because a relatively simple calculation can be used to convert average revenue parameters into individual profit parameters.

TABLE 5-1

Regression Results of Time-Series Model for Regional Average Revenues

	Basmati	*Kharif* Fodder	Wheat	*Rabi* Fodder
Constant	5.870**	7.161***	4.446***	7.679***
	(2.61)	(30.2)	(70.6)	(15.5)
Time trend	0.065*	0.127**	0.092***	0.152**
	(1.82)	(2.39)	(8.31)	(2.05)
Log of support price, basmati	–0.120			
	(–0.26)			
μ	0.508***	0.495	0.370*	0.672**
	(3.36)	(1.19)	(1.85)	(2.11)
Standard error	0.156	0.365	0.159	0.387
R^2	0.891	0.822	0.930	0.859
No. of observations	19	10	19	10

Source: The author's calculation. See the text for the data source for regression.
Notes: Dependent variables are log of gross revenues; absolute values of *t*-statistics are indicated in the parenthesis; μ is the coefficient of the first order auto-regression in the error term, estimated by the Cochrane-Orcutt method.
*** significant at 1% level, ** at 5% level, and * at 10% level (two-sided test).

TABLE 5-2

CV and Correlation Coefficients of Prices and Average Revenues

	CV	Correlation Coefficients (ρ) with Gross Revenue					
		*k*1	*k*2	*r*1	*r*2	*km*	*rm*
Prices							
Basmati	0.141	0.832	–0.394	0.381	0.278		
Kharif fodder	0.353	–0.428	0.993	–0.304	0.515	0.345	0.507
Wheat	0.086	0.306	0.223	0.684	0.071		
Rabi fodder	0.415	0.122	0.599	–0.141	0.962	–0.142	0.029
Milk	0.146	–0.013	0.576	0.279	0.188		
Gross revenues							
Basmati (*k*1)	0.156						
Kharif fodder (*k*2)	0.365	–0.464					
Wheat (*r*1)	0.159	0.471	–0.309				
Rabi fodder (*r*2)	0.387	0.371	0.503	–0.064			
Kharif milk (*km*)	0.140	0.019	0.443	0.306	0.049		
Rabi milk (*rm*)	0.151	–0.045	0.709	0.251	0.328		

Notes: 1. Constructed from the results in Tables 4-2 and 5-1.
2. Only those parameters which are used in constructing variables for Chapter 6 are reported.

From equation (5.5), the parameters associated with individual profits can be expressed as

$$\overline{\pi_{hi}} = (1-c_i)\cdot u_i(Z_h)\cdot E[Rev_i], \quad i = k1,\, k2,\, r1,\, r2,\, km,\, rm,$$

$$CV_{\pi_{hi}} = \frac{k_i}{1-c_i} CV_{Rev_i},$$

$$\rho_{\pi_{hi},\pi_{hj}} = \frac{\rho_{Rev_i,Rev_j}}{k_i k_j}, \quad i, j = k1,\, k2,\, r1,\, r2, \tag{5.6}$$

$$\rho_{\pi_{hi},\pi_{hk}} = \frac{\rho_{Rev_i,Rev_k} - c_k \dfrac{CV_{w_k}}{CV_{Rev_k}} \rho_{w_k,Rev_i}}{k_i k_k}, \quad i = k1,\, k2,\, r1,\, r2;\; k = km,\, rm,$$

where

$$k_i = \sqrt{1 + CV_{u_{hi}}^2\left(1 + \frac{1}{CV_{Rev_i}^2}\right)}, \quad i = k1,\, k2,\, r1,\, r2,$$

$$k_j = \sqrt{1 + CV_{u_{hj}}^2\left(1 + \frac{1}{CV_{Rev_j}^2}\right) + c_j^2 \cdot \frac{CV_{w_j}^2}{CV_{Rev_j}^2} - 2c_j \cdot \frac{CV_{w_j}}{CV_{Rev_j}} \cdot \rho_{w_j,Rev_j}}, \quad j = km,\, rm,$$

$$CV_{u_{hi}} = \frac{\sqrt{\mathrm{Var}(\eta_{hi})}}{u_i(Z_h)}.$$

Idiosyncratic yield risk affects the *CV* and ρ of net profits via CV_{uh}, the last term in the above expression. The symbol c_j, which appears in the equation for milk that defines k_j, is the mean ratio of green fodder costs to milk revenues. Crop activities and milk production show different expressions for ρ and *k* in (5.6), since input prices in crop production are assumed to be nonstochastic whereas those in milk production are stochastic when households select the crops to be grown. Uncertainty in green fodder price is perceived by farmers both as output price risk and as input price risk.

Crop production costs are defined to include all cash costs, such as the costs of machinery services, hired labor, irrigation, fertilizer, pesticides, and seeds. Milk production cost is defined as the sum of the costs of livestock maintenance, hired labor, green and dry fodder (including the imputed value of fodder produced in the farm), and concentrates.

Based on these definitions, c_i's were calculated from the household data for each agricultural activity. *Rabi* fodder showed the highest cost ratio of 0.69

because it requires a large amount of hired labor and water. The lowest ratio was 0.22 for *kharif* fodder, which requires less labor and water. The cost ratios for basmati and wheat were estimated at 0.46 and 0.51, respectively. Milk production was associated with higher cost ratios between 0.62 and 0.67, mostly due to the cost of green fodder.

IV. Variability and Correlation of Net Profits at the Individual Farm Level

Using regression results in the second section of this chapter and those in Chapter 3, parameters characterizing variability and correlation of net profits at the individual farm level were calibrated. Tables 5-3 and 5-4 present the means and standard deviations of the *CV* and ρ coefficients, calculated for each sample household each year. Estimates in Table 5-3 are based on a household yield multiplier model without household dummies and those in Table 5-4 on a household yield multiplier model with household fixed effects. Two sets of numbers are very similar with the same qualitative implications. The standard deviations are smaller than one-tenth of the mean coefficients in all cases, suggesting a small inter-household variation. The two tables are different in several aspects from Table 5-2, as follows:

First, the *CV*s of individual profits of six farm activities are much greater than those of regional gross revenues. The multipliers k_i or k_j defined in equation (5.6) are all greater than unity including those for milk profitability. By construction, k_i is greater than unity for crop activities. On the other hand, whether the value is greater or smaller is indeterminate for milk production. The multiplier in the table is greater than unity for milk production because the effect of an idiosyncratic shock that increases the *CV* outweighs the effects of the positive correlation between fodder price and milk revenue that decreases the *CV*.

Second, the order of the *CV*s of profits among the four crop activities is different. The *CV* of *kharif* fodder profit becomes smaller than that of wheat and comparable to that of basmati, the competing crop in *kharif*. On the other hand, the *CV* of *rabi* fodder profit becomes larger than unity, due to higher input costs required to produce berseem, the most important *rabi* fodder crop.

Third, in sharp contrast to Table 5-2, the correlation coefficient between fodder and milk profits in Table 5-3 or in Table 5-4 takes a negative sign with a large absolute value. The coefficient is estimated at –0.65 in *kharif* and at –0.61 in *rabi*. On the other hand, the difference between the correlation coefficients among crop profits in Table 5-2 and Tables 5-3/5-4 is small, and the sign of the coefficients never changes.

TABLE 5-3

CV AND CORRELATION COEFFICIENTS OF PRICES AND NET PROFITS AT THE INDIVIDUAL FARM LEVEL

	CV	Multiplier *k*	Correlation Coefficients (ρ) with Net Profit			
			*k*1	*k*2	*r*1	*r*2
Prices						
Basmati	0.141		0.496	–0.360	0.222	0.256
	(n.a.)[a]		(0.022)	(0.002)	(0.010)	(0.001)
Wheat	0.086		0.182	0.204	0.399	0.065
	(n.a.)		(0.008)	(0.001)	(0.017)	(0.000)
Milk	0.146		–0.008	0.527	0.162	0.174
	(n.a.)		(0.000)	(0.002)	(0.007)	(0.001)
Net profits						
Basmati (*k*1)	0.488	1.682				
	(0.022)	(0.074)				
Kharif fodder (*k*2)	0.477	1.092	–0.253			
	(0.027)	(0.005)	(0.012)			
Wheat (*r*1)	0.543	1.719	0.164	–0.165		
	(0.024)	(0.071)	(0.014)	(0.007)		
Rabi fodder (*r*2)	1.234	1.085	0.204	0.424	–0.035	
	(0.091)	(0.005)	(0.010)	(0.003)	(0.002)	
Kharif milk (*km*)	0.631	1.618	0.260	–0.651	0.286	–0.443
	(0.061)	(0.047)	(0.012)	(0.015)	(0.013)	(0.005)
Rabi milk (*rm*)	0.796	1.991	–0.076	–0.146	0.144	–0.611
	(0.027)	(0.021)	(0.003)	(0.005)	(0.006)	(0.005)

Source: Constructed from the results in Tables 3-13, 4-2, 5-1, and 5-2. See the text for details.

Notes:
1. Standard errors are indicated in the parenthesis.
2. The number of observations is 177.
3. Based on regression results in Table 3-13 for a yield multiplier model without household dummies.

[a] Since *CV* of prices are common to each household in the sample by definition, there is no variation.

The correlation coefficients between fodder and milk profits in Table 5-3 or in Table 5-4 are substantially negative because fodder is the most important input in milk production and fodder price is the most variable. The fourth equation in (5.6) shows that the correlation becomes negative if (i) the cost share of fodder in milk production (c_k) is large, (ii) the *CV* of fodder price is relatively large compared with the *CV* of milk revenue, and (iii) the correlation between fodder price and fodder revenue (ρ_{w_k,Rev_i}) is highly positive. All three conditions are fulfilled in the study area. The negative correlation be-

TABLE 5-4

CV AND CORRELATION COEFFICIENTS OF PRICES AND NET PROFITS AT THE INDIVIDUAL FARM LEVEL WITH HOUSEHOLD FIXED EFFECTS

	CV	Multiplier *k*	Correlation Coefficients (ρ) with Net Profit			
			*k*1	*k*2	*r*1	*r*2
Prices						
Basmati	0.141		0.577	–0.359	0.250	0.265
	(n.a.)[a]		(0.048)	(0.006)	(0.024)	(0.003)
Wheat	0.086		0.212	0.203	0.449	0.068
	(n.a.)		(0.018)	(0.003)	(0.043)	(0.001)
Milk	0.146		–0.009	0.526	0.183	0.180
	(n.a.)		(0.001)	(0.008)	(0.018)	(0.002)
Net profits						
Basmati (*k*1)	0.421	1.455				
	(0.036)	(0.123)				
Kharif fodder (*k*2)	0.479	1.096	–0.294			
	(0.028)	(0.017)	(0.025)			
Wheat (*r*1)	0.486	1.538	0.215	–0.185		
	(0.051)	(0.160)	(0.033)	(0.018)		
Rabi fodder (*r*2)	1.194	1.049	0.246	0.437	–0.040	
	(0.089)	(0.013)	(0.022)	(0.007)	(0.004)	
Kharif milk (*km*)	0.629	1.613	0.304	–0.650	0.323	–0.460
	(0.061)	(0.047)	(0.026)	(0.018)	(0.032)	(0.008)
Rabi milk (*rm*)	0.795	1.987	–0.088	–0.145	0.163	–0.633
	(0.027)	(0.021)	(0.007)	(0.006)	(0.016)	(0.009)

Source: Constructed from the results in Tables 3-14, 4-2, 5-1, and 5-2. See the text for details.

Notes: 1. Standard errors are indicated in the parenthesis.
2. The number of observations is 177.
3. Based on regression results in Table 3-14 for a yield multiplier model with household dummies.

[a] Since *CV* of prices are common to each household in the sample by definition, there is no variation.

tween fodder and milk profit suggests that it is advantageous to combine fodder and milk production in one farm in terms of risk diversification.

As a final remark, a comparison of these findings with those from the ICRISAT India data was attempted. In semiarid India, mean household crop income variability was estimated to range approximately from 33 per cent to 47 per cent in terms of the coefficient of variation (Walker and Ryan 1990, Table 10.6).[4] These figures are mostly smaller than those in Tables 5-3 and 5-4. Contrary to the expectation that irrigated agriculture should yield more stable income than rainfed agriculture, this study has found the opposite situation. It is true that crop yields per acre are more stable in irrigated agriculture such as in the rice-wheat zone in Pakistan’s Punjab than in semiarid India. Nevertheless, what matters to farmers is the variability in net profits. In semiarid India, farmers do not apply a large quantity of purchased inputs to crops whose yields are very variable. Furthermore, market prices of those crops are strongly negatively correlated with crop yields. Therefore, profit variability of these crops is not large compared with their yield variability. On the other hand, in irrigated Pakistan, because of higher input costs and lower price-yield correlation, profit variability is much larger than yield variability in terms of the coefficient of variation.

V. Conclusions

In this chapter, variability of net profits at the individual farm level has been investigated. It was found that the addition of idiosyncratic yield shocks and adjustment for input costs result in a much larger variability of net profits than implied by the variability of regional average gross revenues. These adjustments have led to a seemingly unexpected finding of higher profit variability in irrigated Pakistan than in semiarid India. Therefore, an empirical analysis of production risk based on secondary data of prices and aggregate yields alone would be highly misleading. Such an analysis is likely to underestimate the true production risk faced by farmers. Furthermore, the order of riskiness among crop activities is likely to change after these adjustments.

Estimation results have also shown that the correlation between green fodder profit and milk profit at the individual farm level is substantially negative because green fodder is the most important input in milk production and its price is the most volatile. This negative correlation implies that it is advantageous, in terms of risk diversification, to combine fodder and milk production in one enterprise.

In the past studies, especially those based on mathematical programming or farming-system approach (Gotsch et al. 1975; Perry 1982; Byerlee and Husain 1992), the advantage of combining fodder production and milk production in one farm had been analyzed from the viewpoint of saving transaction costs of green fodder. The conclusion in this chapter will be reinforced by this traditional argument—when the price differential between selling and buying prices is large, households would find it more advantageous to combine the two activities. On the other hand, this study shows that this advantage exists even when the price wedge is negligible. The author’s observations in the sample villages suggest that the price wedge is not large. It is a common practice for farmers to trade green fodder in villages at the price that equals market selling price minus transportation costs to the market. This way of transaction implies that the buying price in villages is not equal to market price plus transportation costs, which is usually assumed in models with an emphasis on the price wedge; on the contrary, selling and buying prices of fodder in villages are approximately equal.

Notes

1 This chapter is extracted from Kurosaki (1997).

2 In the case of the U.S. agriculture, for example, Heifner and Coble (1996) addressed this issue by estimating price-yield correlations at the farm level.

3 Data on these fodder yields were estimated from a sample survey mostly conducted in the districts in the vicinity of the sample villages. Therefore, the use of the provincial numbers is justified considering the scarcity of data.

4 Walker and Ryan estimated these numbers directly from the household panel data, which covered a nine-year period. Therefore, their estimates are not strictly comparable to our estimates, which were derived indirectly from both time-series data and three-year panel data.