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# RISK AND INSURANCE IN A HOUSEHOLD ECONOMY: ROLE OF LIVESTOCK IN MIXED FARMING IN PAKISTAN

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## I. INTRODUCTION

PRODUCTION risk is inherent in agriculture due to the spatial nature of farming and its dependence on weather. With a complete set of markets, including insurance markets against risk, a competitive equilibrium is Pareto-optimal (Arrow [2], Debreu [12]) and production decisions by farm households are separable from their consumption preferences (Singh et al. [43]). Under this condition, production decisions by agricultural households can be analyzed in a model of expected profit maximization without considering higher moments of random variables.

If insurance markets are missing or imperfect, however, this separability may no longer hold and risk considerations may affect farm management. The fact that formal insurance arrangements are seldom available in developing countries indicates that insurance markets are incomplete. Following the seminal work of Townsend [44], several authors have shown that rural households in South Asia including Pakistan are insured much better than previously expected but that a hypothesis of optimal risk sharing which is necessary for complete insurance markets is rejected in many cases (Morduch [26] [27], Rashid [36]).

The literature on the economic behavior under uncertainty and incomplete insurance markets has been expanding. The first category covers *ex ante* adjustments to control the distribution of risk variables, such as enterprise selection and diversification on the farm and off the farm (Walker and Ryan [46], Fafchamps [14]); marketing options including interlinked transactions (Bardhan [4], Goetz [16]); and risk-controlling inputs (Just and Pope [19], Rosegrant and Roumasset [37]). The second category examines *ex post* adjustments contingent on a realized state, such as use of credit markets (Eswaran and Kotwal [13], Rosenzweig [38], Udry [45], Morduch [26]); accumulation and decumulation of assets such as savings (Deaton [10], Paxson [32]), bullocks (Rosenzweig and Wolpin [40]), and land (Cain [7], Zimmerman [48]); reliance on extended family (Kotlikoff and Spivak [20], Cain [7]), marriage relationship (Rosenzweig and Stark [39]), or remittances (Rosenzweig [38], Lucas and Stark [25]); and establishment of rural reciprocity arrangements (Fafchamps [15], Coate and Ravallion [9]).

Among these arrangements to overcome the incompleteness in insurance markets, this paper focuses on enterprise selection and on-farm diversification and accumulation/decumulation of farm assets. This is because the most important and theoretically interesting character of agricultural households lies in their simultaneous decisions on production and consumption (Singh et al. [43]). Unlike rural consumer/laborer households without production assets, agricultural households can adjust production decisions to control their exposure to risk according to their preferences. It is this character that differentiates farm households from consumer/laborer households.

This paper contributes to the expanding literature by adding an empirical evidence that livestock play an important role in risk control. The analysis is based on three-year data of agricultural households from the Punjab Province of Pakistan. The study area is well irrigated and famous for the rapid adoption of high-yielding varieties of wheat in the late 1960s and the early 1970s. Nevertheless, yield risk on individual farms is not negligible. Price risk also affects agricultural households since most of them market their products through private channels. During the 1980s, Pakistan witnessed a shift toward livestock products in the composition of value added in agriculture. This paper suggests that the shift within a farm had improved household welfare through a reduction in income variability.

In the following, Section II describes the agricultural system in the study area and characterizes sample households, focusing on the importance of livestock animals in a household economy. Section III decomposes per capita household income into enterprise sources and then decomposes each source into deterministic and transient portions. The decomposition quantitatively shows that livestock enable households to decrease their exposure to risk through diversification and asset decumulation. Section IV, after testing a hypothesis of full risk sharing, analyzes welfare implications of the empirical findings. Section V is a summary with some policy implications.

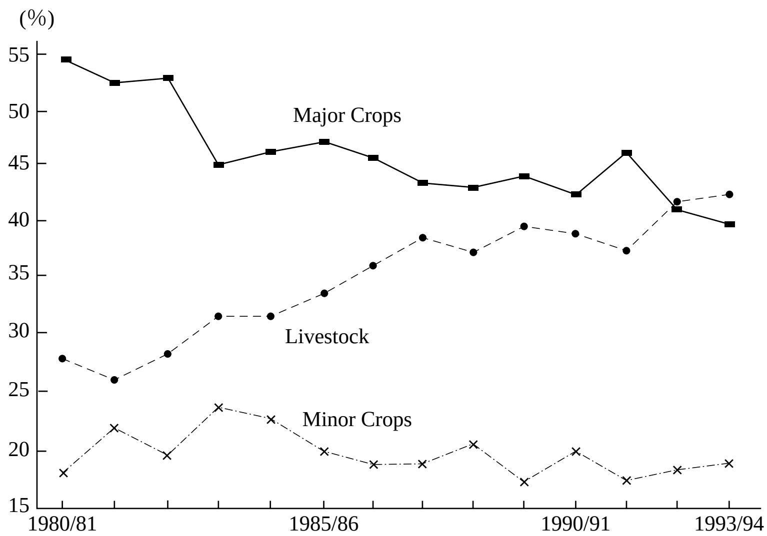
## II. STUDY AREA AND DATA DESCRIPTION

### A. *Overview of Pakistan's Agriculture*

Agriculture is the most important sector of Pakistan's economy that accounts for about one-fourth of the gross domestic product, earns about 60 per cent of export revenues in primary and processed forms, and provides employment for half of the country's rapidly increasing labor force [30]. Due to its highly productive irrigation network, the province of Punjab accounts for the largest share of most agricultural products in the country. In the early 1990s, the province produced more than 70 per cent of the country's wheat, 80 per cent of cotton, 50 per cent of sugarcane, and 40 per cent of rice, and raised more than 70 per cent of the country's buffaloes and 50 per cent of the cattle [31, 1990/91 edition].

The annual growth rate of agricultural production averaged more than 4 per cent over the past twenty-five years, although the rate has decreased recently (Byerlee and Siddiq [6]). Major contribution to this substantial growth stemmed from the rapid expansion of irrigation facilities, introduction of high-yielding varieties (HYVs) and subsidized inputs, and public sector investment on rural infrastruc-

Fig. 1. Composition of Agricultural Value Added, Pakistan



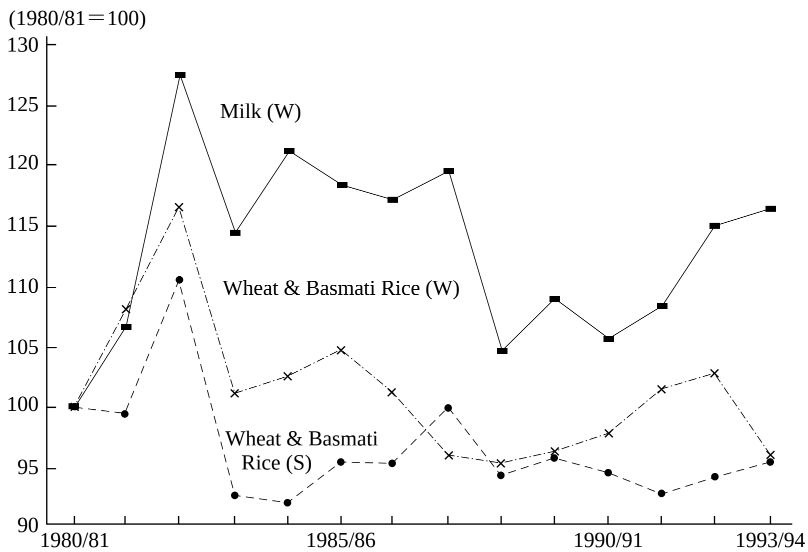

Source: Calculated from [30].
Note: The percentages are based on value added data in current factor costs.

tures. The spread of HYVs was remarkable in wheat due to the country's well-developed irrigation system.

A recent phenomenon that deserves attention is the change in agricultural composition. In terms of national value added from agriculture in current factor costs, the share of twelve major crops such as wheat, rice, and cotton declined from close to 55 per cent in the early 1980s to around 40 per cent in the early 1990s (Figure 1). The share of other minor crops declined to less than 20 per cent during the same period. The livestock share increased from less than 30 per cent to more than 40 per cent. A recent estimate of gross and net farm income shows a similar pattern, both for Pakistan and for the Punjab Province alone (Abbasi et al. [1]).

The change in value added composition in favor of the livestock sector can be explained, at least partially, by relative prices. Grain prices, whether wholesale prices or the government support prices, did not rise as fast as milk prices during the period (Figure 2). Salam examined terms of trade between the agricultural and the manufacturing sectors [41]. He reached a similar conclusion that both barter terms of trade and income terms of trade worsened for the crop subsector while those for the livestock subsector improved. The change in relative prices is a phenomenon that reflects a rising demand for livestock products. Income elasticities of demand for these products are higher than those for other food commodities in Pakistan (Deaton and Grimand [11], Azim and Shafiq-ur-Rehman [3]). Since very little empirical literature has investigated the microeconomic mechanism of supply side under this context, this paper attempts to investigate it, focusing on risk and insurance.

Fig. 2. Relative Prices of Milk and Grains, Pakistan




Source: Calculated from [30].
Note: "Milk (W)" is an index of wholesale price of milk relative to wholesale price index (WPI). "Wheat & Basmati Rice (W)" is the average of indices of wholesale prices of wheat and basmati rice relative to WPI. "Wheat & Basmati Rice (S)" is the average of indices of government support prices of wheat and basmati rice relative to WPI.

Livestock animals are an indispensable component in farm management in Pakistan. A traditional farm in the Indus basin used to have a pair of bullocks for draft power and several buffaloes for milk production. Despite the increased use of tractor power, livestock have remained important because milch animals such as cows and she-buffaloes have been substituted for draft animals. As is shown in Table I, the national population of bullocks for work declined from 5.8 million in 1976 to 5.0 million in 1986, at an average annual growth rate of −1.5 per cent. On the other hand, the number of cows and she-buffaloes in milk increased during the same period at an annual growth rate of 5.2 per cent and 4.7 per cent, respectively.

## B. *Mixed-Farming in the Study Area*

To analyze household behavior under the above context, this study uses micro-household data collected from the rice-wheat zone in the Punjab Province. Agriculture in the Punjab is characterized by two cropping seasons: *kharif* (monsoon season) with harvest from October to December and *rabi* (non-monsoon season) whose crops are harvested from March to May. Wheat is a staple food that dominates other crops in *rabi* throughout the province. As the zone name indicates, rice crops are the most important during *kharif* in the study area due to the soil charac-

TABLE I

BOVINE LIVESTOCK POPULATION IN PAKISTAN, 1976 AND 1986

| | 1976 | | 1986 | | 1976–86 Growth Rate* (%) |
|---|---|---|---|---|---|
| | Numbers (1,000) | Composition (%) | Numbers (1,000) | Composition (%) | |
| Cattle: | | | | | |
| Male: for work | 5,811 | 39.1 | 4,992 | 28.5 | −1.52 |
| Male: youngstock | 2,239 | 15.1 | 2,864 | 16.3 | 2.46 |
| Female: in milk | 2,436 | 16.4 | 4,075 | 23.2 | 5.15 |
| Female: dry | 1,828 | 12.3 | 2,165 | 12.3 | 1.69 |
| Female: youngstock | 1,942 | 13.1 | 2,504 | 14.3 | 2.54 |
| Total | 14,855 | 100.0 | 17,541 | 100.0 | 1.66 |
| Buffaloes: | | | | | |
| Male: for work | 164 | 1.5 | 88 | 0.6 | −6.22 |
| Male: youngstock | 1,575 | 14.8 | 2,371 | 15.1 | 4.09 |
| Female: in milk | 3,582 | 33.8 | 5,725 | 36.5 | 4.69 |
| Female: dry | 1,710 | 16.1 | 2,338 | 14.9 | 3.13 |
| Female: youngstock | 2,799 | 26.4 | 4,157 | 26.5 | 3.96 |
| Total | 10,611 | 100.0 | 15,705 | 100.0 | 3.92 |

Sources: Calculated from [28][31, 1981/82 edition].

* The growth rate is a compound annual growth rate, defined as $\ln(Y_{1986}/Y_{1976})/10$.

teristics. The zone is the home of the basmati variety of rice famous for its aroma. Basmati rice is a festive food in the local diet and it is cultivated mainly as a cash crop. The zone accounts for the largest share of rice production and a significant portion of wheat in the province.[1]

Other *kharif* cash crops, such as the IRRI variety of paddy, sugarcane, cotton, and maize for grain account only for a minor part in the area. Next to rice and wheat, fodder crops account for a large portion of cropped land both in *kharif* and *rabi*. Most farmers in the area keep livestock animals and allocate a significant portion of the cultivated land to fodder crops. The most popular fodder crop in *kharif* is *jowar* (sorghum) and that in *rabi* is *berseem* (Egyptian clover). The sum of areas devoted to fodder crops and the dominant grain crops (rice in *kharif* and wheat in *rabi*) is 80 to 90 per cent in the rice-wheat zone [29].

The role of livestock in the study area is closely related to crop production and family consumption (Perry [33], Lockwood [24], Zafar [47]). 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

[1] See Byerlee and Husain [5] and references therein for the details of the farming system and recent agricultural development in the rice-wheat zone.

farmyard 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 work as an insurance. For these reasons, the social status of a farm in the study area is a function not only of its landholding size but also of its livestock herd size (Hirashima [18]).

From the viewpoint of risk diversifications, keeping livestock has both positive and negative aspects. Yields of fodder crops and milk are not as erratic as those of 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 extreme events such as a severe flood.

### C. *Data Collection and Profile of Sample Households*

Microeconomic data used in this study were collected from five villages in the Sheikhupura district by the Punjab Economic Research Institute (PERI), Lahore.[2] The initial data were collected by enumerators using a repeated interviewing method and covered three agricultural years and six cropping seasons from 1988/89 to 1990/91.[3] The data set used in this study includes ninety-seven household observations for each year. Among them, fifty-nine households were surveyed continuously with consistent information for all three years. This portion of the data set provides core information for the analysis. To supplement the data set with qualitative information, the author also surveyed the sample villages in 1992 and 1993.

The villages are scattered around the main road connecting two cities, Sheikhupura and Sargodha, and close to a town with a population of approximately 15,000. The town is a typical rural town in the Punjab with developed infrastructure for agricultural marketing. There is a local wholesale market (*mandi*) where various agricultural products are traded. Prices in *mandi* are freely determined, reflecting the ongoing demand-supply conditions. Price risk is especially high for green fodder, which is a bulky and perishable commodity and for which there is minimal government intervention (Kurosaki [23]). The provincial food department opens a public procurement facility for wheat in the town in the harvest season. Thus, the harvest wheat price is supported directly by the government while the paddy price of basmati rice is supported indirectly through the procurement of cleaned rice by a public export corporation (Kurosaki [22]). The dominant market-

2 Thanks are due to Dr. Muhammad Jameel Khan, Director, the PERI for access to the data and the villages. Without his help, this study would have been impossible.

3 An agricultural year corresponds to the period from July to June and includes two cropping seasons, *kharif* and *rabi*, in this order. See Haque and Saleem [17], Cheema and Saleem [8], and Saleem and Cheema [42] for the overall sampling procedure and the aggregate provincial results for each year.

TABLE II

SUMMARY STATISTICS OF KEY VARIABLES OF SAMPLE HOUSEHOLDS

| Variables | 1988/89 | | 1989/90 | | 1990/91 | |
|---|---|---|---|---|---|---|
| | Mean | Std. Dev. | Mean | Std. Dev. | Mean | Std. Dev. |
| Farm area | 10.20 | 8.16 | 10.11 | 7.74 | 10.23 | 8.29 |
| Household size (numbers) | 8.44 | 3.64 | 8.25 | 3.41 | 8.22 | 3.31 |
| Household size (AMEU*) | 6.98 | 2.96 | 6.87 | 2.78 | 6.87 | 2.76 |
| Crop sector: | | | | | | |
| Basmati rice yield (paddy) | 27.70 | 5.95 | 29.41 | 6.08 | 23.53 | 5.47 |
| Basmati rice area | 5.68 | 5.72 | 5.73 | 5.08 | 5.74 | 5.44 |
| Wheat yield | 27.59 | 4.60 | 20.81 | 5.33 | 20.10 | 5.00 |
| Wheat area | 6.02 | 5.72 | 5.90 | 4.97 | 6.34 | 5.63 |
| *Kharif* fodder area | 2.86 | 1.85 | 1.85 | 1.25 | 1.85 | 1.24 |
| *Rabi* fodder area | 1.62 | 1.10 | 1.54 | 1.01 | 1.69 | 1.26 |
| Total crop income (1) | 30,499 | 28,888 | 25,957 | 21,458 | 24,978 | 20,493 |
| Livestock sector: | | | | | | |
| Milk yield | 30.91 | 9.84 | 29.39 | 10.37 | 26.94 | 9.53 |
| Milk animals | 4.38 | 2.27 | 4.36 | 2.17 | 5.65 | 3.31 |
| Draft animals | 1.62 | 1.14 | 1.75 | 1.17 | 1.28 | 1.14 |
| Total livestock income (2) | 8,907 | 7,094 | 8,793 | 6,414 | 16,978 | 10,751 |
| Farm income (3) = (1) + (2) | 39,406 | 27,954 | 34,750 | 23,240 | 41,957 | 24,903 |
| Off-farm income (4) | 6,290 | 3,281 | 6,265 | 3,706 | 8,122 | 3,514 |
| Household income (5) = (3) + (4) | 45,696 | 27,347 | 41,015 | 21,172 | 50,079 | 23,034 |
| Total expenditure | 21,289 | 9,140 | 25,122 | 10,146 | 28,030 | 11,037 |
| Wheat budget share (%) | 14.0 | 2.0 | 13.1 | 1.5 | 12.9 | 1.4 |
| Milk budget share (%) | 27.7 | 2.4 | 25.9 | 1.3 | 27.4 | 1.1 |

Notes: 1. The number of observations was fifty-nine each year except for "milk yield" and "milk animals" in the first and the third years for which fifty-eight households reported positive milk production.

2. Units are: acre for area, maund/acre for grain yield, adult equivalent units (AU) for livestock animals, maund/AU for milk yield, and Pakistan rupees (Rs.) for monetary variables. "Maund" is a local unit of weight that equals about 40kg. U.S.$1.00 = Rs. 19.215, 21.445, 22.423 in each year.

* Adult-male equivalent units.

ing channel for fresh milk in the villages is represented by milk collectors called *dodhi*. They collect milk from the villagers every morning.

Table II summarizes statistics of key variables for the core fifty-nine households. The average farm size was 10.2 acres and the average family size was 8.3 persons or 6.9 in adult-male equivalent units.[4]

Wheat occupied approximately six acres in *rabi* on average. Wheat is the largest

[4] The adult-male equivalent units used in this paper are: 1.0 for adult male (over ten years old), 0.9 for adult female (over ten years old), and 0.52 for children up to ten years old.

source of calory intake and the imputed expenditure on wheat accounted for 13 to 14 per cent in the family budget. The area devoted to basmati rice was slightly less than six acres on average. The budget share of rice expenditure was less than 4 per cent, indicating that rice is mostly cultivated as a cash crop. All sample households had market surplus of basmati rice. Although the sales to private agencies allowed the farmers to store and sell later, this practice was rarely observed mainly due to the lack of liquidity and storage facilities.

*Kharif* fodder occupied about 2 acres and *rabi* fodder occupied about 1.5 acres on average. The number of bullocks for cultivation declined in the last year, partly due to the development of a tractor service market and partly to the substitution by milch animals. No bullock rental was observed. More than 90 per cent of the sample farmers who used tractor power in crop production did not own a tractor. The size of a milch livestock herd was four to five adult animal units,[5] and it increased in the last year. The imputed expenditure on milk and milk products was estimated to 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 in the sample households.

The table shows that inter-year variations in total expenditure were relatively small. One of the reasons for this stability is that the variable was constructed by summing up expenditures on major consumption items only. Therefore, the level of total expenditure is underestimated. Its relative stability over the survey period might indicate that expenditures not covered by the survey worked as a cushion for accommodating income variability. Nevertheless, the variable provides useful information on the stability of household consumption, which is analyzed in Section IV in detail.

## III. DECOMPOSITION OF PER CAPITA INCOME VARIATION

This section decomposes household income into enterprise sources and then decomposes each source into deterministic and transient portions. The data source is the micro-household survey described in the previous section. All the monetary variables in this section are made real using the consumer price index, expressed in 1988/89 Pakistan rupees.[6] Then they are divided by the household size in adult-male equivalent units to convert them to per capita term. In the following, “per capita” refers to per adult-male equivalent units.

### A. *Definition of Each Source of Household Income*

Household income was decomposed into three sources: crop income ($Y_C$), livestock income ($Y_L$), and off-farm income ($Y_N$). The first two represent agricultural

[5] The adult-animal equivalent units (AU) used in this paper are 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.

[6] The average exchange rate of Pakistan rupees to the U.S. dollar during the year 1988/89 was 19.215 (Rs. / $) [30].

enterprises. To separate the effects of *ex post* insurance from that of *ex ante* diversification, livestock income was further decomposed into milk income ($Y_{LM}$) and livestock-sales income ($Y_{LS}$). The sum of $Y_C$ and $Y_L$ is denoted as $Y_F$ that stands for farm income. From the correlation between $Y_F$ and $Y_N$, income diversification between on-farm and off-farm enterprises could be investigated.

Crop income ($Y_C$) is defined as gross crop income minus gross crop cost. Gross crop income is the sum of revenues from grains, grain by-products, and fodder outputs. Gross crop cost includes fertilizer and pesticide costs, maintenance costs of draft animals, maintenance costs (in case of an owner) or paid expenditure (in case of a nonowner) on tractor and tubewell services,[7] all the wages paid to hired labor, and land revenues including canal water charges. Economic meaning of the crop income is, therefore, the sum of profits from crop management, imputed wage to family labor, and imputed rent to owned land and owned agricultural machinery.

Livestock income ($Y_L$) is the sum of milk income and livestock-sales income. Milk income ($Y_{LM}$) is the gross value of milk products minus total costs. Total costs include the paid or imputed costs of green fodder, dry fodder, and concentrates fed to milch animals, and other maintenance costs. Livestock-sales income ($Y_{LS}$) is the value of animals sold during the year minus maintenance costs. The livestock share in farm income was about 30 per cent on average. However it was higher in the last year due to the increased livestock-sales income and the increased size of milch livestock herd when the harvest of both wheat and basmati rice was poor (Table II). Smaller farms depend more on livestock income which accounts often for more than 50 per cent of farm income.

These definitions of farm accounting reflect the observations in the study area. First, since no bullock rental was observed in the surveyed villages and the focus of this paper is on the income fluctuation expressed in market prices, the maintenance costs of draft animals were subtracted from crop income instead of adding their imputed contribution to livestock income. Second, since market transactions of fodder were active in the area and a number of sample households purchased the deficits or sold the surplus of fodder, all revenues from dry fodder and green fodder were evaluated at the market price and included in the crop income. Then the values of fodder fed to the animals were treated as costs in the livestock sector regardless of whether the fodder was harvested from the farmers' own field or purchased from the market.

Finally, off-farm income ($Y_N$) was defined to include agricultural wage income received on other farms, nonagricultural wage and salary, explicit rent income, and received remittances. However, the information was less reliable than that of farm enterprises.

### B. *Decomposition into Deterministic and Transient Portions*

Per capita real income thus defined was further decomposed into deterministic and transient portions. It is assumed that the mean of observed values reflects the

[7] Active water markets exist in the study villages. About 60 per cent of the sample households that did not own a tubewell purchased additional water from tubewell owners.

deterministic part and the residual, zero-mean term reflects the transient shock. The transient portion consists of a shock common to sample households (e.g., rainfall, market price conditions, etc.) and an idiosyncratic shock that affects each household independently (e.g., field-specific production problems, disease affecting a household member, etc.). Assuming additive structure among the components, the empirical model is expressed as

$$Y_{sht} = f_s(Z_{ht}) + u_{st} + \varepsilon_{sht}, \tag{1}$$

where $Y_{sht}$ is per capita real income from sector $s$ for household $h$ in year $t$; $f_s(..)$ is a function of a vector of household characteristics $Z_{ht}$ and corresponds to the deterministic portion of income; $u_{st}$ is a common shock with mean zero; and $\varepsilon_{sht}$ is an idiosyncratic shock with mean zero. Two sources of the transient portion are independently distributed by definition so that $E(u_{st}\varepsilon_{sht}) = 0$.

The function $f_s(..)$ is interpreted as a reduced-form equation of household production decisions. If the theory of duality holds, $f_s(..)$ becomes a profit function with the vector $Z_{ht}$ consisting of market prices and household characteristics of fixed production assets, augmented by an additive term that corresponds to the sum of rents to owned assets. However, the duality theory usually breaks down under uncertainty (Pope [34], Pope and Just [35]). To allow for the non-separability of production decisions from consumption preferences under uncertainty, household consumption characteristics are also included in the vector $Z_{ht}$.

The function $f_s(..)$ is approximated linearly with variables in the vector $Z_{ht}$ defined as: (i) livestock assets (per capita adult-equivalent units of draft and milch animals); (ii) crop production assets (per capita acreage of operated and owned farm land); (iii) per capita real value of house building; (iv) years of education of household head as a proxy for human asset position; and (v) household demographic composition (shares in the total adult-male equivalents of adult male, adult female, and children male). Though these variables might be endogenous to household production decisions in the long run, they are treated in the regression as predetermined since the focus is on the short-run fluctuations. Market prices are not included because their variation is small due to the short time horizon of the data set. Since the data set covers only three years, it is not possible to decompose the residual into $u_{st}$ and $\varepsilon_{sht}$ precisely. Year dummies are included as a rough estimate for $u_{st}$ in the estimation so that the actual estimated model is :

$$Y_{sht} = \beta_{s0} + \sum_k \beta_{sk} Z_{hkt} + u_{s1}(D_1 - D_3) + u_{s2}(D_2 - D_3) + \varepsilon_{sht}, \tag{2}$$

where $\beta$'s, $u_{s1}$, and $u_{s2}$ are coefficients to be estimated.

The detailed regression results are given in the Appendix Table since the coefficients themselves are not relevant here. Overall, their signs are as expected: the coefficient on operated area is significantly positive in determining crop income and the coefficient on milch livestock assets is significantly positive in determining livestock income. Coefficient estimates on $D_1 - D_3$ and $D_2 - D_3$ show that crop income was high in the first year and livestock-sales income increased in the last year, confirming the casual observations from Table II.

TABLE III

INTER-HOUSEHOLD DETERMINISTIC VARIATION OF INCOME: $E(Y_s) = f_s(Z)$ IN EQUATION (1)

A. Key Statistics

| | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|
| $E(Y_{LM})$: Milk income (1) | 1,087.4 | 565.8 | –448.6 | 3,793.8 |
| $E(Y_{LS})$: Livestock sale (2) | 605.7 | 303.3 | 134.5 | 1,862.8 |
| $E(Y_L)$: Total livestock income (3) = (1) + (2) | 1,693.1 | 700.1 | 215.3 | 5,441.5 |
| $E(Y_C)$: Total crop income (4) | 3,899.2 | 3,411.0 | –504.8 | 20,082.9 |
| $E(Y_F)$: Farm income (5) = (3) + (4) | 5,592.3 | 3,643.8 | 530.1 | 22,752.9 |
| $E(Y_N)$: Off-farm income (6) | 1,130.4 | 434.5 | –307.2 | 2,753.7 |
| $E(Y)$: Household income (7) = (5) + (6) | 6,722.7 | 3,551.6 | 1,736.0 | 22,877.3 |

B. Correlation Coefficients

| Deterministic Portion of | (1) $E(Y_{LM})$ | (2) $E(Y_{LS})$ | (4) $E(Y_C)$ | (6) $E(Y_N)$ |
|---|---|---|---|---|
| $E(Y_{LM})$: Milk income (1) | 1.000 | 0.227* | –0.133 | 0.250* |
| $E(Y_{LS})$: Livestock sale (2) | | 1.000 | 0.805* | 0.151* |
| $E(Y_L)$: Total livestock income (3) = (1) + (2) | | | 0.241* | 0.267* |
| $E(Y_C)$: Total crop income (4) | | | 1.000 | –0.342* |
| $E(Y_F)$: Farm income (5) = (3) + (4) | | | | –0.269* |
| $E(Y_N)$: Off-farm income (6) | | | | 1.000 |

Notes: 1. The numbers in the table are estimated from the regression results shown in Appendix Table.
2. Number of observations is 177.
3. * indicates that the coefficient is significant at 5 per cent level (two-sided test).
4. The correlation table reports the coefficients between two income sources that are exclusive of each other only. For example, since milk income (1) is included in total livestock income (3), correlation between (1) and (3) does not provide useful information on risk control effects. Therefore, it is not reported.

## C. *Correlation among the Decomposed Components*

To investigate the household strategy of risk control, correlation coefficients among the components of per capita household income are estimated based on the regression results presented above. Table III analyzes the relationship among deterministic portions, or the inter-household variation, in income-generating positions. The upper half gives statistics of the estimated deterministic portion. The lower half shows the correlation matrix among them. The correlation coefficients between a component and its sum (e.g., between crop income and farm income) are omitted because they are only a weighted sum of the components.

The negative correlation (– 0.27) between $E(Y_N)$ and $E(Y_F)$ suggests that off-farm income reduces the inter-household disparity in farm production assets. The negative relationship stems from the negative correlation coefficient between $E(Y_N)$ and $E(Y_C)$ of – 0.34. Thus, off-farm income contributes to a reduction in inequality among households through the negative correlation with crop income. On the other hand, the correlation between $E(Y_L)$ and $E(Y_C)$ is significantly positive, which reflects the complementary nature of crops and livestock in mixed

TABLE IV

TRANSIENT VARIATION OF INCOME: $e_s = u_s + \varepsilon_s$ IN EQUATION (1)

A. Key Statistics

| | Mean | Std. Dev. | Minimum | Maximum |
|---|---|---|---|---|
| $e_{LM}$: Milk income (1) | 0.0 | 743.2 | –2,363.1 | 2,419.7 |
| $e_{LS}$: Livestock sale (2) | 0.0 | 771.9 | –1,789.9 | 3,387.8 |
| $e_L$: Total livestock income (3) = (1) + (2) | 0.0 | 1,118.6 | –3,792.7 | 5,258.8 |
| $e_C$: Total crop income (4) | 0.0 | 1,925.9 | –8,491.0 | 8,860.4 |
| $e_F$: Farm income (5) = (3) + (4) | 0.0 | 1,947.9 | –8,147.9 | 8,720.3 |
| $e_N$: Off-farm income (6) | 0.0 | 875.5 | –1,292.9 | 4,305.0 |
| $e$: Household income (7) = (5) + (6) | 0.0 | 2,193.6 | –8,214.4 | 9,113.5 |

B. Correlation Coefficients

| | (1) $e_{LM}$ | (2) $e_{LS}$ | (4) $e_C$ | (6) $e_N$ |
|---|---|---|---|---|
| $e_{LM}$: Milk income (1) | 1.000 | 0.090 | –0.157* | 0.140 |
| $e_{LS}$: Livestock sale (2) | | 1.000 | –0.241* | 0.017 |
| $e_L$: Total livestock income (3) = (1) + (2) | | | –0.271* | 0.104 |
| $e_C$: Total crop income (4) | | | 1.000 | 0.014 |
| $e_F$: Farm income (5) = (3) + (4) | | | | 0.074 |
| $e_N$: Off-farm income (6) | | | | 1.000 |

Note: See Table III.

farming in the area. Although it is true that livestock income is relatively more important in farm households with smaller landholding, the absolute level of livestock activity is higher for households with larger landholding since land is an integral part of livestock activity.

Table IV shows the results for the transient portion of income. The transient portion is defined as the fitted values of $u_{st} + \varepsilon_{sht}$ in equation (1) and denoted as $e_s$ for short. The negative correlation (– 0.27) between $e_C$ and $e_L$ is consistent with the hypothesis that crops and livestock are combined to reduce the annual variability of household income. The coefficient is more negative between $e_C$ and $e_{LS}$ (livestock sales income) than between $e_C$ and $e_{LM}$ (milk income). The transient portion of livestock sales income should reflect *ex post* decumulation of assets as a substitute for insurance. The estimation results here support the insurance role of livestock from an angle different from that in the seminal work of Rosenzweig and Wolpin [40]. Furthermore, the correlation between $e_C$ and $e_{LM}$ is significantly negative, indicating the *ex ante* income-smoothing role of livestock income from milk production.

In contrast to Table III, the residuals from $Y_N$ (off-farm income) are not negatively correlated with the residuals from farm income sources (see the last column in Table IV). The signs of correlation coefficients are positive but not statistically significant. Thus, the role of off-farm income in income smoothing is less important than that of livestock income.

## IV. IMPLICATIONS OF INCOME DECOMPOSITION

It may be argued that the results shown in Section III are incidental and not related to households' optimizing behavior to control their exposure to risk. To refute the argument, it is necessary to show that sample households are risk-averse and insurance markets are incomplete. If the households are risk-neutral or insurance markets are complete, the households may maximize expected profit without caring about the correlation coefficients estimated above. Therefore, this section first examines whether the assumptions of risk aversion and incomplete insurance markets are relevant. Then welfare implications of the empirical results are discussed with a simple simulation to highlight the role of livestock in controlling exposure to risk.

### A. *Comovement of Income and Consumption*

A formal econometric test for the first exercise was presented in Kurosaki [23], which estimated a structural household model of land allocation using the same data as in this paper. The study found that all sample households behaved in a risk-averse way and that insurance markets were incomplete. Since the model and the estimation are complicated, for a detailed discussion one should refer to Kurosaki [23], and this paper further supports the findings.

To demonstrate that insurance markets are incomplete, it is necessary to show that the transient variation in income of individual households is transmitted to the variation in consumption expenditure. If there is a mechanism whereby all the income variation is absorbed and households are guaranteed completely smoothed consumption, insurance markets can be considered to be complete.

To investigate the comovement of income and consumption, the model in equation (2) was estimated for total consumption expenditure (see Appendix Table for the coefficient estimates). The correlation coefficient between the deterministic portion of consumption and that of household income was found to be 0.80. This number is large since it corresponds to the inter-household comovement of income and consumption. The correlation coefficient between the transient portion of consumption and that of total income was estimated to be 0.20 and significantly positive at 5 per cent level. Thus, the variation in transient income was transmitted to that in consumption although the relation was weaker than the case for the inter-household variation.

Townsend presents a formal model to test econometrically the necessary conditions for an optimal risk sharing in a village [44]. He applied the model to the data from South India collected by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and showed that households were well insured though the full insurance hypothesis was rejected in many cases.

The current data set is too short in time horizon to run the same tests. Instead, a simplified version of Townsend's model was estimated using pooled data. Under the assumption of a separable utility function between leisure and consumption

TABLE V

REGRESSION RESULTS OF INCOME-CONSUMPTION COMOVEMENT

| Independent Variables | Model 1 | | Model 2 | |
|---|---|---|---|---|
| | Estimated Coefficient | $t$-stat. | Estimated Coefficient | $t$-stat. |
| $c_t$* | 1.143 | 5.89*** | 1.045 | 6.53*** |
| $X_{ht}$ : Total household income | 0.037 | 2.96*** | | |
| : Livestock income | | | 0.042 | 2.09** |
| : Crop income | | | −0.022 | −1.80* |
| : Off–farm income | | | 0.228 | 9.22*** |
| $R$-squared | 0.175 | | 0.453 | |
| Adj. $R$-squared | 0.170 | | 0.443 | |

Notes: 1. The dependent variable is $c_{ht} - \alpha_h$ (per capita consumption expenditure minus the fixed household effect on consumption). Thus, its mean is zero, and its standard deviation is 381.7 (1988/89 rupees).
2. All the independent variables are transformed by subtracting the mean so that there is no intercept in this model.
3. * indicates that the coefficient is significant at 10 per cent level, ** at 5 per cent level, and *** at 1 per cent level (two-sided test). When the coefficient on $X_{ht}$ is significantly positive, the full insurance hypothesis is rejected.
4. OLS is used in the estimation and the number of observations is 177.

and of homogeneous risk preferences among households, Townsend's model for constant absolute risk aversion can be expressed as

$$c_{ht} = \alpha_h + \beta c_t^* + \zeta X_{ht} + \varepsilon_{ht}, \tag{3}$$

where $c_{ht}$ is per capita consumption expenditure; $\alpha_h$ is the fixed household effect on consumption, i.e., the weight of household $h$ in income redistribution relative to the village average, $c_t$* is the village-average consumption in each year; $X_{ht}$ is the household income; and $\varepsilon_{ht}$ is a disturbance term with zero mean.[8] The parameter $\alpha_h$ is replaced by the deterministic consumption estimated by the model in equation (2) and moved to the left hand side in equation (3). To avoid the endogeneity problem, $c_{ht}$ is excluded each time when $c_t$* is calculated. Under the assumption of full village insurance, $\beta$ should be unity and $\zeta$ should be zero. Households are fully insured when their own income does not account for their consumption ($\zeta = 0$) once the village-average consumption level is included and household fixed effects are controlled.

Table V presents the regression results estimated by OLS. The columns under Model 1 apply to a model with total household income in $X_{ht}$. Coefficient estimate on household income is significantly positive at 1 per cent level, but its magnitude is small with the value of 0.04. The columns under Model 2 apply to a model in which three sources of income are distinguished. The overall explanatory power of the regression is improved. Coefficient estimate is positive and statistically significant for livestock income and off-farm income at 5 per cent and at 1 per cent,

[8] Townsend's model included a higher order demographic adjustment term, but it is dropped since it is not important for the purposes here.

respectively. Coefficient estimate on crop income is unexpectedly negative but significant only at 10 per cent level.

These results imply that the full village insurance is rejected although the transmission of income variation to consumption variation is not large, a finding similar to that for South Indian households (Townsend [44]). The coefficients on individual income variables are more or less larger in Pakistan than those reported in South India, indicating a lower degree of insurance in Pakistan if the difference is significant. Since the variable of total consumption expenditure is underestimated, including only major expenditure items, the actual expenditure might have followed individual income more closely than estimated here.

### B. *Incidence of Risk and Role of Livestock Sector*

Since the full insurance hypothesis is not supported from sample observations, income variation affects sample households. Then, to what extent? To answer this question rigorously in terms of household welfare, it is necessary to specify a household utility function and estimate it structurally.[9] Instead, this paper analyzes the variability of income because it is one of the major factors that affect household welfare under uncertainty.

Adding all income sources yields total household income ($Y_{ht}$). By removing subscripts $h$ and $t$ for simplicity, the coefficient of variation ($CV_Y$) is given by

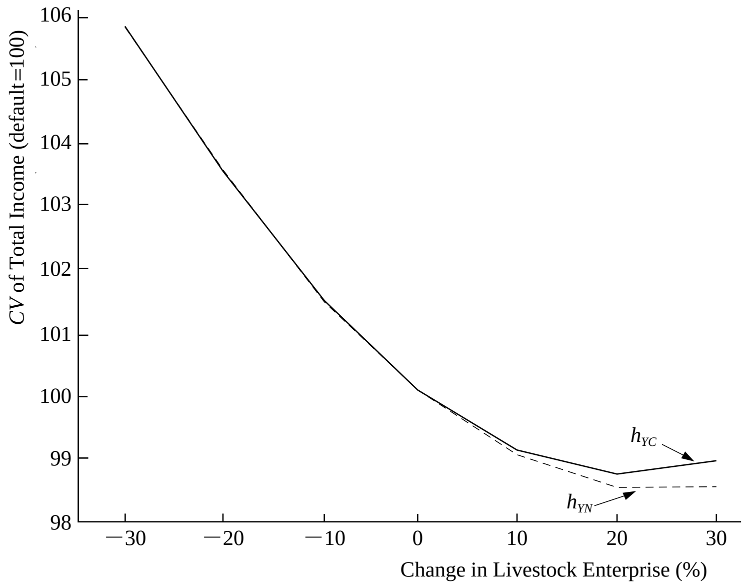
$$\begin{aligned} CV_Y &= \frac{1}{\bar{Y}} \sqrt{\mathrm{Var}\,(\textstyle\sum_s Y_s)} = \frac{1}{\bar{Y}} \sqrt{\textstyle\sum_s \mathrm{Var}\,(Y_s) + \sum_s \sum_{r \neq s} \mathrm{Cov}\,(Y_s, Y_r)} \\ &= \sqrt{\textstyle\sum_s h_s^2 \cdot CV_{Y_s}^2 + \sum_s \sum_{r \neq s} h_s \cdot h_r \cdot CV_{Y_s} \cdot CV_{Y_r} \cdot \rho_{Y_s, Y_r}}\,, \end{aligned} \tag{4}$$

where $h_s$ is an enterprise composition weight defined as $E(Y_s) / E(Y)$, and $\rho_{Y_s,Y_r}$ is a correlation coefficient. For each of the core household observations, the value of $CV_Y$ was calculated. The estimates were distributed between 0.16 and 0.53 with a mean of 0.34 and standard deviation of 0.06. These numbers were quite high and comparable to those reported for semiarid India (Walker and Ryan [46, Figure 4.7, p. 85]). Although yield risk is reduced in the study area due to irrigation compared with semiarid India, higher production costs of crops decrease their profit margins and increase the risk in Pakistan (Kurosaki [23]), resulting in comparable values of income variability in the two regions.

To investigate the income-smoothing role of livestock income in Pakistan, the effect on $CV_Y$ of a change in $h_s$ in equation (4) was simulated. In the simulation, $CV_{Y_s}$ was approximated by the standard deviation of $e_s$ from Table IV divided by the value of $E(Y_s)$ from Table III and assumed constant, and $h_s$'s were changed with the restriction that their sum was unity and the mean household income remained the same. Although households can adjust crop choices when their production asset composition or relative prices are changed, so that $E(Y)$ and $\rho_{Y_s,Y_r}$ should also change (Kurosaki [23]), it was assumed that these adjustments did not take place, by keeping $E(Y)$ and $\rho_{Y_s,Y_r}$ constant. In other words, the simulation shows a very

[9] See Kurosaki [23] for the application based on this approach.

Fig. 3. Effects of Change in Household Income Composition




short-run effect on $CV_Y$ of a change in relative prices in favor of livestock products.

Figure 3 plots the results of a change in the weight of the livestock sector ($h_{YL}$) evaluated at sample mean. The vertical axis shows an index of $CV_Y$ with its starting value equal to 100. The two curves in the figure represent, respectively, a case in which the change in the livestock weight replaces the crop income ($h_{YC}$) and a case in which the change replaces the off-farm income ($h_{YN}$).

Both curves are downward sloping, indicating that a marginal increase in livestock income stabilizes household income. The two curves are very similar in the left half of the figure, or in the region where the livestock share decreased compared with the default. A shift of income from the livestock source to the crop source by 7.6 points increases the coefficient of variation of income by 5.9 per cent.[10] The slope is more gentle in the right half of the figure, with a reversed direction in the end. Thus, a further increase of livestock weight from the default might lead to an increase in income variability.

The simulation has a clear implication to what had occurred during the 1980s. The shift in the macrostructure of Pakistan's agriculture from the crop sector to the livestock sector was associated with the increasing weight of the livestock sector within each agricultural household. Thus, the change should have decreased the income variability of individual households. A decrease in income variability

[10] The starting value of $h_{YL}$ is 0.252. The weight becomes 0.176 after a 30 per cent decrease in livestock weight. This is equivalent to a shift of 7.6 points (= 25.2 per cent − 17.6 per cent) of expected income from the livestock sector to the crop sector.

ceteris paribus improves household welfare. It is true that net welfare effect is not determined since the change in relative prices might have resulted in a change in expected income.[11] Nevertheless, the simulation suggests that a rise in prices of livestock products should have had a positive welfare effect by providing more stabilized income than before. Considering the fact that livestock income is more important in smaller farms, the change should have benefitted them more. In that sense, the change, ceteris paribus, might have improved rural equity also in Pakistan.

## IV. SUMMARY AND CONCLUSION

This paper empirically investigated how agricultural households in Pakistan control their exposure to risk through enterprise selection and asset accumulation / decumulation. The analysis used three-year household data on production and consumption from the rice-wheat zone of the Punjab Province, where most agricultural households combine livestock keeping and crop cultivation within a farm. Decomposition of per capita income into deterministic and transient portions showed that livestock holding contributes to a reduction in income variability through the negative correlation of livestock income with crop income and through *ex post* decumulation of livestock assets contingent on a realized income in the crop sector. Thus, the paper has added to the expanding risk literature an evidence of rural insurance mechanism through livestock (Rosenzweig and Wolpin [40]).

An analysis of per capita consumption expenditure covering major consumption items showed that the full insurance model proposed in Townsend [44] is not supported. This finding implies that individual consumption levels comove with individual income levels even after control for village-average consumption levels and household fixed effects. Therefore, a reduction in income variability has a welfare-improving effect. A simulation based on the income decomposition showed that a shift in enterprise composition toward livestock products reduces household income variability.

These empirical results suggest that the rises in the share of the livestock subsector in agricultural value added in Pakistan should have improved the welfare position of households with substantial livestock holding. Since smaller farms have a relatively larger livestock herd in the Pakistan Punjab, the recent phenomenon might have had an equity-improving effect as well. Furthermore, because livestock have an additional welfare value as an effective insurance measure, the farmers might have had a stronger incentive to accumulate livestock than those who maximize expected profit from agriculture. In other words, the seemingly large size of livestock holding from the criterion of profit-maximizing efficiency might be rational and efficient for a poor, risk-averse household. Therefore, a welfare component of on-farm and off-farm diversification should be considered in

[11] Especially, increases in fertilizer prices relative to grain support prices during the 1980s reduced expected per-acre profits of grains (Kurosaki [21]). This should have worsened household welfare ceteris paribus via decreased mean crop income.

formulating a policy that attempts to change the agricultural structure of the country.

The adjustments toward risk analyzed in the paper are possible because agricultural households decide consumption and production jointly. Especially, they can use production adjustments to control their exposure to risk according to their preferences. In that sense, agricultural households as an organizational institution have an advantage to overcome the incompleteness in insurance markets.

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APPENDIX TABLE

Regression Results of Income Decomposition

| Independent Variables | Dependent Variables ($Y$): Milk Income (1) | Livestock Sales Income (2) | Total Livestock Income (3) = (1) + (2) | Crop Income (4) | Farm Income (5) = (3) + (4) | Off-Farm Income (6) | Total Household Income (7) = (5) + (6) | Consumption Expenditure (8) |
|---|---|---|---|---|---|---|---|---|
| *C* | 1,178.0** | 431.0 | 1,609.0** | −1,780.8 | −171.8 | 1,533.3*** | 1,361.5 | 4,149.8*** |
| | (2.371) | (0.861) | (2.202) | (−1.476) | (−0.137) | (2.622) | (0.961) | (17.418) |
| *DRAFT* | 496.9 | 62.0 | 434.9 | −326.4 | 108.5 | −45.2 | 63.3 | −289.6* |
| | (1.554) | (−0.192) | (0.924) | (−0.420) | (0.134) | (−0.120) | (0.069) | (−1.888) |
| *MILCH* | 1,269.0*** | 195.6 | 1,464.6*** | 1,069.1** | 2,533.7*** | −204.0 | 2,329.7*** | −0.2 |
| | (7.019) | (1.074) | (5.508) | (2.435) | (5.538) | (−0.959) | (4.517) | (−0.002) |
| *AOPE* | −260.2** | 30.8 | −229.4 | 2,664.0*** | 2,434.5*** | −242.4* | 2,192.1*** | 222.5*** |
| | (−2.100) | (0.246) | (−1.259) | (8.85) | (7.762) | (−1.662) | (6.2) | (3.744) |
| *AOWN* | −132.4 | 100.8 | −31.5 | 184.6 | 153.1 | −68.6 | 84.5 | 37.8 |
| | (−0.991) | (0.749) | (−0.161) | (0.569) | (0.453) | (−0.436) | (0.222) | (0.59) |
| *HOUSV* | 22.9 | 32.9 | 5.9* | −26.2 | 29.7 | 128.3*** | 158.0*** | 50.2*** |
| | (1.104) | (1.575) | (1.83) | (−0.519) | (0.565) | (5.253) | (2.669) | (5.043) |
| *EDU* | 3.5 | 11.7 | 15.2 | 108.1*** | 123.3*** | −14.8 | 108.5** | −19.6** |
| | (0.214) | (0.704) | (0.628) | (2.707) | (2.963) | (−0.764) | (2.313) | (−2.480) |
| *WAM* | −938.9* | −633.0 | −1,572.0* | 977.6 | −594.4 | −763.9 | −1,358.3 | −1,835.6*** |
| | (−1.711) | (−1.145) | (−1.948) | (0.734) | (−0.428) | (−1.183) | (−0.868) | (−6.977) |
| *WAF* | −635.1 | −84.3 | −719.4 | 245 | −474.4 | −155.3 | −629.7 | −1,195.0*** |
| | (−1.122) | (−0.148) | (−0.864) | (0.178) | (−0.331) | (−0.233) | (−0.390) | (−4.404) |

APPENDIX TABLE (Continued)

| Independent Variables | Milk Income (1) | Livestock Sales Income (2) | Total Livestock Income (3) = (1) + (2) | Crop Income (4) | Farm Income (5) = (3) + (4) | Off-Farm Income (6) | Total Household Income (7) = (5) + (6) | Consumption Expenditure (8) |
|---|---|---|---|---|---|---|---|---|
| | Dependent Variables ($Y$) | | | | | | | |
| *WCM* | –180.8 | –226.8 | –407.6 | 333.5 | –74.1 | –601.2 | –675.3 | –236.3 |
| | (–0.414) | (–0.515) | (–0.634) | (0.314) | (–0.067) | (–1.168) | (–0.541) | (–1.127) |
| $D_{13}$ | –32.5 | –71.0 | –103.6 | 831.2*** | 727.6*** | 94.5 | 822.1*** | –190.4*** |
| | (–0.385) | (–0.833) | (–0.832) | (4.047) | (3.4) | (0.95) | (3.408) | (–4.694) |
| $D_{23}$ | –48.1 | –194.5** | –242.6** | 14.3 | –228.3 | –97.0 | –325.3 | 137.4*** |
| | (–0.579) | (–2.320) | (–1.984) | (0.071) | (–1.085) | (–0.991) | (–1.371) | (3.446) |
| Mean of $Y$ | 1,087.4 | 605.7 | 1,693.1 | 3,899.2 | 5,592.3 | 1,130.4 | 6,722.7 | 3,355.2 |
| Std. dev. of $Y$ | 940.6 | 836.0 | 1,344.4 | 3,905.5 | 4,110.9 | 973.8 | 4,145.2 | 601.1 |
| $R$-squared | 0.379 | 0.202 | 0.343 | 0.788 | 0.792 | 0.198 | 0.74 | 0.651 |
| Adj. $R$-squared | 0.338 | 0.149 | 0.299 | 0.774 | 0.778 | 0.145 | 0.723 | 0.627 |

Notes: 1. OLS is used in the regression and the number of observations is 177.

2. $t$-statistics are given in the parenthesis.

3. All the dependent variables are given in real prices at 1988/89 rupees and in per capita term defined by adult-male equivalent units (AMEU).

4. Definitions of independent variables are: $C$ = intercept, *DRAFT* = draft animal in adult equivalent units per capita, *MILCH* = milch animal in adult equivalent units per capita, *AOPE* = acreage of operated agricultural land per capita, *AOWN* = acreage of owned agricultural land per capita, *HOUSV* = value of house building in 1988/89 rupees per capita, *EDU* = years of education of household head, *WAM* = adult-male equivalent units (AMEU) of adult males in total AMEU, *WAF* = AMEU of adult females in total AMEU, *WCM* = AMEU of children males in total AMEU, $D_{13} = D_1 – D_3$ and $D_{23} = D_2 – D_3$ where $D_i$ is a dummy variable for year $i$.

5. * indicates that the coefficient is significant at 10 per cent level, ** at 5 per cent level, and *** at 1 per cent level (two-sided test).