Milk Districts and Efficiency of Smallholder Dairy Producers in Pakistan

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Abstract:

Milk districts are private rural milk supply chain networks that might provide innovative way to address issues of rural development and poverty. Little is known how the milk districts benefit the participating dairy producers. Do they produce favorable production conditions and incentives to the participating farms? How these production conditions affect relative inefficiency of the farms? Do the number of industry players collecting farmer milk in a village matter in determining farm inefficiency of dairy farms? We estimate the stochastic production frontier and technical inefficiency effects model by employing data of a cross-section survey of dairy households from rural Punjab in Pakistan for the calendar year 2005. While we find that relative technical inefficiency of farms in milk districts is significantly reduced, we detect stronger power of the milk districts in further reducing technical inefficiency if they are located in remote areas, or they are bigger farms. An efficient private milk market develops as the number of economic agents competing for the rural milk supplies increases. The advantage to experienced farmers in reducing inefficiency is present, which remains until the age of 69-years. The remaining differences in relative inefficiency are accounted for by timely feeding of water to milch animals, severe long-term depressive disorders, and better feeding regimes.

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1. Introduction:

While the search for ways to address poverty in developing countries goes on, the milk district model is a private sector initiative that might also provide new and innovative way to address issues of rural development and poverty by building supply chains [see, Goldberg and Herman (2005)]. In this regard, Nestle has a long and rich history of setting up supply chain networks "by working with producers directly or through farmer cooperatives and governmental institutions." Some recent success stories from developing countries are Pakistan, Brazil, Mexico, Chile, India and China. While these case studies have reported positive outcomes of these interventions, little is known how the milk districts benefit the participating dairy producers. This paper seeks to provide evidence on the impact of milk districts on efficiency of smallholder dairy producers in Pakistan.[1]

Fresh milk being a highly perishable item demands prompt and efficient collection from milk producers for use by consumers and manufacturers of milk. The supply chain for milk involves numerous players where the traditional milk collectors, known as *dodhis*, play the dominant middlemen role between millions of subsistence and commercial dairy farmers and consumers [Burki et al. (2004)].[2] With the burgeoning urbanization and income growth in Pakistan, as cities started growing in size, the demand

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[1] For a detailed report on the impact of milk districts on efficiency and welfare of dairy producers in Pakistan, see Burki and Khan (2007).

[2] While the exact number of dodhis is not known, Pakistan Dairy Development Company (2006) notes that about one million dodhis are at work in Pakistan.

for urban milk rapidly increased, which, in turn, promoted commercial dairy production of farmer milk that led to augmented supplies from rural producers for the use of numerous processing plants of ultra high temperature (UHT) treated and pasteurized milk. However, due to long distances, short life of fresh milk, lack of storage and transportation facilities, most of the milk produced in far flung rural areas failed to reach milk processing plants.

Milk districts are defined as rural supply chain network for the milk processing industry, which function on the basis of: (a) self-collection of farmer milk by the milk plants, e.g., Nestle's milk collection model; (b) third-party milk collection, e.g., Haleeb, Nirala, Noon, etc.; and (c) farmer cooperatives, e.g., HALLA (Idare-e-Kisan). Nestle Pakistan is the biggest processing industry of the sector, collecting 1040 tons of milk daily from over 140,000 farmers in about 3500 villages.[3] With the setting up of the milk districts favorable production conditions are created in the form of modern milk storage facilities, better and dependable transportation networks, regular payment schedules, and buyer-side competition. For instance, Nestlé's milk district model generally functions with the setting-up of rural milk collection centers, which provide access to chillers in remote rural areas. In effect, the milk districts make the low cost rural production system viable where smallholder dairy producers employ mostly family labor, and rely on roughages, grasses and crop residue as fodder. Billions of rupees are being injected annually into the participating villages and towns by the industry players for their milk purchases. However, farmers from non-milk collecting districts have not directly benefited from this development.

The impact of milk districts on efficiency has not been studied before. Are the milk districts producing favorable production conditions and incentives to the dairy producers? How these production conditions affect the relative inefficiency and allocation of dairy resources? Do the number of industry players matter in farm efficiency of the dairy households? This paper attempts to answer these questions using a cross section survey

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[3] Other major industry players include Haleeb, Nirala, Halla, Noon, Milac, Dairy Bell, Dairy Crest, Premier, and Army dairies. More recently, Engro Foods have launched their first milk processing project at Sukkur in the brand name of Olpers, while the second plant is being set up in Sahiwal.

of 800 smallholder dairy producers from rural Punjab in Pakistan for the calendar year 2005. The results suggest that dairy farms in milk districts improve their long term viability by establishing a steady and secure link with the processing industry. In general, while technical inefficiency of dairy farms located in the milk districts is significantly reduced, we detect stronger power of milk districts in further reducing technical inefficiency of farms if they are located in remote areas or they are larger farms. As the number of economic agents competing for the rural milk supplies increases a relatively efficient private milk market develops. The layout of the paper is as follows. Section 2 outlines the survey of dairy households and sampling methods. Section 3 describes the empirical framework. Section 4 analyses the estimation results and examines the impact of milk districts on dairy efficiency. Section 5 presents our conclusions.

2. Survey of Dairy Households and Sampling Methods:

A survey namely, the LUMS Survey of Dairy Households in Rural Punjab 2005, was designed to draw a representative sample of 800 dairy households from rural Punjab, who owned at least one milching animal (buffalo or cow), sold milk for at least 6 months, and did not share ownership of farm resources with other households during the calendar year 2005.[4] Punjab is the most populous of the four provinces producing nearly 70 percent of total fresh milk in the country. While dairy farms are evenly spread in Punjab, milk collecting districts are mostly concentrated in Southern Punjab. The dairy survey was conducted from January 2006 to April 2006.

We used cluster sampling as a probability sampling plan where the total sampled area (rural Punjab) was divided into sections according to the agro-climatic (crop) zones, mouzas/villages and target groups. Districts in Punjab have significant differences in climate (arid vs. non-arid), soil conditions, temperature, rainfall, and water availability.

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[4] The authors organized and supervised the survey, which was carried out by a three-member team of professional. A 26-page survey questionnaire was developed and appended by the WHO’s self reporting questionnaire (SRQ-20), meant for measuring prevalence of depression in dairy farmers. Pre-testing of the survey questionnaire was done in the second week of December 2005 after which the questionnaire was revised.

Otherwise identical dairy producers may produce different quantities of milk if faced with different temperature, rainfall and water availability. Therefore, to allow for different environmental production conditions being faced by the dairy producers, we followed Pinckney (1989) and classified districts into five agro-climatic (or crop) zones consisting of (1) wheat-rice, (2) wheat-mix, (3) wheat-cotton, (4) low intensity barani, and (5) barani (rainfed).

In stage 1, we randomly picked 10 districts (two districts from each agro-climatic zone) from 34 districts of Punjab.[5] In stage 2, mouza/village was used as the basic geographical unit due to its convenient and divisible nature.[6] Four mouzas/villages were randomly drawn from each selected district based on the list of mouzas/villages obtained from *Pakistan Mouza Statistics 1998* [Government of Pakistan (1999)]. Out of the 40 mouzas/villages sampled, 26 had at least one industry player involved in milk collection. In stage 3, lists of commercial dairy farmers operating in each selected mouza/village were first prepared in consultation with the notables of the villages, and local milk collection units of the dairy industry where applicable. On the basis of these lists, 20 dairy farms were randomly selected from each mouza/village with equal probability. Five replacement dairy households were also selected from each mouza/village in case the selected dairy households could not be interviewed. Of the 800 dairy households sampled, 160 dairy households were drawn from each agro-climatic zone, 10 districts and 40 mouzas/villages.

The hallmark of the dairy economy of Pakistan is the dominance of subsistence dairying households who keep buffaloes and cows in small herd sizes. Table 1 indicates that 46 percent of sample farms consist of herd sizes 1–2 (under subsistence), another 30 percent of commercial diary households operate herd sizes of 3–4 (near subsistence). The rest of the commercial dairying households in our sample maintain large herd sizes.

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[5] The sample districts were Hafizabad and Narowal in wheat-rice zone, Sargodha and Okara districts in mixed-cropping zone, Pakpattan and Khanewal districts in wheat-cotton zone, Muzaffargarh and Layyah in low-intensity zone, and Jhelum and Attock in barani zone.

[6] Mouza is the smallest administrative unit under the revenue department which may consist of one big village or few small villages. Punjab province has 23385 mouzas with an average of 600 mouzas in each district.

Table 1: Distribution of dairy households by herd size and farm type (numbers, percent)

Herd Size	Milch buffalo farm	Milch cow farm	Both milch cow and buffalo farm	Total farms
1 to 2	222 (44.7)	86 (67.7)	61 (34.6)	369 (46.12)
3 to 4	158 (31.8)	24 (18.9)	61 (34.6)	243 (30.37)
5 to 6	63 (12.7)	13 (10.2)	32 (18.2)	108 (13.5)
7 to 10	41 (8.2)	4 (3.1)	18 (10.2)	63 (7.87)
11 to 15	8 (1.6)	0	4 (2.3)	12 (1.5)
16 and High	5 (1.0)	0	0	5 (0.62)
Total	497 (62.1)	127 (15.9)	176 (22.0)	800 (100)

Note: Numbers in parentheses are percentages.
Source: LUMS Survey of Dairy Households in Rural Punjab, 2005

Because buffalo milk has higher butter fat content as compared with cow milk, consumers and dairy processors in Pakistan prefer buffalo milk over cow milk. Due to higher demand for buffalo milk it also sells at a higher price than the cow milk.[7] In our sample, 62 percent of the respondents keep milch buffaloes and another 22 percent keep both milch cows and buffaloes, while only 16 percent of sample farms keep milk cows only. There is relatively much higher concentration of subsistence dairy farms (herd sizes of 1-2) who keep milch cows (68 percent) and relatively much lower proportion of cow farms in higher size categories, which also confirms that, presently, cow farms are not popular among the commercial dairy farms. Nearly 43 percent of sample dairy farms are either landless or they cultivate up to 5 acres of land, 32 percent cultivate between 5 and 12.5 acres, about 15 percent operate from 12.5 to 25 acres, while only 10 percent dairy farms operate more than 25 acres of land.

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[7] About 66 percent, or two-third, of the milk available for human consumption in Pakistan is that of buffalo milk, and only 33 percent is that of cow milk [Government of Pakistan (2001)].

Table 2: Distribution of sample dairy farms by mode of selling milk

District	Sell milk to dodhi/IFS	Sell milk to milk-processors
Sargodha	41	39
Narowal	80	0
Hafizabad	25	55
Pakpattan	3	77
Okara	5	75
Muzaffargarh	40	40
Layyah	43	37
Khanewal	17	63
Jehlum	80	0
Attock	80	0
Total	414	386

Source: LUMS Survey of Dairy Households in Rural Punjab, 2005

Dairy farms in our sample sell fresh milk to both informal and formal sources. The informal sources include traditional milk collectors, marketers and consumers, e.g., small-, medium-, and large-scale dodhis, village milk shops, city milk shops and neighbors, etc. The formal sources include third-party milk collection for the industry players, farmer cooperatives, and self-collecting systems, e.g., village milk collecting agents, milk collection centers and chilling units of the processors of UHT and pasteurized milk. The survey evidence on the distribution of sample dairy farms by mode of selling milk is presented in Table 2 where we note that 52 percent of sample farms sell milk to informal sources, while 48 percent of farms sell milk directly to the milk processing industry. As the table suggests, the number of dairy farms selling milk to the industry varies across districts. In three of the sampled districts namely, Narowal, Jhelum and Attock, industry is not yet present. On the other hand, there is almost a complete capture of the rural milk market by the processing industry in Pakpattan and Okara districts where 94 percent or more sample dairy farms sell milk directly to the processors.

3. Dairy Household Inefficiency Frontier Model:

Research on dairy efficiency has focused more attention to the issue of technical inefficiency [Farrell (1957), sometimes also referred to X-inefficiency.[8] This approach uses the concept of a frontier that depicts the maximum amounts of output (or 100 percent efficiency) obtainable from given quantities of inputs, where technical inefficiency of a firm/farm is estimated by deviations from the frontier. Technical inefficiency has been considered widely in the literature by making use of both non-parametric and parametric techniques.[9] Researchers have recognized how external or environmental factors, which vary over time and space, can affect relative inefficiency of farms [Sherlund et al. (2002), Gonzalez and Lopez (2007)].

While the large-scale milk collection in the milk districts in Pakistan is believed to have generated huge supply response from milk producers in the participating areas, yet, no attempt has been made to study the impact of milk districts on efficiency of dairy households. Given that the location of a dairy household in the milk district or non-milk district is exogenously determined, it creates diverse environmental conditions that are likely to influence their relative inefficiency. Favorable environmental production conditions in milk districts (e.g., better transportation networks, modern storage facilities, regular payment schedules and intensifying competition among the buyers) are expected to enhance technical efficiency of farms mainly through better allocation of key dairy farm inputs and farm management practices. Here, we adapt frontier inefficiency model to accommodate the environmental conditions, due to milk district model, to investigate the differential impact of these conditions on relative inefficiency of dairy households.

The empirical framework used in this paper involves a stochastic production frontier first introduced by Aigner et al. (1977) and Meeusen and Van den Broeck (1977), which postulates the existence of technical inefficiencies during the production process by the dairy farms. The stochastic frontier production functions are widely used to assess

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[8] The concept of X-inefficiency is due to Leibenstein (1966) who observed that, for a variety of reasons, people and firms/farms may work much below their full potential.

[9] For a review of efficiency literature, see among others, Lovell (1993), Greene (1999).

inefficiencies of firms in various agricultural and industrial settings [Kumbhakar et al. (1991), Battese and Coelli (1995), Hallam and Machado (1996), Sherlund et al. (2002), Mbaga et al. (2003), Hailu et al. (2005), Kompas and Che (2006)].

Let the milk production technology be represented by

$$Y_i = f(X_i;\beta)\, e^{v_i - u_i} \qquad (1)$$

where Y is the output of the *i*th dairy farm, $X_i\,(i=1,\ldots,n)$ is a $1\times k$ vector of values of known functions of inputs for the *i*th dairy farm, β is a $k\times 1$ vector of unknown parameters to be estimated, and $f(X_i;\beta)$ is the assumed functional form. As usual in frontier literature, the stochastic composite error term in Eq. (1) is decomposed into v_i and u_i where v_i is typically taken as iid $N(0, \sigma_v^2)$ and accounts for random variation in output due to factors beyond the control of the farm. The technical inefficiency term, u_i, is a non-negative random variable, independent of v_i, which captures farm-specific inefficiency effects reflecting the extent of the stochastic shortfall of the *i*th farm dairy outputs from the most efficient production.

When *u* equals zero the farm is perfectly technically efficient because it is on the production frontier. It is further assumed that the $u_i s$ are independently distributed, such that u_i is obtained by truncation at zero, that is, $u_{it} \sim N(\mu_i, \sigma^2)$, where $\mu_i = \delta z_i$ where z_i is a vector of observable explanatory variables linked with technical inefficiency of farms, and δ is a vector of unknown coefficients. In effect, the technical inefficiency, u_i, for each dairy farm in Eq. (1) could be replaced by a linear function of explanatory variables reflecting farm-specific characteristics specified by

$$u_i = \delta z_i + \varepsilon_i \qquad (2)$$

where δ is a vector of unknown farm-specific parameter estimates associated with technical inefficiency of dairy farms and ε_i is an unobservable random variable that is obtained by truncation of the normal distribution with mean zero and variance, σ^2. The point of truncation occurs at $-\delta z_i$ or $\varepsilon_i \geq -\delta z_i$.

Several studies have applied a two stage procedure whereby the first stage involves specification and estimation of the stochastic frontier and technical inefficiency effects. In the second stage, the technical inefficiency effects are regressed on various firm/farm characteristics or explanatory variables by the Ordinary Least Squares (OLS) or the Tobit maximum likelihood procedures to find out factors that contribute in technical inefficiency. However, these second stage estimations usually assume that technical inefficiency effects in the first stage of estimation are independently distributed. Kumbhakar et al. (1991), Reifschneider and Stevenson (1991), and Huang and Liu (1994) have proposed models for simultaneous estimation of the stochastic frontier and the technical inefficiency effects for cross-sectional data while Battese and Coelli (1993, 1995) have extended this approach also to the panel data models.

In this paper we follow Battese and Coelli (1993, 1995) technical inefficiency effects model for the cross sectional data. We estimate the translog production frontier for the cross-sectional data, which offers the advantage of being a second-order Taylor series expansion to an arbitrary technology, written as

$$\ln Y_i = \beta_0 + \sum_i \beta_i \ln X_i + 0.5 \sum_i \sum_j \beta_{ij} \ln X_i \ln X_j + v_i - u_i \tag{3}$$

where the technical inefficiency effects, u_i, are assumed to be defined by a linear function of explanatory variables reflecting farm-specific characteristics given by

$$u_i = \delta_0 + \sum_{j=1}^{N} \delta_j z_{ij} + \varepsilon_i \tag{4}$$

where Y and X are the output and inputs for the *i*th farm, the random variable ε_i is defined above. The Cobb-Douglas technology is nested within the translog production technology (i.e., when all $\beta_{ij} = 0$). The dependent variable in the production function Eq. (3) is the estimated gross value of milk[10], and other dairy products sold during the year.

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[10] Due to long recall period (i.e., one-year), milk production reported by dairy farms was subject to large measurement error. To avoid the obvious measurement problem in a key variable, we adopt a procedure, due to Khan (1997, 2000), and predict daily milk production of each dairy animal in our sample. We obtain estimates of daily milk production by using the parameter estimates from Khan (2000) for the respective lactation length of each animal separately for first calves, later calves, and for the summer and winter months together with (i) the reported milk production for each animal on the interview day, and (ii) reported peak time daily milk production of each animal.

The value of milk income is calculated at the price quoted by the dairy farms. Five input variables used in the production function are shed & structure capital, animal capital, fodder, straws & concentrates, and hired & family labor. Shed & structure capital measures the user cost of sheds, structures and electricity costs, etc. Since prices of dairy cattle and buffaloes significantly vary, depending upon among other things on their breed, genetic endowments and age, etc., we calculate the animal capital variable by taking the user cost of each animal on the basis of their value and age. Quantity of fodder consumed is expressed in acres. The quantity of straw and feed concentrate is expressed in 40 kilograms while labor input includes hired & family labor expressed in hours.

A number of farm management practices, farmer attributes and location information was reported in the dairy survey. Several variables were tried as determinants of technical inefficiency. The variables that tested as insignificant determinants of X-inefficiency were dropped from the regression models. Descriptive statistics of the relevant variables are presented in Table 3. The average production of milk and other dairy output was Rs.88.52 thousand per household, which translates to about Rs.243 per day per household. Based on the size, dairy production varied across dairy households ranging from only Rs.900 to around Rs.1 million. Average shed & structure capital was Rs.5713, which was highly variable ranging from only Rs.20 to Rs.66,000 because subsistence farms did not use shed or structures for their dairy animals. It is significant to note that the animal capital turns out to be a major component of the dairy cost with an average amount of Rs.12583 per farm.

Two other major inputs in dairy production are fodders, and straw & concentrate with average use of 0.81 acres for fodders and 2520 kg $(63 \times 40\,\text{kg})$ of straw and concentrate. The average use of family and hired labor was 2097 hours, which translates to 40 hours per week ranging from only 2 hours per week to 144 hours per week. In one sense this is hardly surprising result for a country like Pakistan where small dairy households rarely employ full time dedicated workers for day-to-day management of their dairy animals. Therefore, we measure family & hired labor in hours worked per day

Table 3. Descriptive statistics for the variables of the frontier production function and inefficiency model

Variables	Mean	Std. Dev	Min	Max
Frontier Production Function:				
Milk production & other dairy outputs (Rs.)	88517.9	87053.1	900.2	958176
Shed & structure capital (Rs.)	5713	5486.3	19.6	66220.8
Animal capital (user cost)	12583	10709	720	131850
Fodders (acres)	0.81	0.7693	0.0085	9.1882
Straws and concentrates (40kg)	62.81	118.797	5.13	2811.50
Family & hired labor (hours)	2097	1380.70	104	7488
Technical Inefficiency Model:				
Herd size (number)	3.51	2.73	1	30
Head age (years)	49.25	13.58	17	95
Feed water (no. of times feed water to animals)	2.34	0.51	1	4
Distance pucca road (km)	0.861	1.06	0	8
Depression (if SRQ≥8=1, otherwise=0)	0.119	0.324	0	1
Head literate (yes=1, no=0)	0.447	0.497	0	1
Molasses (yes=1, no=0)	0.025	0.156	0	1
Milk district (yes=1, no=0)	0.525	0.499	0	1
Nestlé in milk district (yes=1, no=0)	0.425	0.495	0	1
No player (no industry player in mouza, yes=1, no=0)	0.425	0.495	0	1
One player (one player in mouza, yes=1, no=0)	0.250	0.433	0	1
Two player (two players in mouza, yes=1, no=0)	0.225	0.418	0	1
Three player (three players in mouza, yes=1, no=0)	0.10	0.300	0	1
Sargodha district (yes=1, no=0)	0.1	0.300	0	1
Narowal district (yes=1, no=0)	0.1	0.300	0	1
Hafizabad district (yes=1, no=0)	0.1	0.300	0	1
Pakpattan district (yes=1, no=0)	0.1	0.300	0	1
Okara district (yes=1, no=0)	0.1	0.300	0	1
Muzafargarh district (yes=1, no=0)	0.1	0.300	0	1
Layyah district (yes=1, no=0)	0.1	0.300	0	1
Khanewal district (yes=1, no=0)	0.1	0.300	0	1
Jehlum district (yes=1, no=0)	0.1	0.300	0	1
Attock district (yes=1, no=0)	0.1	0.300	0	1
Sample size	800	---	---	---

Source: LUMS Survey of Dairy Households in Rural Punjab, 2005 rather than person-days. In this way, we also discount for likely underemployment of female family labor that often look after the animals. While most dairy households in Pakistan combine stall-feeding with grazing, some households who follow grazing only option also spend very little time on dairy management, which explains fewer hours spent.

Average herd size in our sample of commercial farmers was 3 to 4 animals. Average age of household head was 49 years, which varied from 17 years to 95 years. It is generally believed that animals that are fed sufficient quantity of water yield more milk. Since most cows and buffaloes are tied, they are not free to drink water at will. The frequency of feeding water to animals ranges from 1 to 4 in our sample with mean value of 2.34. Average distance of dairy farms from pucca road was 0.86 km where the maximum distance from a farm was 8 km.

The psychiatric epidemiological studies show that anxiety and depressive disorder is not only common occurrence in developing countries, but is also associated with disability. These figures are particularly higher in Pakistan where according to Mirza and Jenkins (2004) "the overall mean prevalence in men and women in the six studies of random community samples (n=2658) was 33.62 percent, with the point prevalence varying from 28.8 percent to 66 percent for women (overall mean 45.5 percent) and from 10 percent to 33 percent for men (overall mean 21.7 percent)."[11] Quite consistent with these numbers we note that about 12 percent of the dairy farmers in our sample were under high degree of long-term depression measured by the self-reporting questionnaire (SRQ-20). These disorders are likely to have important economic consequences. Only 45 percent of farmers in our sample were literate and 2.5 percent farmers were feeding molasses to their milch cows and buffaloes.

Milk district indicates presence of milk collecting agents or milk collection centers of the milk processing industry. We note that 52.5 percent of the sample area (or 21 of

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[11] Some of the factors positively associated with the occurrence of anxiety and depressive disorders in Pakistan are female sex, middle age, low level of education, financial difficulty and relationship problems [Mirza and Jenkins (2004)].

the 40 mouzas) were located in milk districts. In rest of the sample area, industry was not present and thus only traditional milk collecting agents were buying farmer milk. Likewise, due to presence of vast milk collection network of Nestlé in rural Punjab, we note that in 42.5 percent of the sample (or 17 mouzas), either Nestle was the only industry player or was competing with some other processors to purchase farmer milk in the remote areas.

The number of milk processors competing for farmer milk in villages indicates the extent of imperfect competition in the farmer milk buying market. Profit maximizing behavior of milk collecting agents causes the market price of fresh milk to be less than the price that would prevail in a perfectly competitive environment. The assumption of perfect competition obviously does not hold in rural milk markets. Traditionally, dodhi is the only purchaser of farmer milk in far flung rural areas, and there are sometimes only a few other purchasers. The market structure is said to be a monopsony when there is a single buyer of fresh milk such as traditional milk collecting agents. This market structure closely resembles with the picture prevailing in the non-milk districts. Where there are two buyers of fresh milk a doupsony is said to exist; if there are several buyers oligopsony is the proper title.

Based on the market structure in the commodity market, a variety of categories of market structures can be classified for factor and commodity markets.[12] Because the analytical outcome on price of fresh milk is roughly the same irrespective of the organization of the commodity and resource markets, we do not differentiate between them for our empirical analysis. We expect that the conditions become more competitive with the entry of milk processing industry because among other things farmers look for

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[12] Traditional milk collecting agents in Pakistan sell milk in perfectly competitive urban markets. They function just like the middlemen, who are often not the producers of milk products themselves; they simply transport and sell fresh milk to a variety of urban consumers, sweet shops, confectionaries, wholesalers or retail shops in an otherwise perfectly competitive urban market for fresh milk. For the processing industry, however, commodity markets are essentially oligopolistic since only a few players control most of the processed milk market.

better prices for fresh milk. Therefore, we introduce four dummy variables to depict the extent of imperfect competition prevailing in the farmer milk buying market.

No Player is a dummy variable indicating that no industry players are present in the village due to which traditional milk collecting agent has the monopsony power in buying farmer milk. In our data, 42.5 percent of the respondents were selling milk directly to dodhi or other traditional milk collecting agents. One player, two players and three players indicate presence of respectively one, two or three industry players (or their agents) competing in a village for the farmer milk. About 25 percent of the respondents were located in villages where one industry player was present, 22.5 percent where two industry players were present, and 10 percent where three industry players were present.

4. Estimation Results:

A. Production frontier results

The maximum likelihood estimates of the parameters of the production function and the inefficiency model are estimated simultaneously using the procedure in computer program FRONTIER 4.1 [Coelli (1996)]. Hypothesis testing regarding functional forms and specifications is conducted on the basis of generalized likelihood ratio tests,[13] which have approximately a χ^2 distribution, except cases where the null hypothesis also involves the restrictions of $\gamma = 0$. In such cases, the asymptotic distribution of the likelihood ratio test statistic is a mixed-χ^2 distribution and therefore the appropriate critical values are drawn from Kodde and Palm (1986). Table 4 presents the results of the hypothesis tests regarding functional forms and model specifications with generalized

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[13] The generalized likelihood-ratio test is defined by $LR = -2\left\{\ln\left[LH_0/LH_1\right]\right\} = -2\left\{\ln\left[L(H_0\right]-\ln\left[L(H_1\right]\right\}$ where $L(H_0)$ and $L(H_1)$ denote the values of the likelihood function under the null and alternative hypothesis, respectively [Coelli et al. (1998). Under the null-hypothesis the test statistic has approximately chi-square distribution with parameters equal to difference between the parameters involved in the null and alternative hypothesis.

likelihood ratio tests. Our results in Table 4 show that the translog production frontier is rejected in favor of the Cobb-Douglas production frontier at the 1-percent level of significance.

Table 4. Generalized likelihood ratio hypothesis tests

Null Hypothesis	Critical value ($\alpha = 0.01$)	Test statistics	Decision
H_0 : Cobb-Doublas vs. translog production	30.58	19.66	Fail to reject H_0
$H_0 : \gamma = \delta_0 = \delta_1 = ... = \delta_{19} = 0$	41.02[a]	514.9	Reject H_0
$H_0 : \gamma = 0$	6.63[a]	282.10	Reject H_0
$H_0 : \delta_0 = \delta_1 = ... = \delta_{19} = 0$	40.29	317.64	Reject H_0
$H_0 : \delta_1 = \delta_2 = ... = \delta_{19} = 0$	38.93	211.1	Reject H_0

[a] Critical values are taken from Table 1 of Kodde and Palm (1986) using 1-percent level of significance.

We begin by presenting results of a parsimonious model based on Eq. (3) – Eq. (4) where we include as covariates only dummy variable for milk and non-milk districts plus a complete set of other control variables that are included in all models (see Model 1, Table 5). We then go on to show how exogenous inefficiency of dairy farms is influenced when we add other covariates to the model: (a) remoteness of villages measured by distance from the main pucca road and herd-size, and (b) by the level of competition measured by the number of industry players present in a village (see Models 2 to 4, Table 5).

Our estimates of the coefficients for the Cobb-Douglas frontier production function and the technical inefficiency model in Table 5 indicate that all input elasticities possess the expected signs. The estimated coefficients are very similar in magnitude for all the specifications. Our estimates suggest that animal capital, fodder, and straw & concentrate continue to be the most important determinants of raising output in smallholder dairying while labor and shed & structure capital do not significantly increase dairy output. To illustrate, the coefficient of animal capital in each case is large, positive and statistically significant indicating that the elasticity of output with respect to animal capital is highest.

These estimates show that every 1-percent increase in the value of animal capital results in about 0.89-percent increase in dairy output. Similarly, dairy output is also statistically significantly correlated with fodder, however, this relationship with straw & concentrate is less precise in some specifications.

The estimated fodder, and straw & concentrate elasticities are relatively much smaller (at approximately 0.04 and 0.05, respectively) and marginally significant suggesting that these inputs are not much of a limitation. By contrast, shed & structure capital, and hired & family labor are not a constraint in raising dairy production, as suggested by their statistically insignificant coefficients. While the observed pattern for hired & family labor is explained by disguised unemployment of family labor, these results suggest that excess supply of straws & concentrate, and family labor can be used more productively by further expanding the capacity of the dairy farms (e.g., by purchasing more dairy animals). The policy makers can help by devising simpler and dairy-friendly credit policies, which carry great potential in dairy development in the country.

The estimated scale elasticity is measured by the sum of all the input elasticities. The estimated returns to scale at the point of approximation is less than one (0.98), and we fail to reject the null hypothesis of constant returns to scale by using the Wald test. In other words, a proportionate increase in the use of all inputs brings about a proportionate growth in dairy output.

B. Effects of Milk Districts on Dairy Efficiency

The estimate for γ parameter in our basic model (model 1) is significantly greater than zero (0.959, *t*-value=84.88), which indicates that most of the residual variation in this model is on account of inefficiency effects. Hence the production frontier model is a significant improvement over the standard OLS regression model. This result is supported by the second hypothesis in which we test that the technical inefficiency effects are absent from the model, or $\gamma = \delta_0 = ... = \delta_{19} = 0$. In Table 4, generalized likelihood ratio test results based on the basic model (model 1, Table 5) indicate that this hypothesis is rejected at the 1-percent level of significance; it confirms that most of the dairy farms are operating below the production frontier due to which the estimated inefficiency of these farms is high. The third null hypothesis, $\gamma = 0$, implies that the inefficiency effects are not stochastic, which is rejected at the 1-percent level of statistical significance. The fourth null hypothesis, $\mathrm{H}_0 : \delta_0 = \delta_1 = ... = \delta_{19} = 0$, entails that all the explanatory variables in the inefficiency model are jointly zero is rejected, which indicates that the linear explanatory variables accounting for the sources of technical inefficiency are significant even though the individual parameters of some variables may not be significant. The fifth null hypothesis, $H_0 :\ \delta_1 = \delta_2 = ... = \delta_{19} = 0$, implies that the effects of all the explanatory variables in the inefficiency model are zero is also rejected.

Our primary interest in this paper is to explore the differential impact of milk districts on X-inefficiency of dairy farms. In the technical inefficiency model (see, Table 5), the dependent variable is measured in units of inefficiency ranging over the (0, ∞) interval so that a score of zero indicates full efficiency and scores of more than zero indicate inefficiency. Likewise, coefficients with positive signs indicate increase in inefficiency and vice versa.

The estimated relationships between technical inefficiency and its correlates are qualitatively similar and robust for all the regressions. The parameter for herd size indicates that farmers who are maintaining large herds are relatively less inefficient than those maintaining small herds. The estimated negative coefficient for head-age predicts that, on average, older and experienced farmers are less inefficient than the younger ones. The positive age-square coefficient further reveals that the advantage to experienced farmers in reducing inefficiency remains until they reach the age of 69-years.

Table 5. Estimation results for the frontier production function and inefficiency model

Variables	Model 1	Model 2	Model 3	Model 4
Frontier Production Function:				
Constant	2.817***	2.807***	2.79***	2.843***
	(12.18)	(12.21)	(13.04)	(13.39)
Shed & structure capital	-0.001	-0.001	-0.001	-0.001
	(-0.15)	(-0.20)	(-0.09)	(-0.19)
Animal capital	0.888***	0.889***	0.891***	0.884***
	(29.29)	(31.08)	(31.77)	(33.19)
Fodders	0.037*	0.038*	0.035*	0.035*
	(1.74)	(1.79)	(1.68)	(1.69)
Straws and concentrates	0.050**	0.044*	0.048*	0.054**
	(1.99)	(1.66)	(1.87)	(2.16)
Family & hired labor	0.010	0.012	0.012	0.010
	(0.64)	(0.79)	(0.73)	(0.65)
Technical Inefficiency Model:				
Constant	2.88***	2.434***	2.48***	2.979***
	(4.52)	(4.00)	(4.22)	(4.64)
Herd size (number)	-0.096***	-0.044	-0.101***	-0.103***
	(-3.39)	(-1.26)	(-3.71)	(-3.60)
Head age	-0.068***	-0.062***	-0.063***	-0.067***
	(-2.73)	(-2.71)	(-2.75)	(-3.03)
Age^2	0.00049**	0.00045**	0.00045**	0.00049**
	(2.25)	(2.13)	(2.21)	(2.41)
Feed water (no. of times)	-0.372***	-0.269**	-0.266**	-0.395***
	(-2.63)	(-2.36)	(-2.34)	(-3.00)
Distance pucca road (km)	0.161***	0.198***	0.189***	0.161***
	(2.91)	(2.90)	(3.23)	(3.68)
Depression (if SRQ≥8=1, otherwise=0)	0.659***	0.632***	0.683***	0.592***
	(3.50)	(4.09)	(3.43)	(3.89)
Head literate (yes=1, no=0)	0.076	0.069	0.096	0.071
	(0.80)	(0.72)	(0.98)	(0.72)
Molasses (yes=1, no=0)	-1.333*	-0.947	-1.315*	-1.319*
	(-1.78)	(-1.21)	(-1.76)	(-1.70)
Milk district (yes=1, no=0)	-0.647***	-0.242	---	---
	(-3.18)	(-1.39)		
Milk district*distance pucca road	---	-0.245*	---	---
		(-1.79)		
Milk district*herd size)	---	-0.074*	---	---
		(-2.08)		
Nestlé in milk district (yes=1, no=0)	---	---	-0.287*	---
			(-1.68)	
One player (yes=1, no=0)	---	---	---	-0.872***
				(-3.71)
Two players (yes=1, no=0)	---	---	---	0.032
				(0.18)
Three players (yes=1, no=0)	---	---	---	-1.196***
				(-3.45)
District controls	YES	YES	YES	YES
$\sigma^2 = \sigma_u^2 + \sigma_v^2$	0.845***	0.755***	0.848***	0.787***
	(3.94)	(5.22)	(4.66)	(5.70)
γ	0.959***	0.956***	0.960***	0.956***
	(87.88)	(105.16)	(113.58)	(114.08)
Log-likelihood	-252.20	-250.50	-254.65	-247.94
Sample size	800	800	800	800

*, ** and *** indicate statistically significant at the 90 percent, 95 percent and 99 percent confidence level, respectively

Timely feeding of water to milch animals plays a significant role in increasing milk production. Holding other things as constant, farmers who feed more water to their milch animals are likely to be less inefficient than those who don't. Furthermore, dairy farms located too far away from the main pucca roads (remote rural areas) are more inefficient. Remoteness of dairy farms increases inefficiency because they do not face more favorable exogenous operating conditions and thus it points to the potential benefits of developing rural road networks. The significantly positive coefficient on dummy variable for depression in all the specifications could be interpreted as indicating relatively higher inefficiency of farmers who are suffering from severe long-term depression than those who are not suffering from the depressive disorders.

Our interest also lies in testing whether feeding molasses does explain any of the variation in efficiency index of dairy farms.[14] Molasses is a dummy variable that accounts for the possibility of likely variation in technical inefficiency due to better feeding regime. From the estimated coefficients in different specifications we can see that molasses has a negative effect on technical inefficiency, and that in each case this effect is large and statistically significant. This finding suggests potential benefits of feeding adequate amounts of concentrate to the milch animals.

Substantial insight can be gained from a careful investigation of the impact of milk districts on the technical inefficiency of dairy farms. Milk districts improve long-term viability of dairy farms by establishing a steady and secure link with the industry for supply of fresh milk. Prior to the arrival of the milk processing industry, local dairy producers were completely excluded from the urban market dynamics, fair and transparent prices to farmers for their supplies of fresh milk and regular stream of weekly payments. Therefore, one may predict that technical inefficiency of dairy farms located in the milk districts would be lower, because participating farms would maximize their effort to increase their dairy production.

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[14] The amount of concentrate fed to dairy animals in Pakistan is generally inadequate. For example, only 2.5 percent of sample respondents reported feeding molasses to milch cows or buffaloes.

First, we take dummy variable, milk district, as a determinant of inefficiency that takes a value of one for farms located in the milk district and zero otherwise. This variable accounts for the possibility that predicted inefficiency varies across farms in milk and non-milk districts if differential effects associated with the rural milk supply chain of the milk processing industry are present. From the results in Table 5, we can see that milk district has negative estimated coefficient in all the specifications, and that this effect is statistically significant at the 1-percent level in model 1 (without interaction terms). These results confirm our earlier conjecture of differential impact of milk districts, which is indicated by the lower technical inefficiency of the farms that are located in the milk districts. In other words, the composite effect of milk districts in the sample suggests that farm inefficiency of the participating farms is significantly reduced as these farms tend to employ much fewer resources to produce given levels of dairy output.

Second, we explore that when exogenous inefficiency of dairy farms located in remote areas is too high, how building of milk districts into these remote rural villages influences their relative inefficiency. We take this into account by introducing in the model an interaction of the milk district dummy variable with distance from *pucca* road and denote it as (milk district*distance pucca road). We expect this relative parameter to have a negative sign. Our results in Table 5 suggest that remoteness is not a constraint if farms are located in the milk districts. For example, the negative and statistically significant coefficient of the interaction term $(-0.245, t = 1.79)$ reveals that milk districts tend to eliminate inefficiency of dairy farms with their increasing distance from the *pucca* road. In sum, we detect stronger power of milk districts in reducing technical inefficiency.

Third, we ask whether location of dairy farms in the milk districts influences technical inefficiency of smaller vs. larger herds. To this end, we introduce interaction term (milk district*herd size) in model 2 to allow for the differential effects associated with milk districts to vary by herd size. As already noted, the estimated coefficient on herd size $(-0.062, t = -2.71)$ is negative and statistically significant at the 1-percent level suggesting that as herd size increases technical inefficiency of dairy farms decreases. From the parameter of the interaction term $(-0.074,\ t = -2.08)$ we further predict that the inefficiency reducing effect of increasing herd size becomes even stronger for farms in the milk districts, as suggested by the difference in the two delta coefficients $(-0.062\ -0.074)$ is -0.136 in the same direction. .

Fourth, we envisage that as conditions become more competitive with the entry of other industry players, farmers look for better prices, improved dairy extension services, and more economical ways to manage their dairy farms. To this end, we introduce three dummy variables (one player, two players, and three players) in model 4 indicating the number of milk processors competing for fresh milk in a village, where no industry player is the excluded category. According to the predictions of the theory of the firm, firm efficiency and productivity is expected to be higher and technical inefficiency lower when there is more competition; the sign of these parameters is then expected to be negative. As expected, with increase in the number of industry players, technical inefficiency of dairy farms decreases in our sample. The estimated coefficients for one player $(-0.872,\ t = -3.71)$ and three players $(-1.196,\ t = -3.75)$ are large, negative and statistically significant at the 1-percent level, which indicate that, on average, dairy farms located in villages where one industry player and three industry players are present are less inefficient than the excluded category. The difference in the estimated delta $(-0.872 - 1.196)$ is -2.068, predicting that improvement in technical inefficiency of farms that deal with three industry players is much greater than those who deal with only one industry player. These results clearly show that increase in the number of industry players tends to decrease technical inefficiency of dairy farms. While the statistically insignificant coefficient for two players $(0.032,\ t = 0.18)$ is surprising, it may be blamed on the high collinearity between one player and two players.

Last, motivated by the above findings, we also examine the effect of Nestlé's presence on the relative inefficiency of dairy farms. We consider Nestlé in milk district, which is also a dummy variable taking value 1 when a dairy farm is observed in villages where Nestlé is present, and takes value 0 when a dairy farm is observed in villages where Nestlé is not present. The negative sign for Nestlé in milk district coefficient $(-0.287, t=-1.68)$ indicates that even though technical inefficiency is lower for the dairy farms where Nestlé is present, the differential effect of Nestlé's presence is smaller in magnitude than the composite effect of milk district (Table 5, model 1). This result suggests that efficiency and productivity effects on dairy farms are far greater when other industry players are also present as compared with a market where Nestlé is a single player. This is hardly a surprising result if seen in the light of the theory of the firm where monopsony/duopsony power allows firms to reap extra profits.

C. Cross-sectional properties of X-efficiencies

To better understand the separated effects on production efficiency, next we consider mean predicted efficiency to make cross-sectional comparison among farms by milk districts and farm characteristics, as well as the market structure of the villages. Predicted mean technical efficiency scores from Model 1 are presented in Table 6 to indicate the separated cross-sectional effects. Averaging over the full sample, the mean and the median estimated efficiency are 73.1 percent and 81 percent, respectively. These efficiency results suggest that on average the dairy farms in our sample loose about 37 percent of their dairy output due to being technically inefficient.

The mean and median efficiency of farms in milk district is 79 percent and 85 percent, respectively. On the contrary, the mean and the median efficiency of dairy farms not in the milk districts are much lower at 66 percent and 73 percent, respectively. It appears from these results that farms in non-milk districts fail to adapt to better management practices to dairy farming. This result is further supported by the standard deviation of 0.144 and 0.227 in milk and non-milk districts, respectively, which reveals that farms located in milk districts cluster relatively much closer to the production frontier than the farms in non-milk districts.

Table 6. Descriptive statistics of estimated efficiency of the dairy farms

Estimated efficiency of farms by	Mean	Median	Std. Dev	Min	Max	N
Milk district model:						
Milk district	0.794	0.85	0.144	0.10	0.95	420
Not in milk district	0.662	0.73	0.227	0.02	0.96	380
Villages where Nestlé is present	0.788	0.84	0.149	0.10	0.95	340
Nestlé not present	0.689	0.760	0.220	0.02	0.96	460
Farmers' long-term stress levels:						
With major depression	0.681	0.76	0.216	0.02	0.96	95
Without major depression	0.738	0.82	0.195	0.02	0.96	705
Feeding of concentrates:						
Feed molasses	0.882	0.89	0.039	0.78	0.92	20
Don't feed molasses	0.727	0.81	0.200	0.02	0.96	780
Here size:						
Herd size 1-2	0.681	0.75	0.218	0.04	0.96	369
Herd size 3-4	0.757	0.82	0.177	0.02	0.96	243
Herd size 5-6	0.776	0.85	0.170	0.02	0.95	108
Herd size 7-10	0.821	0.88	0.125	0.39	0.95	63
Herd size 11-15	0.804	0.89	0.204	0.20	0.92	12
Herd size 16 or more	0.900	0.89	0.031	0.87	0.95	5
Feeding of water to milch animals:						
Feed water once a day	0.583	0.83	0.471	0.04	0.88	3
Feed water two times a day	0.742	0.82	0.197	0.02	0.96	534
Feed water three times a day	0.705	0.78	0.198	0.10	0.95	252
Feed water four times a day	0.820	0.86	0.130	0.45	0.92	11
Village market structure:						
No industry player	0.659	0.72	0.230	0.02	0.96	340
One industry player	0.785	0.84	0.153	0.26	0.95	200
Two industry players	0.776	0.84	0.164	0.10	0.94	180
Three industry players	0.806	0.85	0.114	0.33	0.94	80
Full sample	0.731	0.81	0.199	0.02	0.96	800

Source: Authors' estimations

In Figure 1 we plot the empirical cumulative distribution functions of the estimated technical efficiency scores of dairy farms in the milk and non-milk districts. The figure clearly indicates the superior efficiency performance of dairy farms in the milk districts as compared with the non-milk districts. Further insights are provided in Figure 2 where we compare the frequency distribution of mean technical efficiency of dairy farms in the milk and the non-milk districts. For the milk district sample, a relatively large number of dairy farms cluster closer to the high end of technical efficiency than at the low end, which is in sharp contrast to the efficiency levels of farms in non-milk district sample. Very few dairy farms in milk districts have mean technical efficiency of less than 70 percent, but a relatively large number of dairy farms in non-milk sample have mean efficiency between 20 percent and 70 percent. As one would have expected, the separated effect of farms' location in Nestlé operated villages is no different from their being in the milk districts; however, consistent with the predictions of the inefficiency regressions reported in Table 5, we note that the differential effect of Nestlé's presence on efficiency of dairy farms is smaller than the composite effect.

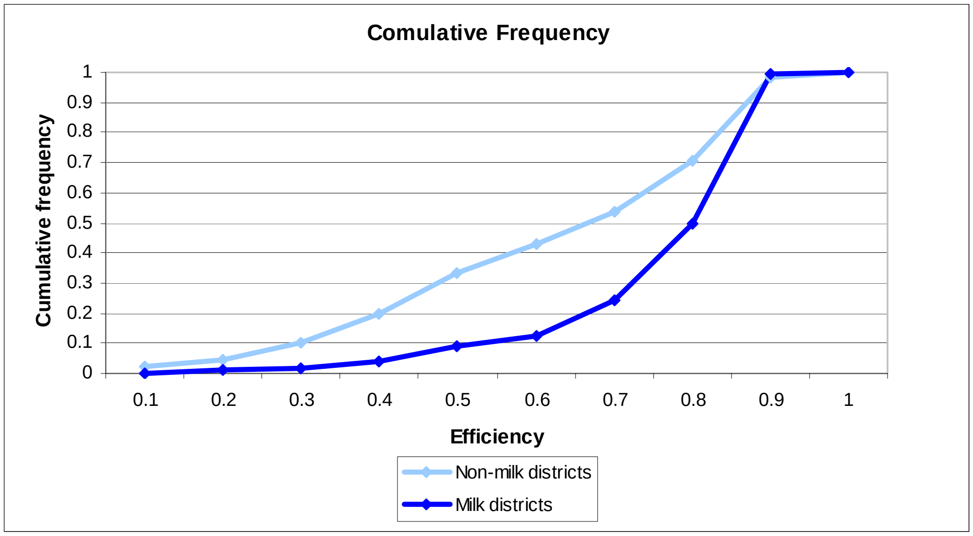


Figure 1. Cumulative distribution function for estimated technical efficiency

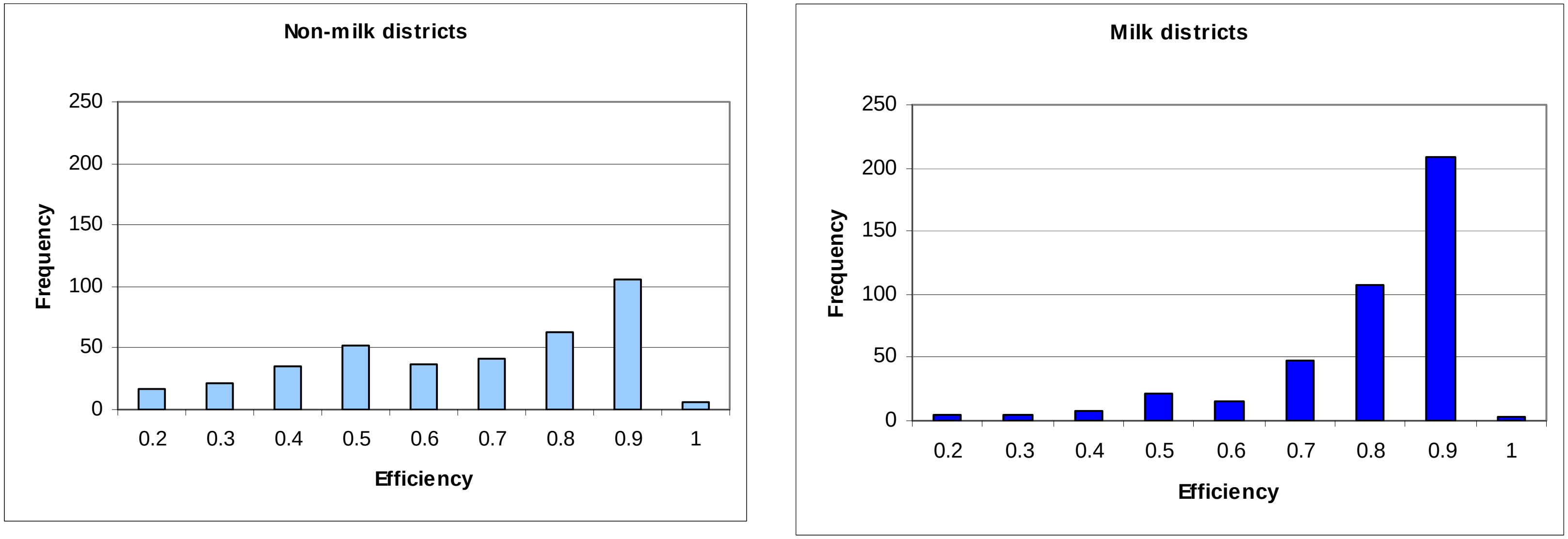


Figure 2. Frequency distribution of mean technical efficiency levels

To single out the performance effects by regions, we present the distribution of mean efficiency by districts and mouzas in the histograms of Figures 3 and 4 where districts and mouzas are ranked from the best performers to the worst performers; Narowal district is the best performer and Jhelum district is the worst performer. Four of the five top performing districts are from the milk districts. Similarly, an important result emerging from Figure 4 is that 15 of the top 20 mouzas in our sample are from the milk districts, whereas 13 of the bottom 20 mouzas are from the non-milk districts. In general, these findings also tend to corroborate the positive contribution and efficacy of the milk districts in increasing production efficiency of dairy farms.

To understand the role played by the evolving market structure on relative efficiency of dairy farms, we also consider the differential effects of the number of industry players present in a village (see Table 6 and Figure 5). Consistent with the predictions of the theory, technical efficiency of dairy farms is positively correlated with the number of

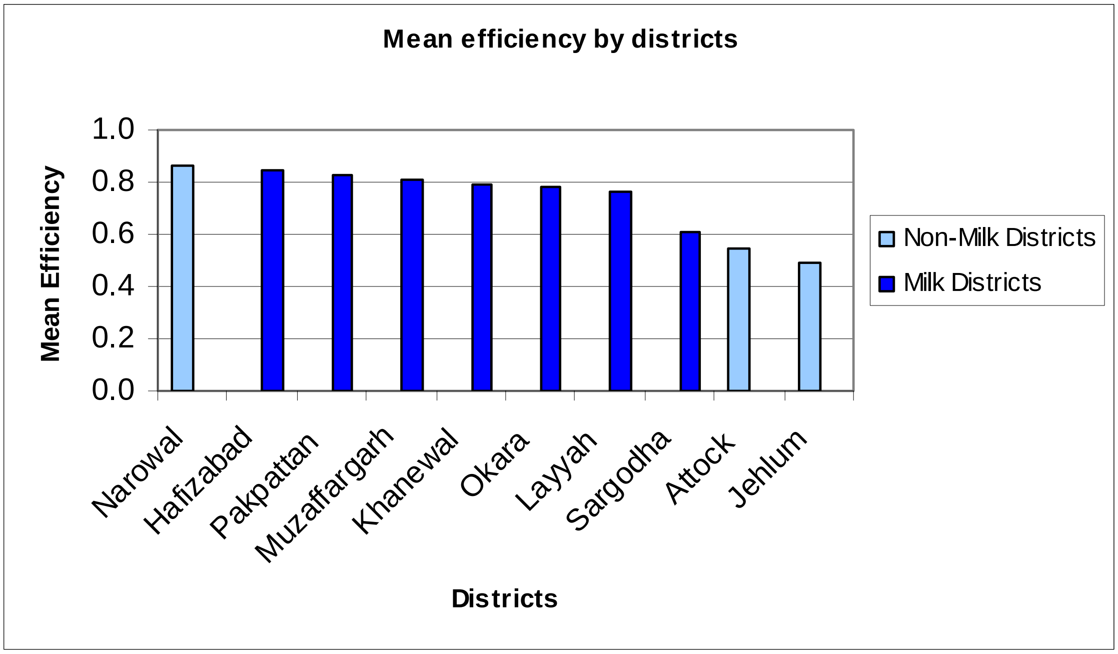


Figure 3. Mean technical efficiency levels by districts

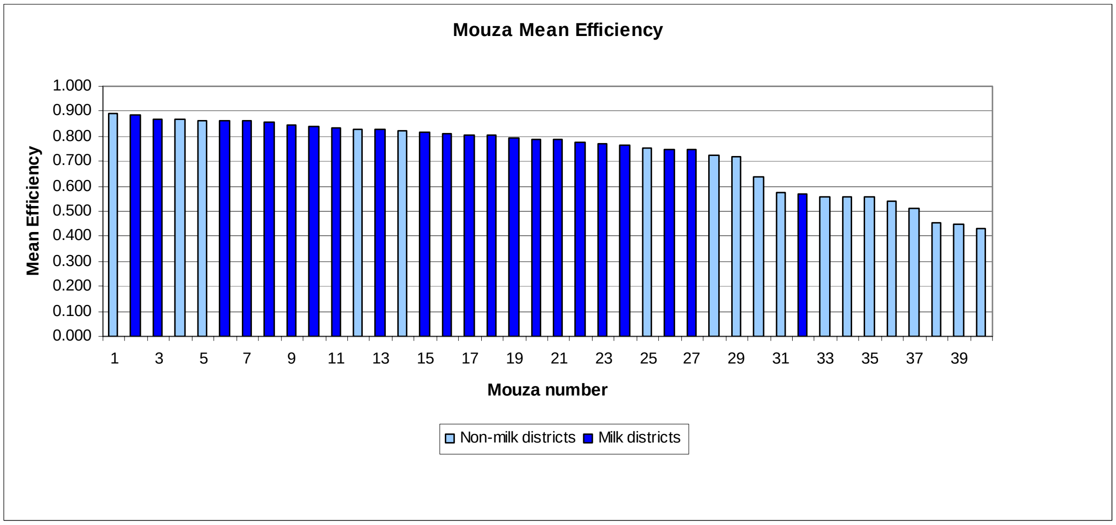


Figure 4. Mean technical efficiency levels by mouza

industry players. In general, the mean technical efficiency of the dairy farms is lower when traditional milk collectors (e.g., dodhi) enjoy monopsony power on the fresh milk supply chain. However, we note an overall increase of 12.6 and 14.7 percentage points in the mean estimated efficiency of dairy farms when respectively one industry player and three industry players are present in the village (Table 6). In other words, mean technical efficiency significantly improves when the number of industry players goes up to three. This result is further corroborated by the lowest standard deviation of efficiency for three players $(SD = 0.114)$. It suggests that farms dealing with three industry players as a group were clustering closer to the production frontier than farms represented by other forms of market structures. It is interesting to note that the difference between one and two industry players is almost zero in mean and median technical efficiency, which strengthens our earlier position that the two variables are highly collinear due to which the regression coefficient for two players was imprecisely estimated.

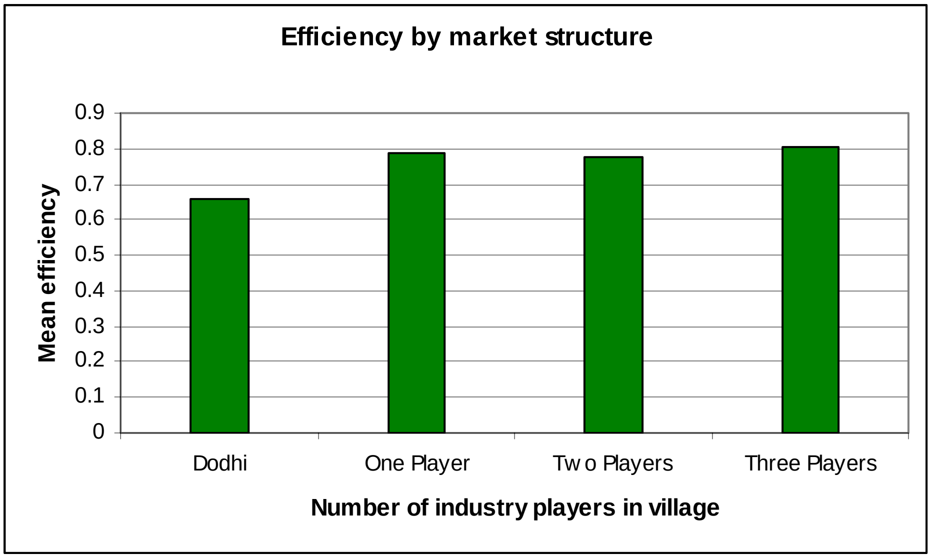
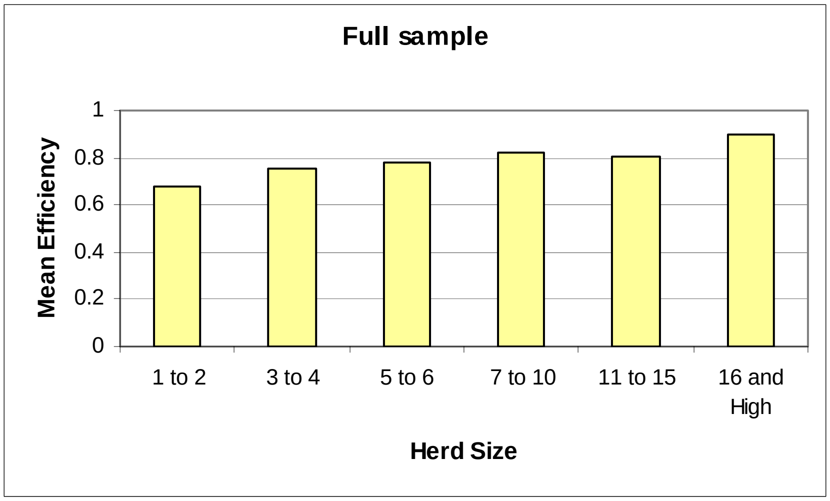


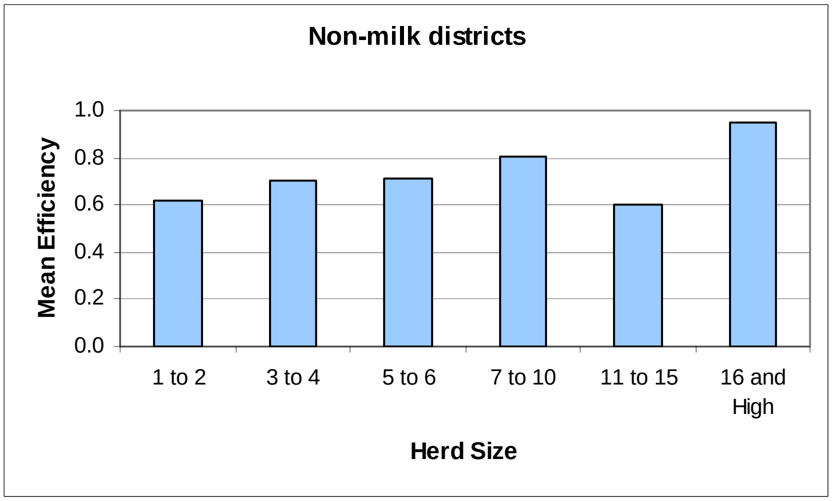
Figure 5. Mean technical efficiency levels by market structure in villages

Table 6 and Figure 6 (panel A) shows that the largest herd size category of 16 or more dairy animals is most efficient (90 percent efficiency) while the subsistence dairy producers or herd size 1–2 are least efficient (68 percent). It should be noted that the largest efficiency gains occur while moving from herd size 1–2 to herd size 3–4. The mean technical efficiencies are estimated to be 76 percent for herd size 3–4, 78 percent for herd size 5–6, 82 percent for herd size 7–10 and 80 percent for herd size 11–15, suggesting an average efficiency differential of close to 2 percentage points between these four herd size categories.

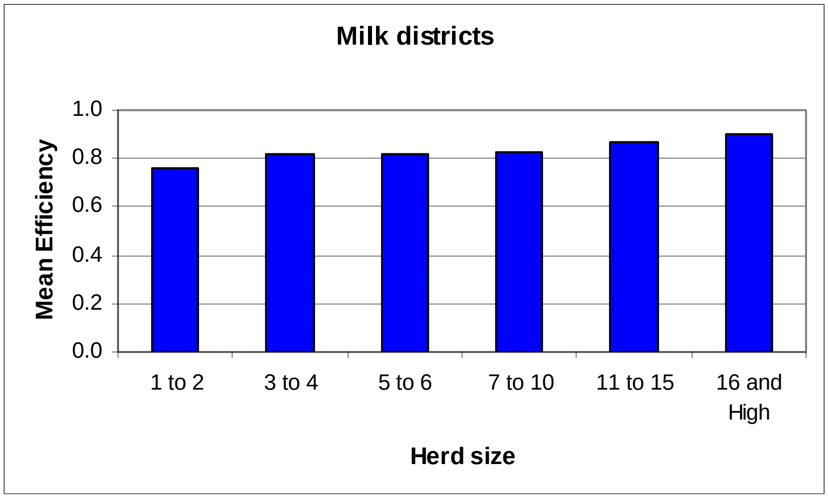
In order to compare efficiency of farms by herd size, we also present in Figure 6 (panel B and panel C) the distributions of estimated efficiency for the milk districts and non-milk districts sub-samples. Stacked up against each other in terms of technical efficiency, what appears from Figure 6 is that mean technical efficiency in milk districts for herd size 1–2, 3–4 and 5–6 is in each case relatively much higher as compared with efficiency levels in non-milk districts. Since most of the farms in our sample fall in these categories, it implies that dairy farms in non-milk districts as a group are less efficient.



Panel A



Panel B



Panel C

Figure 6. Mean technical efficiency levels by herd size

A further examination of the distribution of technical efficiency by feeding practices of the dairy farms indicates that, although only 2.5 percent of the sample dairy farms report feeding of molasses to the dairy animals, the estimated mean and median technical efficiency of these farms is 15 percentage points and 8.5 percentage points higher, respectively than those who do not feed molasses. Similarly, the mean and the median efficiency of the dairy farms who do not adequately feed water to their dairy animals also appears to be significantly lower than those who are more prudent in managing their herds. It also appears that, although the majority of the dairy farms feed water to their dairy animals only twice a day, our results show that large efficiency gains accrue to those dairy farmers who feed their animals four times a day, a practice that could easily be adopted apparently without any additional cost.

That the depression is a common occurrence in the dairy sector of rural Punjab is confirmed by the prevalence of long-term depression in 11.8 percent of the sample respondents, and the estimated efficiency differentials between those with and without major depression also corroborate how this disability can cause economic adversity. Table 6 depicts that the mean and the median efficiency index significantly falls for the farmers who report major depression (68 percent and 76 percent) as compared with respondents with no depressive disorders (74 percent and 82 percent). These results suggest that farmers without major depressive disorders cluster much closer to the frontier production function than those with major depression.

5. Conclusions:

This paper clearly shows that the location of dairy households in the milk and non-milk districts, while exogenously determined, creates diverse environmental production conditions and varied incentives to the farmers, which have direct or indirect bearing on their relative efficiency. With the setting up of the milk districts, favorable production conditions are created in the far flung rural areas in the form of modern milk storage facilities, better and dependable transportation networks, regular payment schedules and buyer-side competition. We note that setting-up of rural milk collection centers and accessibility to chillers in remote rural villages makes the low cost rural milk production viable where smallholder dairy producers employ family labor and rely on roughages, grasses and crop residue as fodder. We show that presence of these attributes is critical in dairy farm development since they encourage better allocation of key dairy farm resources, and thus enhance the dairy sector performance.

We use the frontier inefficiency effects model to accommodate the environmental production conditions created by setting up of the milk districts, and examine their differential impact on relative inefficiency of smallholder dairy producers in rural Punjab. We employ cross-section survey data of 800 dairy producers and the Cobb-Douglas production technology. The results show that animal capital, fodder, and straw & concentrate continue to be most important determinants of raising dairy output, while labor and shed & structure capital do not significantly increase dairy output in our data. The marginal significance attached to hired & family labor is attributed to the disguised unemployment of family labor. The scale elasticity estimates in this study show that if the present trends continue, dairy producers are expected to bring about a proportionate increase in dairy output with proportionate increase in dairy inputs.

Our results predict that farmer inefficiency is lower for farms in milk districts because the participating farms maximize effort to increase their dairy production. Farms in milk districts improve their long run viability by establishing a steady and secure link with the processing industry for supply of farmer milk. Inefficiency of smallholder dairy producers in milk districts is significantly reduced as they employ much fewer resources to produce given output levels. While, in general, remoteness of dairy farms from major paved roads enhances inefficiency because remote farms do not face favorable exogenous operating conditions, we detect stronger power of milk districts in reducing technical inefficiency of farms located in remote areas. Milk districts tend to eliminate inefficiency of dairy farms with their increasing distance from the pucca road. Farmers with large herd size are less inefficient than small herd sizes, yet the inefficiency reducing effect of herd size becomes even stronger when large farms are located in the milk districts.

Economic theory predicts that farm productivity would be high and farm inefficiency would be low as conditions become more competitive. Increased competition leads to better prices for farmer milk, improved dairy extension services, and more economical ways to manage dairy farms. Increase in the number of industry players in our data tends to decrease technical inefficiency of dairy farms. We also consider differential effect of Nestlé's presence on relative inefficiency of farms and find that technical inefficiency is lower in farms where Nestle is present, but efficiency and productivity gains to dairy farms are far greater when other industry players are also present.

To the extent that older and experienced dairy farmers are less inefficient than the younger ones, the advantage to experienced farmers in reducing inefficiency remains until they reach the age bracket of 69 years. Timely feeding of water to milch animals plays a significant role in increasing milk production; farmers who feed water to their dairy stock more frequently are likely to be less inefficient than those who don’t. We also find relatively higher inefficiency of farmers who are suffering from severe long term depression than those who are not suffering from this ailment. Efficiency differential also accrue due to better feeding regime; our results confirm potential benefits of feeding adequate amounts of concentrate to the milch animals.

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